A DECISION SUPPORT SYSTEM TO ASSESS CLIMATE CHANGE IMPACTS ON RURAL COMMUNITIES

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DECLARATION

I, Musiiwa Felicity LURULI, hereby declare that the present dissertation, submitted to the Institute of Groundwater Studies, Faculty of Natural and Agricultural Sciences, University of the Free State, Bloemfontein, South Africa, in fulfilment of the degree of Magister Scientiae, is my own work. It has not been previously submitted by me to any other institution of higher education. In addition, I declare that all sources cited have been acknowledged by means of a list of references.

I furthermore cede copyright of the dissertation and its contents in favour of the University of the Free State.

Musiiwa Felicity LURULI

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GLOSSARY

ADAPTATION: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007c).

ADAPTIVE CAPACITY: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007c).

AFFORESTATION1: Planting of new forests on lands that have not been recently forested.

AQUIFER: A geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

CARBON DIOXIDE: A colourless, odourless, non-poisonous gas that is a normal part of the ambient air. Carbon dioxide is a product of fossil fuel combustion. Although carbon dioxide does not directly impair human health, it is a greenhouse gas that traps terrestrial (i.e., infrared) radiation and contributes to the potential for global warming.

CHANGE OF CLIMATE: is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

DEFORESTATION: Those practices or processes that result in the conversion of forested lands for non-forest uses. This is often cited as one of the major causes of the enhanced greenhouse effect for two reasons: 1) the burning or decomposition of the wood releases carbon dioxide; and 2) trees that once removed carbon dioxide from the atmosphere in the process of photosynthesis are no longer present.

ECONOMY: System of production, distribution, and consumption of economic goods.

ECOSYSTEM: An organic community of plants, animals and bacteria and the physical and chemical environment they inhabit.

EMISSIONS: Releases of gases to the atmosphere (e.g., the release of carbon dioxide during fuel combustion). Emissions can be either intended or unintended releases.

ENERGY: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form for useful work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks.

EVAPOTRANSPIRATION: The loss of moisture from the combined effects of direct evaporation from land and sea and transpiration from vegetation.

FOSSIL FUEL: A general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the earth's crust over hundreds of millions of years.

FOSSIL FUEL COMBUSTION: Burning of coal, oil (including gasoline), or natural gas. The burning needed to generate energy release carbon dioxide by-products that can include unburned hydrocarbons, methane, and carbon monoxide. Carbon monoxide, methane, and many of the unburned hydrocarbons slowly oxidize into carbon dioxide in the atmosphere. Common sources of fossil fuel combustion include cars and electric utilities.

GLOBAL WARMING: The progressive gradual rise of the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns.

GREENHOUSE EFFECT: Trapping and build-up of heat in the atmosphere (troposphere) near the earth's surface. Some of the heat flowing back toward space from the earth's surface is absorbed by water vapour, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

HEAT: Form of kinetic energy that flows from one body to another when there is a temperature difference between the two bodies. Heat always flows spontaneously from a hot sample of matter to a colder sample of matter. This is one way to state the second law of thermodynamics.

HYDROLOGICAL CYCLE: The continuous circulation of water between oceans, the atmosphere and land. The sun is the energy source that raises water by evapotranspiration from the oceans and land into the atmosphere, while the forces of gravity influence the movement of both surface and subsurface water.

MITIGATION: An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007c).

RADIATION: Energy emitted in the form of electromagnetic waves. Radiation has differing characteristics depending upon the wavelength. Because the radiation from the Sun is relatively energetic, it has a short wavelength (e.g., ultraviolet, visible, and near infrared) while energy re-radiated from the Earth's surface and the atmosphere has a longer wavelength (e.g., infrared radiation) because the Earth is cooler than the Sun.

TEMPERATURE: Measure of the average speed of motion of the atoms or molecules in a substance or combination of substances at a given moment.

ACRONYMS AND ABBREVIATIONS

CO_2	Carbon dioxide
CBO	Community –Based organisation
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DWA	Department of Water Affairs
IPCC	Intergovernmental Panel on Climate Change
NGA	National Groundwater Archive
NGO	Non- governmental organization
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UV	Ultraviolet
WfGD	Water for Growth and Development Framework
WRC	Water Research Commission

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1:
INTRODUCTION

1.1 SETTNG THE SCENE

More than 19 million or 39% of South Africans live in rural areas (DEA, 2010). Eighty per cent of rural areas are commercial/subsistence farming areas with low population densities, and 20% are township areas. These later areas usually have a high population density and are often overexploited agriculturally (DEA, 2010). Small subsistence farming and homestead food production are done in rural areas on both high potential and marginal farming land, with approximately 1.3 million small-scale farm units. Even with this scale of agricultural practice, the harvest from some semi-arid areas, as well as the country's poorest 'household areas' may not be sufficient for food provision throughout the year (DEA, 2010). People in rural areas often face economic difficulties and frequently rely on urban allowances and social welfare grants for survival. In most cases, the social welfare consists of child support grants and state pensions for the elderly (DEA, 2010).

Since 1994, basic services, such as water, sanitation and energy, have been provided to some of the rural residential areas in South Africa. Approximately 15.3 million people in rural residential areas are without access to sanitation services (DEA, 2010). Natural resources such as wood and surface water are used extensively in rural areas where basic services have not yet been provided. Groundwater has also been provided to some rural communities by the installation of abstraction boreholes (DEA, 2010). Groundwater is mostly utilised by farmers for irrigation and also employed for domestic water by communities in some arid parts of South Africa (DEA, 2010).

People who do not have access to boreholes still depend on groundwater that feeds springs and wetlands (DEA, 2010). Communities that are dependent on springs and wetlands are more vulnerable to the risk of water shortages as a result of drought. These communities are also exposed to health risk since surface water bodies are generally more vulnerable to pollution.

Along with the existing challenges, rural human settlements, infrastructure and the built environment may also encounter the following climate change challenges (DEA, 2010):

- Small cash farming and subsistence farming are most vulnerable to alterations in temperature.
- As these farming communities largely depend on rain-fed agricultural practices, changes in precipitation may have a positive and a negative effect on farming, production and on their livelihood.

- Employment may be affected by changes in agricultural practices. The reduction in farming activities may impact negatively on employment growth within the poor communities.
- In some areas, extreme heat events may impact on human health, as well as the health of crops and livestock. Growth in the economic sectors and production could be affected.
- Flooding and drought may expose natural resources on which most rural communities are highly dependent. Such events may have an impact on the availability of water, as well as the quality of the fresh water supply.
- Despite the fact that rural areas are likely to be the earliest and most significantly affected by climate change, they are underrepresented in the climate monitoring network.

1.2 PROBLEM STATEMENT

Most vulnerable and poor communities are already starting to be impacted on by climate change around the world (IPCC, 2001). The effect that extreme weather conditions, such as an increase in droughts, extreme heat, tropical storms, sea level rises and high rainfall causing floods, may have on most portions of Africa, could have adverse effects on poor rural communities (IPCC, 2007). These changes are expected to modify the average climatic conditions and poor countries tend to be particularly vulnerable to this. These communities often have limited access to basic essential services, such as water supply from municipalities. The vulnerability may furthermore be compounded by an uneven distribution and overexploitation of water resources (DEA, 2010). Understanding sensitivities and vulnerabilities of systems and communities is necessary to inform adaptation actions.

It is anticipated that climate change will impact men and women differently (Babugura, 2010). There are sufficient data to show that rural women often struggle to obtain fuel or water ahjgnd maintain livelihoods (IPCC, 2007) when men migrate to the cities in search of employment. Addressing climate change as a threat, particularly to (rural) women must be a priority (IPCC, 2007).

The analysis of vulnerability and adaptation options can be applied to water (both as a problem or a solution) and human systems (IPCC, 2007). In such an analysis, the links between the social, ecological and physical systems need to be addressed. This will allow the decision-makers to manage the vulnerability of communities and make the necessary adaptations within the larger context of planning and development.

1.3 AIM AND OBJECTIVES OF THE STUDY

This investigation forms part of a Water Research Commission (WRC) project K5/2027 entitled: 'Development of decision-support guidelines for vulnerability assessments and adaptation requirements among rural economies and communities, including gender issues (phase 1)'. The aim of the dissertation is to develop a framework to assess the vulnerability of rural communities to climate change, with a specific focus on groundwater and issues relating to gender. Specific objectives of the research are to:

- Study previously completed research on rural community vulnerabilities and adaptation to climate change (international best practice, but with a particular focus on South Africa), and adaptation assessment frameworks.
- Develop the methodology and approach for the assessment of vulnerability in South Africa.
- Develop the framework that entails a series of steps required for identifying and prioritising vital vulnerabilities for rural communities, by incorporating results described in the literature as well as on-going research projects.

1.4 RESEARCH METHODOLOGY

A systematic approach was taken in answering the questions that the research poses. With the process of collecting and analysing data, as well as interpreting information to achieve the research objectives, the following actions were taken:

- The available literature on climate change, vulnerability and adaptation was reviewed.
- Literature on conceptual frameworks of decision support systems was reviewed.
- A study site (village) was selected by using a social vulnerability index to identify communities that may be vulnerable to the impacts of climate change.
- A hydrocensus and water sampling were done in the vicinity of the village to determine the locations of boreholes and to obtain information on these boreholes (water depths, water use, borehole equipment, etc.). Water samples were collected and submitted to an accredited laboratory for chemical analyses, and the results were used to determine the quality of the water and its suitability for its intended use. Data were interpreted to assess the quality of the water available to the community.
- The Millennium Ecosystem Assessment Conceptual Framework was used to develop a questionnaire for the purpose of conducting face-to face interviews with the members of the community living in the selected village.

- A decision-support framework applicable to rural communities in South Africa was developed to assess whether communities are vulnerable to the impacts of climate change.
- The decision-support framework was applied to the village selected for the current study to identify the risks faced by the community with respect to the impacts of climate change. The vulnerability of the village was assessed by evaluating the responses to the closed questions of the questionnaire. This evaluation was done by assigning values to the risks in terms of their importance to human wellbeing (rate) and the degrees to which the risks affected the respondents (in their own opinions) (weight). The weights and rates were used to calculate a value which is used as an indication of the vulnerability of the community to climate change.

1.4.1 Literature review

A review of the literature relevant to the current investigation was conducted. The literature reviewed covered topics such as climate change, community resilience, gender equality, water scarcity, water quality vulnerability, and adaptation. Literature sources included books, journals, consultant reports, and official government reports.

1.4.2 Questionnaire and face-to-face interviews

The questionnaire was compiled based on the results of previous studies on the vulnerability associated with climate change. The questions posed addressed factors such as: income of a household, education within the communities, farming and agricultural practices within the communities, climatic conditions and personal security. The questionnaires were used as guidelines during personal interviews with the stakeholders or community members.

Mostly women were interviewed, as the men were absent due to their current employment or because they were in the process of searching for employment. Most of the women in the study area are unemployed; these women stay at home to maintain and take care of their families and possessions.

1.4.3 Hydrocensus

All water-related features in the vicinity of the village were identified, including: 1) rivers, 2) dams, 3) boreholes, 4) rain collection tanks and 5) abandoned boreholes and wells. Potential sources of water contamination (mines, abandoned mines animal kraals) were identified. Visible features indicating the potential for water contamination were identified (e.g. borehole casing rusted away at the surface). The coordinates of these identified boreholes were recorded using a hand-held GPS and the borehole positions were plotted on a map. The static water level in each borehole was measured with a dip meter. Water samples were collected from each of the identified borehole.

Plastic container bottles were used for water sampling. Samples were submitted to an accredited laboratory for analyses to determine the water quality and the suitability of the groundwater for its intended use.

1.4.4 Data interpretation and development of decision-support system

All data collected during the previous phases of the investigation were interpreted to assist in the development of a framework for the assessment of the vulnerability of rural communities to climate change.

1.5 DISSERTATION STRUCTURE

This dissertation is structured in such a way that each chapter is independent of the others. Different materials and methods are used to compile a framework to answer the questions of the research project. The framework is then tested by means of application to a case study, the results of which highlight the findings of the investigation.

This dissertation consists of eight chapters, structured as follows:

- **Chapter 1: Introduction**. This chapter gives a brief discussion of the study and the methodology followed to achieve the objectives of the study.
- **Chapter 2: Literature review**. Relevant literature focusing on climate change, vulnerability, adaptation and gender issues is studied. All of these topics are reviewed in relation to rural communities.
- **Chapter 3: Conceptual framework**. This chapter gives an overview of the audience that could be reached by the study, the manner in which research questions are addressed and which method or framework is used to achieve the objectives.
- **Chapter 4**: **Description of the study area.** In this chapter the study area is first selected by considering a map of the social vulnerability index to identify communities that may be vulnerable to the impacts of climate change. Other factors considered in the selection process include accessibility and the language spoken in the area (face-to-face interviews are to be conducted). Once the study area is selected, a description of the study area is given with regard to location, climate, geology, as well as the hydrogeological conditions.
- **Chapter 5: Research questionnaire**. A questionnaire was compiled and face-to-face interviews were conducted with community members of a selected village. The questionnaire was developed according to the indicators used to select the area of study with reference to

the millennium framework system. The questionnaire consisted of open-ended questions as well as closed questions.

- **Chapter 6: Hydrocensus and water quality.** A hydrocensus and water sampling were done in the vicinity of the village to determine the locations of boreholes and to obtain information on these boreholes. Water samples were collected and submitted to an accredited laboratory for chemical analyses, and the results were used to determine the quality of the water and its suitability for its intended use.
- **Chapter 7: Development of a framework for decision-support system for vulnerability assessment**. The results from the questionnaire were used to identify the indicators that can contribute to the vulnerability of the community. These indicators were then used to develop the parameters for the development of the framework for decision support system for vulnerability.
- **Chapter 8: Summary and conclusions.** This chapter summarises the results of the investigations and provides conclusions based on the results of the investigations. Recommendations are also made based on the application of the developed framework to a selected site.

CHAPTER 2:
LITERATURE REVIEW

2.1 CLIMATE CHANGE

The IPCC defines climate change as a change in the state of climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2007). Climate change is most likely to bring extreme weather changes and climate variability, such as frequent heat waves, less frequent cold spells, and a greater intensity of heavy rainfall events (IPCC, 2001). The climate system evolves in time under the influence of its own internal climatic changes as well as the changes in external factors that affect it (IPCC, 2007). The factors that are responsible for climate change can either be natural or human induced (DEA, 2010).

2.1.1 Natural causes

There are several natural factors that could cause climate change. These include:

2.1.1.1 Solar variations

The Sun is a fundamental factor in climate. The energy radiated from the Sun is not constant but exhibits changes in intensity. These changes are referred to as solar variations. If there is a variation over time in the amount of energy emitted by the sun, there is bound to be an effect on the Earth's climate (IPCC, 2001). Solar variation may play a role in climate change as a decrease in the solar activity may cause an ice age of short duration, as it did in 1650 and 1850 (Ludi, 2009). Another common example is a sunspot, where due to intensified magnetic energy, one patch of the Sun's surface becomes cooler than its surroundings, causing a relatively dark spot (Ludi, 2009). When there are a large number of sunspots, the Earth's climate can be expected to be slightly cooler.

2.1.1.2 Volcanic eruptions

Immense volumes of dust and poisonous gases may be ejected into the atmosphere by explosive volcanic eruptions. Of all the gases emitted into the atmosphere, sulphur dioxide poses the most significant threat (Burroughs, 2001). Large volumes of gas can cause significant impacts on the climatic conditions. At the point of these eruptions, tiny particles are produced which are suspended in the air, forming an aerosol. The particles are then converted into sulphuric acid aerosols (Burroughs, 2001). These aerosols remain suspended in the atmosphere for several years while reflecting back into space solar energy (Burroughs, 2001), causing a cooling effect on the Earth's

surface. This may oppose the greenhouse warming effect for a few years following an eruption (IPCC, 2007).

2.1.1.3 Ocean currents

Ocean currents play a major role in transporting energy to high latitudes. However, significant changes in the transport pattern can have substantial climate implications (Burroughs, 2001). Phenomena such as El Niño occur as results of the interactions between the ocean and atmosphere. The El Niño phenomenon happens every two to six years.

The climate at the poles and the equator also depend on ocean currents. The concentration of CO_2 in the atmosphere is affected by the oceans. Through the movement of CO_2 into or out of the atmosphere, climate may be disturbed by changes in ocean circulation (IPCC, 2001).

2.1.1.4 Changes in the Earth's orbit

Every year the Earth makes a full orbit around the sun. The Earth also spins around its own axis within a one-day period. The axis around which spins takes place occurs at an angle with respect to the horizontal plane defined by the Earth's orbit around the Sun. This angle is called the tilt of the Earth. The tilt of the Earth is not constant, but goes through an annual cycle. In addition, the tilt also changes on a much longer cycle which lasts approximately 40 000 years.

As the tilt of the Earth changes, climatically important changes in the temperature of the seasons may be caused. Temperatures in summer and winter depend on the magnitude of the tilt; for smaller tilts, cooler summers and milder winters are expected, whereas warmer summers and colder winters are expected for larger tilts.

2.1.2 Anthropogenic causes

Human activities result in emissions of four principal greenhouse gases: carbon dioxide, methane, nitrous oxide and the halocarbons. Concentrations of these gases increase with time, as the gases accumulate in the atmosphere (IPCC, 2007). Since the start of the industrial era, human activities have contributed significantly to greenhouse gas concentrations.

2.2 WATER-RELATED IMPACTS OF CLIMATE CHANGE

Climate change impacts have been reported in many parts of the world on a wide spectrum of both the natural environment and the human environment (IPCC, 2007). This section, however, only discusses water-related impacts:

- Climate change is causing an increase of extreme weather conditions such as heat waves, floods and droughts (Mukheibir and Sparks, 2006). Mukheibir and Sparks (2006) further state that the effects are interrelated and will tend to worsen in the future. Global warming due to climate change may lead to changes in a number of components of the hydrological cycle and hydrological systems such as: a) changing precipitation patterns, intensity and extremes, b) widespread melting of snow and ice, c) increasing atmospheric water vapour, d) increasing evaporation, and e) changes in soil moisture and runoff have been observed in the last several decades (IPCC, 2008). Changes in climatic conditions may result in floods, droughts, melting of ice and changes in groundwater levels, as well as ocean freshening (Chen et al., 2004).
- The impact of climate change on precipitation is expected to result in an increase in the occurrence of extreme droughts in many parts of Africa. It is predicted that Southern Africa will also continue to experience increases in droughts and floods attributed to El Niño / La Niña (the so-called Southern Oscillation Effect) as the temperature increases over the Indian Ocean (Mukheibir and Sparks, 2006). Water resources are among the most important natural resources that are affected by climate change as different hydrological processes are altered. (IPCC, 2008).

The DST (2010) reported that agriculture uses at least 62% of the available water resources in South Africa. The effects of climate change on agriculture will be driven by various factors, which include:

- Reduced or increased precipitation,
- Changes in wet periods and gaps between rain events,
- Higher evaporation and evapotranspiration (ET) rates,
- Altered seasons,
- Changes to weather variables such as temperature, and,
- Alterations in soil water availability due to changing wetting patterns.

Of all the continents, Africa's economy is likely to suffer the most from the climate change impacts (IPCC, 2007). The effects of changes in climate and extreme events on the economy and agriculture within the context of a developing continent imply that many socio-economic spheres of life will be affected. These effects could include: a) loss of employment, b) impacts on health, c) demographic changes d) migration, and e) social inequalities (IPCC, 2007).

2.2.1 Impact of Climate Change on Surface Water

Climate change may have an impact on inland freshwater and wetlands through altered rainfall, with recurrent and intense events disturbance such as famines, storms and floods (Döll, 2009).Climate change could have obvious impacts on surface water resources. The spatial distribution of precipitation, as well as its temporal occurrence, will likely undergo changes (Haji, 2011). Changes in temperature will cause changes in the evaporation rates from open water bodies. Increased average ambient temperatures could lead to larger snow melts and less ice in the colder regions.

Changes in the precipitation will cause changes in the volumes of surface runoff reaching the surface water bodies. Muller (2007) stated that average stream flows could increase or decrease by up to 40% for a temperature change of 1 to 3 degrees Centigrade. On the other hand, reduction in stream flows and water body volumes could result in increases in the pollutant concentrations (Haji, 2011). Surface water resources become unreliable due to the effects of climate change, a greater dependence on groundwater resources is inevitable.

High precipitation intensity may lead to high volumes of runoff, which then projects to high volume of flood. These extreme precipitations will result in increased run-off which could lead to the increased transport of pollutants from urban, industrial and agricultural areas to receiving water bodies. The higher the runoff, the more water carries out volumes of contaminants from different areas which may result in worse pollution in fresh water (EPA, 2011).

2.2.2 Impact of Climate Change on Groundwater

Groundwater is an important component of the hydrological system. Because surface water resources are becoming increasingly exploited to support the increasing populations and development, the role of groundwater as a water resource is becoming even more prominent (William, 2001). In most cases, in areas with vegetation and forests cover, a good deal of natural recharge occurs (Calder *et al.*, 2003). When an area is covered by vegetation, less surface runoff occurs, allowing more time for the infiltration of water into the subsurface.

Groundwater that flows in shallow aquifers is part of the hydrological cycle. It can be affected by variations in the climate and changes in the recharge processes (Chen *et al.*, 2002), as well as human interferences in many locations (Petheram *et al.*, 2001). Human impacts can occur through increases in groundwater abstraction for crop irrigation. This may lead to the depletion of aquifers and the resulting lowering of groundwater levels.

Spatial and temporal variability in the major climate variables are not the only factors controlling groundwater recharge. Understanding the relative importance of these factors is critical for

estimating recharge rates and for assessing water quality (Şen, 2009). The vadose zone soil water budget also depends on groundwater recharge which is driven by precipitation. Recharge occurs when the soil moisture is increased to field capacity and effective precipitation at the soil surface surpasses evapotranspiration. Precipitated water is subjected to various processes, including: interception, evaporation, and surface runoff. The effect of each of these processes depends on the intensity of the rainfall, the ambient temperature, and the soil properties.

Rising temperatures may change evapotranspiration rates; this may reduce infiltration rates from natural precipitation. This process may cause a reduction in recharge and in some areas decrease the amount of groundwater contribution to surface water bodies.

Soil moisture is a function of precipitation and evapotranspiration. It can sustain forestry and vegetation when temperatures and evapotranspiration are in balance. When this balance is disturbed, loss of vegetation could occur. This could in turn cause the infiltration of precipitated water through the soil to become insufficient to allow recharge to the aquifers (Nearing *et al*., 2005).

Clayey soils may also greatly affect infiltration rates, as their presence may lead to the formation of a surface barrier to infiltration (Wells *et al*., 2003). This occurs due to the impact of raindrops on the surface of the soil, causing the surface of the soil to compact, and also leading to the settling of fine-grained detached material on the surface of the soil. This may cause clogging of the micro pores within the soil. There may also be a breakdown of aggregates and the dispersion of clay material as a result of the rapid absorption of moisture, resulting in a change in soil permeability (Stuart *et al*., 2011).

Scholes and Biggs (2004) suggested that climate change could affect the water balance (the difference between water entering the system and water leaving the system) in South Africa. The amount of water available in the system could be significantly reduced, leading to the aridification of some parts of South Africa.

Warming trends may also affect global evapotranspiration patterns, which have direct implications for the sustainability of surface- and subsurface-water resources (IPCC, 2008).When groundwater abstractions exceed the long-term average groundwater recharge, aquifer depletion and a decrease in groundwater levels will occur. Such aquifer depletions may occur particularly in semi-arid and arid regions with little groundwater recharge but with so-called ‘fossil’ or ‘non-renewable’ groundwater resources that were formed during more humid climate periods (IPCC, 2008).

A decrease in the groundwater level as a result of reduced recharge and/or increased abstraction could also impact on groundwater quality. In coastal regions, the freshwater/saline water boundary may be disrupted, resulting in saline water intrusion into the aquifer system. Such impacts could

also occur in inland aquifers, such as the carbonate rock aquifer in the Winnipeg region of Canada (Grasby and Betcher, 2002).

2.3 VULNERABILITY OF ECOSYSTEM TO CLIMATE CHANGE

According to Adger and Kelly (1999) the concept of 'vulnerability' is considered a powerful analytical tool for disclosing states of susceptibility to harm, power discrimination and marginality of both physical and social systems. However, the pattern of vulnerability may change over time; challenges faced in terms of vulnerability may therefore also change.

2.3.1 Factors Contributing to Climate Change Vulnerability

According to the IPCC (1996) the vulnerability of a system to climate change may be defined as the magnitude to which the system may be damaged or harmed by climate change. Vulnerability depends on the ability of the system to adjust to new climatic conditions and on the sensitivity of the system. Sensitivity may be described as the degree to which changes in climatic conditions may impact the system (IPCC, 1996). The definition of vulnerability must be reliant on estimates of potential climate change and adaptive responses (Adger and Kelly, 1999).

Climate change is dynamic and could have highly variable potential impacts. The extent of climate change can be defined by its impact on humans; these impacts may include: death, damage to property, and infrastructure losses. Climate change is also directly linked to the extent to which a region is vulnerable to the impacts of disasters affecting the populations within the region (IPCC, 1996).

Drought and heavy precipitation are the most important climatic extremes to consider when assessing vulnerability. The impacts could include changes in groundwater recharge which may be caused by the variability in the annual and seasonal distribution of precipitation, as well as changes in the evaporation/evapotranspiration. Changes in the evapotranspiration may be caused directly by temperature changes, and indirectly by changes in the vegetation that depends on soil moisture. Since the availability of surface water may be reduced due to higher evaporation rates and variable rainfall patterns, increased demands may be placed on the groundwater resource (Alley, 2001). Extreme precipitations will result in increased run-off which could lead to the increased transport of pollutants from urban, industrial and agricultural areas to receiving water bodies. The higher the runoff, the more water carries out volumes of contaminants from different areas which may result in worse pollution in fresh water (EPA, 2011).

In this section, vulnerability factors are examined. These factors influence the capacity of individuals, communities and societies to mitigate the risk of increased natural hazards as a result of climate change.

2.3.1.1 Drought

When drought affects groundwater systems, there is a decrease in groundwater recharge and groundwater levels as well as groundwater discharge. This type of scenario is called groundwater drought and it generally happens within a time scale of months to years (van Lanen and Peters, 2000). Groundwater drought is the sustained and extensive occurrence of below average availability of groundwater. Countries that have experience drought have been challenged with food scarcity and water scarcity. This usually occurs in rural areas that still rely on ground water for their day to day activities including farming.

2.3.1.2 Rainfall

The world's arid areas are faced with rising temperatures caused by climate change and, more importantly, less and more erratic rainfall due to the disruptions of hydrological cycles. The already critical state of water scarcity and conflicts over water allocation may be worsened (IPCC, 2007).

Communities based in poor rural areas that are situated in Africa's driest areas are suffering most from these climatic changes. There may be serious risks posed to rain-fed farming communities by climate change and rainfall variability (Cooper *et al*., 2008). In most cases climate change and rainfall variability pose the risk of floods and degrading water quality.

Changes in the erosive power of rainfall may be induced by changes in precipitation in the future (IPCC, 2007). Nearing (2001) stated that "The most direct impact results from change in the erosive power of rainfall are soil erosion". Climate change can be expected to affect soil erosion based on a variety of factors, including: a) precipitation amounts and intensities, b) temperature impacts on soil moisture and plant growth, and c) direct fertilization effects on plants due to greater CO_2 concentrations.

Soil erosion responds both to the total amount of rainfall and to differences in rainfall intensity; however, the dominant variable appears to be rainfall intensity and energy rather than rainfall volumes alone (Nearing *et al*., 2005). Another major factor is that, if rainfall volumes and intensity were to change together, the erosion rate might change significantly.

2.3.1.3 Temperature

An important factor impacting on the groundwater table is also temperature, through human strain and high evapotranspiration (Alley, 2001). Human strain influences are seen in the summer months

when water becomes scarce as water tables decrease and surface water dry up, a large number of communities starts to be contingent on groundwater. Farmers may then use boreholes to abstract water for irrigation and other farming activities

2.3.2 Population Vulnerability

Population vulnerability can be divided into five categories of vulnerability: natural, human, social, financial and physical vulnerability Nearing *et al* (2001).

2.3.2.1 Natural vulnerability

Factors influencing natural vulnerability include:

- Availability of water: Climate change impacts on water are wide ranging with far reaching implications, both known and unknown. The water stressed regions are vulnerable to climatic and non-climatic pressures which threatens the water security in these regions. Water security determines the economic, social and cultural development of a region. The main challenge in sustainable water resource management is good governance, which ensures best practices in water use through efficient use and wastage minimization. Under the climate change sphere, for each key sector, water use needs to be redefined and re-examined. Inefficacies in water use, administration and authority make the rural expanses more vulnerable to climate change induced water tension (Nearing, 2001).
- Agricultural suitability and land degradation: The capability of cultivation to adjust and manage with the changes in climate depends on factors such as a) population growth, b) poverty and starvation, c) arable-land and water re]sources, d) farming technology and entree to inputs, e) crop varieties altered to local conditions, f) access to knowledge, g) infrastructure, h) agricultural extension services, i) marketing and storage systems, j) rural financial markets, and k) economic status and success. The livelihoods of populations and communities are highly reliant on these factors, and the developing countries, predominantly the least developed countries, are most vulnerable. As a result of this dependency, the developing countries are less able to accustom and are predisposed to climate-change damage, just as they are vulnerable to other social, environmental and economic stresses (IPCC, 2008).

2.3.2.2 Human vulnerability

Human vulnerability can be divided into two sub-categories human wellbeing and health (DEA, 2010). Poverty can be identified by the following components:

- Human wellbeing is specified by life expectancy, literacy, education and standards of living. The Human Development Index (HDI) is a standard means of determining the human well-

being, with specification to child welfare. It is used to extricate whether an area is a developed, a developing or an under-developed country (DEA, 2010).

- Health is described with the incorporation of infant mortality. This is defined as the quantity at which an infant die per 1000 live birth (one year of age or younger) (DEA, 2010). Dehydration was found to be the most common cause of infant mortality worldwide due to diarrhoea. Some countries have high infant mortality rates and low life expectancies and this normally occurs in countries with a high level of poverty. (DEA, 2010).
- Climate change may impact negatively on the population's health, mostly through heat stress and probably increases in vector-borne (e.g., dengue fever and malaria) and waterborne diseases. The decline in the availability water and therefore food production (especially if water for irrigation is scarce) will have a secondary impact on human health associated with nutritional and hygiene issues (DEA, 2010).
    - Underweight children are an indication of the affliction of disease that climate change is contributing to (UNICEF, 2007). Malnutrition is a disease caused by lack of body required nutrients. Climates change, could increase this disease by contributing to children suffering from hunger and water scarcity and injection of water that had been salinated due to coastal flooding. As precipitation drops, crops might wither and livestock may die, exposing children to starvation and diminishing water supplies for drinking and hygiene.

2.3.2.2.1 Vulnerability of children

Due to the fact that children are physiologically and metabolically less able than adults in terms of adapting to heat and other climate related exposure, they are sensitive to changes in climate (DEA, 2010).

Factors, such as population density, age distribution, economic development, dependence on climate-sensitive sectors, food availability, health status, prevalence of climate-sensitive diseases, local environmental and geographical conditions and quality and availability of social services determines vulnerability at either individual or community level (UNICEF, 2007).

2.3.2.2.2 Health

McMichael *et al*. (2004) suggested that the possible impressions of climate change on health of the population and the health-related effects of global climate change are anticipated to be being heavily focused in the poor communities. The authors suggest that:

- Rainfall, as well as extreme temperature such as heatwaves, drought and floods, has immediate impact on morality as well as long-term effects.

- There is a likelihood that climatic change will affect biodiversity, ecosystem goods as well as the services that we rely on for human health.
- Changes in rainfall and temperature may have an impact on the distribution of vector diseases, e.g. those of dengue and malaria as well as the incidence of diarrhoeal diseases.

2.3.2.2.3 Food security

Food security is a challenge in many rural areas because of high levels of dependence on limited and farmhouse food production. Many small-scale farmers are already experiencing challenges due to their reliance food production that is harvested in the current dry land; this is combined with limited capital investment in soil fertilisation as well as weed and seed, pest and disease control. Dependence on water also increases their risk on food security (DEA, 2010). Most children living in these farming homes may face a decrease in food production of food and this would have an unfavourable effect on their nutritional and health status.

2.3.2.2.4 Education

Access to school is always a challenge for children who are in a rural area where transport is lacking. A total of 11.6% of primary school and 20.7% of secondary school children in Limpopo have to travel long distances by public transport or on foot to get to school (Murambiwa and Hall, 2011). This problem increases when floods or storms invade to schools making them inaccessible, especially if schools are damaged during such events.

2.3.2.3 Social vulnerability

Social vulnerability can be described as traits of a person or group and their situation that stimulate their capacity to anticipate, deal with, resist as well as improve from the effects of a natural hazard such as climatic change. The following indicators may be used to determine social vulnerability: (IPCC, 2010).

2.3.2.3.1 Conflict

In the recent past, a number of foreign affairs experts have tried to show the link between climatic change and the social tensions that can give rise to conflict. While critics may believe this is simply a fad in international affairs, history suggests otherwise (IPCC, 2010). Over the past millennia, climate change has been a factor in conflict and social collapse around the world. The changing climate has influenced how and where people migrate, affected group power relations, and provided new resources to societies while taking away others (IPCC, 2010). Such circumstances cause large-scale alterations in lifestyles and illustrate pathways from climate change to conflict.

2.3.2.3.2 Displacement

Human migration, it can be required or willingly, will with no doubt be one of the most significant results of environmental degradation and climatic change in the coming decades (Maserumela, *.et.al* 2008). A number of experts debate that large numbers of people are already on the move, with millions more expected to follow as evidence of climate change mounts (IPCC, 2005).

2.3.2.4 Financial vulnerability

Disaster that is climate related damages have intensified in recent past decades (IPCC, 2010). Even though mainly determined by socio-economic change, the rise monetary losses by an order of magnitude within the last four decades cannot wholly be explained by population or economic growth. The fourth assessment report of the IPCC (2007) found increased impacts of extremes such as cyclones and flooding as a result of altered concentrations and frequencies of natural hazards, many of which are expected to rise in frequency or severity in various places in a future warmer climate. Impacts of disaster can be shocking and demand huge amounts of money to repair/ rebuild to their former glory, especially in extremely unprotected low and middle-income countries. (Maserumela, *.et.al* 2008)

2.3.2.5 Physical vulnerability

Physical vulnerability is a suggestion that biophysical impacts of climate change will occur in various mechanisms, and that it will have significant influence on the physical resource integrity and future viabilities. In this case agricultural production will be vulnerable to climate change if climatic parameters such as temperature and precipitation cause significant negative impacts on yields. On natural ecosystems, vulnerability can occur when individuals or communities of species are stressed with climatic changes, vulnerability can occur on natural ecosystem.

2.4 ADAPTATION TO CLIMATE CHANGE

IPCC (2001) defines adaptation as an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities. Adaptation can involve both building adaptive capacity thereby increasing the ability of individuals, groups, or organizations to adapt to changes, and implementing adaptation decisions thereby transforming that capacity into action.

Adaptation: It is a process where the natural or human system is modified in response to actual or anticipated climatic stimuli or their effects. This process controls harms or exploits beneficial opportunities for the existence of the systems.

2.4.1 Types of Adaptation

Different types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation.

According to the IPCC (2007), the different types of adaptation can be explained as follows:

- Anticipatory Adaptation – Adaptation that happens before the manifestation of climatic change can take place. It is also known as proactive adaptation.
- Autonomous Adaptation – Adaptation that does not constitute a conscious response to climate stimuli but is triggered by ecological changes in natural systems and by markets or welfare changes in human systems. Also stated to as spontaneous adaptation.
- Planned Adaptation – Adaptation that takes place as the result of a considered policy decision, based on awareness that conditions are no longer the same or is about to change and that action is required to return to, maintain, or achieve a desired state.

The IPCC (2007) states the following: 'Adaptation carried out can be distinguished along several dimensions: by spatial scale (local, regional, national); by sector (water resources, agriculture, tourism, public health, and so on); by type of action (physical, technological, investment, regulatory, market); by actor (national or local government, international donors, private sector, NGOs, local communities and individuals); by climatic zone (dry land, floodplains, mountains, Arctic, and so on); by baseline income/development level of the systems in which they are implemented (least-developed countries, middle-income countries, and developed countries); or by some combination of these and other categories'.

Adaptation measures should be context and project specific. Criteria to contemplate include net economic benefits; timing of benefits; distribution of benefits; consistency with development objectives; consistency with other government policy expenditures; environmental impacts; spill over effects; implementation capacity; and social, economic, and technical barriers Leary *et al.,* (2008).

2.4.2 Drivers of Adaptation

Adaptation is driven by the need to adjust in a changing environment, system or situation. The table below was adapted from (Tompkins *et al.,* 2010).

Table 2.1: Drivers of adaptation

Triggers /Drivers	Examples
Climatic change impacts	Experienced or perceived, incl. changing weather patterns (heat, drought, extremes, wind storms)
Legislation – non-climatic change	Sustainable development standards (incl. Corporate Social Responsibility, ISO 14001), Agricultural Policy subsidies and other international legislation
Flooding	Flooding (river and coastal)
Conservation	Including biodiversity conservation
Management of risk	Coastal flooding, landslides, water abstraction
Legislation – climatic change	Policy, legislation, incl. Planning Policy Guidance, climate change levy, emission trading schemes, energy conservation
Savings of costs	Production cost
Socially received pressures	Development/population pressures

Actual or perceived climate change impacts include the following, heat, drought, extreme weather and wind storms. Sustainable development standards include: Corporate Social Responsibility ISO 14001, agricultural policy and other non-climate change legislation subsidies. Flooding can occur in river and coastal areas. Biodiversity conservation needs to be undertaken. Risk management need to be implemented Policy, legislation, including planning policy guidance, climate change levy, emission exchange schemes and energy conservation cost savings, by looking at manufacturing costs and social pressures such as development/population pressures need to be implemented.

2.4.3 Adaptation Measures for Rural Areas

Adaptation measures provide beyond single technical solutions but also address the human institutional dimensions problem.

2.4.3.1 Adaptation to forestry

Bastiaan (2009) records that projections of drought in subtropical and southern temperature forest is to become more intense and frequent, especially in the Western United States, northern China, southern Europe, the Mediterranean and Australia. Drought may also intensify fire incidences and predispose pests and pathogens to large areas of forest. The effects of climatic change on forest may result in an extensive social and economic consequence for people whose' s livelihood is reliant on the forest for basic needs and economic needs. In order to overcome the challenges of adaptation,

commitment to reaching the goals of sustainable forest management must be strengthened at both the international and national levels.

Even in the full implementation of adaptation measures, unmitigated climate change would, during the course of the current century, exceed the capability to adapt in many forests. A need to reduce large greenhouse gas emissions from fossil fuels as well as deforestation is obligatory to ensure that forests retain their capacities to mitigate and adapt.

According to Roberts (2009) conserving water resources depend on the role of the agri-environmental programs which is limited as it requires large public funds. As conditions in forest change, there is an inherent need to change management and policy measures to minimise negative impacts and to exploit the benefits derived from climate change.

Chmura *et al.,* (2010) states'' that genetic and silvicultural method can be based on knowledge to escalate adaptive capacities and to decline climate-related vulnerabilities of forests''. Effective approaches to climate adaptation will likely include assisted migration of species and populations and density management. Use of these approaches to increase forest resistance and resilience at the landscape scale requires a better understanding of species adaptations, within-species genetic variation, and the mitigating effects of silvicultural treatments.

Many elements of existing forest management and policy can be perceived as adaptation to climate. Most communities need wood for their means of energy especially in rural areas. It could be for commercial purposes or for domestic purposes were is mostly used for cooking and heating purposes in winter. Preventative measures must be taken even though local practices are based on the assumption that climatic conditions might not change. Planting of a tree as a form of adaptation can assist in keeping the ground stable that during rain, there is not much of runoff and only a good amount of infiltration can occur. Planting of a tree can also be beneficial to local communities; the more trees planted the more oxygen in the atmosphere. If each community member plants one fruit tree, there will be a nutritional benefit. At the same time there is a need to understand that communities have to have the capacity to implement this adaptation strategy (Spittlehouse, 2005).

2.4.3.2 Adaptation to drought

The term drought may refer to a meteorological drought which is a precipitation well below average, hydrological drought refers to low river flows and low water levels in rivers, lakes and groundwater, agricultural drought is when there is low soil moisture, and environmental drought is a combination of the above.

Drought is unfortunately a repetitive feature of the Southern African agricultural climate both between and increasingly within seasons. Drought relief is a common feature almost every year in

the drier areas of Southern African countries, as there appears to be an increasing trend towards a late start to the rainy season, prolonged mid-season droughts and shorter growing seasons.

Communities have the ability to adapt to climate change and rainfall variability is closely related to their levels of vulnerability while their ability to withstand shocks and stresses to livelihoods is considered very critical (Maserumule *et al.,* 2008). Communities' that are poor and reside in rural area are also often excluded from policy-making processes for drought, and as a result, policies formulated at central government level are not sufficiently responsive to the policy needs off citizens at the local level and, therefore, not conducive to local livelihood and adaptation strategies.

2.4.3.3 Adaptation to agriculture

The IPPC (2001) indicates that climate change scenarios generally indicate higher temperatures for most of Africa, although projections for precipitation trends vary from slight increases in West Africa to slight decreases in Southern Africa, creating special challenges in Africa's rain-fed farming systems. It is here that some of the poorest and most vulnerable communities live.

Communities practicing rain-fed agriculture in semi-arid agro-ecological zones can be seriously affected by global environmental changes and it is therefore absolutely necessary to also understand the level and kind of risk and vulnerability that faces them before viable mitigation and adaptation measures are identified.

Climate variability has been extensively modelled, capturing important features of the climate through applied statistical procedures, agro-climatic indices derived from raw climatic data and from remote sensing. Predictions of climate at seasonal to inter-annual timescales are helping decision-makers in the agricultural sector to deal more effectively with the effects of climate variability. Land suitability and agro-climatic zoning have been used in many countries for agricultural planning thanks to the availability of new and comprehensive methodologies; developments in climate, soil and remote sensing data collection and analysis; and improved applications in geographic information systems (GIS). Drought early warning systems are available worldwide at both national and international levels.

This means that the way in which knowledge and information are generated, managed and disseminated, are critical to improving development outcomes that support adaptation. Lack of knowledge and information can constrain adaptation in situations where recognition of climate trends is lagging, where knowledge about new techniques is lacking, or where avenues for transmitting knowledge upward from communities to policy makers is ineffective or absent. To transform its outputs into a usable format for poor farmers, natural scientists should partner with

social scientists in order to engage poor farmers or to transfer information to them in a format that does not cause confusion (Maserumule *et al*., 2008).

The top three adaptation measures adopted by all types of farmers in order of importance are undertaking spiritual practices, cultivating crops other than rice and changing food consumption habits i.e. cheaper food. The commercial farmers showed the highest rate of adoption in all these measures, whilst the traditional farmers showed the lowest rate. In terms of changing production activities and consumption habits, the traditional farmers are the least flexible, showing the least number of farmers who have carried out these changes (Acosta-Michlik and Espaldon, 2008).

2.4.4 Community-based adaptation

Communities around the world have had to co-exist with disasters from the earliest of times. The wealth of their indigenous knowledge and methodologies should be taken into account, and where necessary, be adopted and implemented to lower disaster.

2.4.4.1 Livelihood strategies of adaptation from experience

Community-based activities and organizations are rooted deeply in the society and culture of an area; they enable people to express their real needs and priorities. This creates possibilities for the problems to be defined properly and for the responsive measures to be designed and practical. (Uitto and Shaw, 2008).

There is a huge difference made in a number of accounts of hazard and livelihood risk between adaptation and coping. The distinction is usually made in relation to the time scale in which each one of them happens. Short time scale actions are portrayed as ‘coping’ with change, where longer time scale actions are portrayed as ‘adaptation’ (Osbahr et al., 2008).

According to Boojh (2008) when considering livelihood strategies, the following needs to be taken into account:

- Vulnerability of the area: The main problem in most regions is the availability of water during the dry season. Community base surveys in some rural communities mostly showed that people perceived water as the key resource. Even collected water was a problem, in the summers due to wells drying up and hand pumps releasing no water. During consultation with communities through participatory rural survey, traditional small-scale water harvesting technologies came up as the priority starting point. Some of these technologies were being applied in one or the other form by small and marginal farmers of the area.
- Community based adaptation strategic plans: In such cases the country’s rich heritage of water harvesting systems offers a solution to water conservation issues. These technologies

need to be analysed and considered for adaptation with community participation. In an ecological sense, such small-scale initiatives could be advantageous as they are people and environment friendly without any adverse impact/s at the ecosystem/landscape level.

- Technological and economic benefit for the community: To improve water management there must be simple technologies e.g. , building check dams, developing water sheds, desalting ponds and boreholes, clearing the inlets and outlets to the ponds and water bodies and recharging the boreholes that can be tested and evaluated. The activities can also provide work to the communities.

2.4.4.2 Community resilience

The approach involves appropriate land use and farm management techniques. Otu (2008) conducted a systematic assessment of what enables people to cope with, recover from and adapt to risks and adversities at household and community level. The project focuses on what actions they took to survive the crisis, what their priorities were and how to build on what was already there. It analysis the strengths, skills and resources available within communities and complements efforts on ownership geared towards attaining environmental sustainability, and improving livelihoods. It creates community consensus, builds on local skills and knowledge; empowers women; provides tangible results to establish authority for future projects; strengthens local livelihoods; finds ways of replicating resilience beyond single communities and integrates risk reduction with development.

2.4.4.3 Livelihood adaptation

Scoones (1998) indicates that livelihood is made of the capabilities, assets which (includes both material and social resources) and activities required for a means of living (Scoones, 1998). Various stimuli and constraints influence livelihood responses and these incorporate aspects of behavioural intention and context, including household assets, social norms and networks, gender, class, ethnic group or individual perceptions.

2.4.4.4 Adaptation of technology

Technology has become an important provider of efficiency and knowledge to people's livelihood. It provides physical infrastructure, equipment and machinery(hardware), skills and knowledge and the capacity to arrange and utilise all of those (orgware), but also the one which farmers produce which is called biological technology (IPCC, 2007).

2.4.4.4.1 Availability of technologies in developing countries

There are already a number of examples of application in relation to the technology for adaptation in developing countries. The make of the technological device differs in response to various local

requirements as determined by the specific environmental system and socio-economic situation, starting from coastal protection to new techniques of farming (Sala, 2010). China has developed some of this technology (Bruinsma, 2009).

2.4.4.4.2 Cost of technology

A huge investment is required in the main part of activities in the field of mitigation, and this takes place for some adaptation process which focuses on geo-engineering too (eg.coastal protection). It is also important to note that the major part of the adaptation activities can manifest at a small scale with the head for investment of large amount of capital (Sala, 2010).

2.4.4.4.3 Technology transfer

The technological transfers are more complex in the adaptation process than in mitigation ones. This is a result of the fact that the impact in which communication for sustainable development initiative (CSDI) adaptation is usually site-specific and these results in know-how being less easily transferable. It is indispensable to establish effective methods to diffuse experience and ways to the communities that must deal with problems of adaptation to a new environmental and eliminate circumstances in this field. ITC can play a major role and offer a fundamental contribution (Sala, 2010).

2.4.4.5 Livelihood profile

A livelihood profile is defined by the following:

- Livelihood assets: Petty traders or micro businessmen are forced to consider activities outside farming as a result of limited holding of natural resource in both irrigated and non-irrigated areas. (IPCC, 2010).

Among the petty traders/businessmen two types of trading or business strategies have emerged from these groups (UNFCCC, 2012).These groups do exchange trading between their communities depending on seasons. The things involved in trading depended on what was produced inn that season. In the irrigated areas where rain has occurred, farmers become involved with the petty trading on agricultural product, whilst the one who have live stock exchange on those livestock products.

During drought affected seasons petty traders/businessmen get more involved with non- cultivating products and do businesses such as tea stall processes, shop keeping, selling households' essential goods and various hawking activities. However, this trading group needs seed or revolving money for both these purposes.

Therefore, the petty/traders businessmen were found to have limited but some holding on financial assets such as livestock. The traders in generate some cash from cultivation and sellable livestock in their household domains to enhance the petty business when the demand of more liquid money arises

- Livelihood outcomes: This is an outcome achieve through livelihood strategies by household \members, such as levels of food security, income security, health, well-being, asset accumulation and high status in the community. Food and income insecurity, high vulnerability to shocks, loss of assets and impoverishment count as unsuccessful outcomes (IPCC, 2010).
- Wage Labourers: Climatic and non-climatic conditions affect livelihood situation of the wage labourers. Conditions such as erratic temperature, shortage of rainfall, high evaporation rate and the overriding drought are considered climatic. Conditions that occur that are non-climatic are lack of employment opportunity all year round, lack of cash/savings, food shortage, loss of cultivable land, lack of healthcare facilities, poor wage rate, low female employment opportunities, commuting problems to other locations for work, distressed seasonal migration, suffering and diseases of domestic livestock/poultry, tenancy complexities are among the prominent ones. This non-climatic situation mentioned gives verification that the wage labourer seems largely reliant on the state of migration, economy and society (UNFCCC, 2012).

Relating to the other livelihood groups such as various groups of farmers, fishers and commercial famers this working group continue to be less vulnerable to the climatic factors but largely stay vulnerable to their societal contexts and the want of opportunities. As a consequence, a double adversity of the climatic situation and the direct effect of their current state i.e. the poverty status and the endogenous given conditions (i.e. dowry or patron system) make a ‘spiral effect’ on the livelihoods of the wage labour.

2.4.4.6 Livelihood strategies

According to Boserup (1965), livelihood strategies take into account:

- Agricultural extensification: involves making low-input cultivation after taking new units of land. There is a distinction between extensification and the standard economic theory according to which more marginal units of land will be brought under cultivation when the scarcity of land increases. New units of land conveyed under cultivation may have higher productivity, if and when land is not scarce than the units that are already in use.

- Agricultural intensification: From conception, it involves the employment of more labour on a unit of land, to succeed in greater productivity.
- Livelihood diversification: includes the formation of a portfolio of farming and non-farming livelihoods. Families can support the production of crop to be stable and be sufficient by keeping livestock, employment in other farms in order to get their wages and not only rely on one farm or in other sectors other than farming, they can also be self-employment by gathering.
- Migration: makes it possible for an agricultural household to change its opportunity set and associated risks. Difference should be drawn between local and long distance migration, as well as between temporary and permanent migration. Local migration can open up access to land, other resources, markets, wage employment or self-employment.

2.4.5 Discussion

The process of adaptation varies from region to region. It is the manner in which actual adjustment of physical, economic, social, political and ecological themes will take place.

Nielsen and Rensberg (2010) stated that human adaption to climate change is a heterogeneous process predisposed by more than economic and technological development". It is increasingly acknowledged in the adaptation to climate change literature that factors such as class, gender and culture play a large role when adaptation strategies are either chosen or rejected at the local scale.

In most cases the cost of adaptation is felt by women. Adaptation may require women to extend their labour time and sometimes face risks of exploitation.

Due to some cultural measure practices in some rural areas, it may take a lot of efforts for women to implement. The most effected people in terms of global climatic change are the poor, and it comes with costs (transport, education and information). It may also mean that adaptation may not occur. A lot of studies also indicate that the poor are the last class to be attended to (Archer, 2003).

A number of traditional farmers are practicing subsistence farming and they also cultivate traditional crops. Moreover, their level of income, assets, diversification and information is low. They also provide food for their own consumption or feed for the production of livestock, which then makes it clear why they account for the lowest average farm size (137ha). These are the types of farms that do not have the capacity to implement adaptation strategies.

When assessing the technical capability to alter or bring improvement in agricultural practices, determining the agronomic potential can be used as a means to assess. It is therefore recommended

that a number of criteria's be employed in making judicious selections of adaptation measures from environmental, social and economic point of view(Asian Development Bank, 2009).

2.5 GENDER ISSUES

In order for the policies relating to climate to be active, real and react to the needs of society, women and men must participate in climate change, decision making and implementation thereof on an equal basis (Fothergill, 2004).

> *"Any dramatic and unplanned change to the environment will present practical challenges to how people make their livelihoods, and this in turn will challenge or reaffirm women's and men's roles, and power, in their families, communities, and wider society"(Sweetman, 2009).*

2.5.1 Preamble

There are major gender distinctions in in use, access and management of water. Solving gender and water jointly acknowledges this imbalances and attempting to make sure that contributions of both woman and man are recognised. In order to manage water properly and sustainably, it is necessary to comprehend the various roles of men and women as well as targeting action appropriately.

These differences include:

- Powerful groups of society, usually male dominated, can feat resources more systematically and on a great scale as well as drive industrial transformation of the environment, thus their potential to suffer damage is higher.
- When there is no water provision through piped system, the duty of collecting water is given to children and women who must invest a huge amount of time and energy on this activity.
- Women seldom have equal access to water for productive use and are the first to be affected when there is water shortage.
- Children and women are the most vulnerable to water borne diseases as a result of their roles in water collection, washing of clothes and other domestic activities.

In order to fully comprehend the relationship between gender and climatic change, Terry (2009), states that a number of instructive overviews of gender-disasters must be studied. Some of the literature focuses less explicitly on the external agent (natural hazard, disaster, or for our purposes, climate change) and more on social vulnerabilities to expose different groups to different levels of risk. To put it more generally, although initiating in ecological systems and natural hazards, disasters are inherently social wonder. Their consequences are "linked to who we are, how we live,

and how we structure and maintain our society" (Fothergill, 2004). Unequal distribution of hazard risks are thus linked to inequalities such as poverty, limited access to resources and mobility, as well as culturally constructed expectations that shape work patterns, household divisions of labour, including those that are gendered.

Gender differences in terms of vulnerability can generally be viewed through poverty broadly and the global feminisation of poverty has resulted in women and girls comprising upwards to three fifths of the world's one billion poorest people (UNFPA, 2008). Since disasters excessively affect communities already living in poverty (Fothergill and Peek, 2004), they have major effects on women across the globe and tend to leave poor women even more impoverished. Women and men react to risk differently, because of their location in social structures (Fothergill, 2004).

It is interesting to note that researchers have found that as much as men experience less risk in general than women, as soon as they perceive intensified risk, they are likely to advert the risk than women with comparable risk exposure.

Risk perception differences among men and women also vary by disaster type as well as potential severity. With respect to perceptions of climate risks, Terry (2009) refers to a case study of small farmers in South Africa (conducted by Thomas *et al.,* 2007) in which women farmers recognized heavy rainfalls as a distinct risk, whereas more men than women perceived drought as a distinct climate risk. Terry attributed these differences in perceptions of climate risk to broader livelihood patterns and relationships to livestock and agriculture.

Instead of associating these gaps in mortality to gender differences in strength, size or physical capabilities, socially produced gender relations such as care giving roles, childhood socialisation, and clothing norms affect women's ability to survive disaster. As much as there could be differences regarding climate change, adaptation can readily allurement upon the knowledge in gender and disaster literature, e.g. UN/ISDR (2008) published "Gender Good Practices and Lessons Learned", which offered an educational article regarding women's leadership and handling of natural and environmental resources, reducing the risks of disaster and adaptation to climate change.

It shows that gender sensitive tools and practices used in disaster risk reduction excluding: land and water use and management, alternative livelihoods can be used to antagonise challenges, including those linked to livelihood migration, associated with climate change.

In terms of policy, a number of internal policy discussions have been focusing on the economic impact of climate change, efficiency and technical issues (Hemmad and Rohr, 2009), not tackling the social dimensions of climate change, including gender issues. It is also interesting to note that gender issue are increasingly being well reasoned and analysed in climate change discussions,

forums and conferences in part since women and gender activists have been "inquisitorial the dominant perspective concentrating mainly on technologies and markets and putting" caring and justice in the centre of measures and mechanism.

Table 2.2: Key gender issues in vulnerability to the effects of climate change

Effects / Impacted systems	Key gender issues
Floods	Acknowledgement of and consideration to gender differences in flood vulnerability, prevention and get by mechanisms.
	Formulation of flood reaction and mitigation actions in a manner that is gender sensitive and identifies that men and women have different roles and responsibilities and different types of vulnerability.
	Appropriate representation of gender interests in any preventive, responsive and mitigating measure.
Droughts	Recognition of and attention to gender differences in drought vulnerability and coping mechanisms. Formulation of drought relief, recovery and mitigation mechanisms sensitive to women's and men's different needs roles and vulnerabilities.
Desertification	Given the gender division of labour in most arid and semi-arid environments, any anti-desertification measures should draw upon local knowledge of the environment and take care not to accentuate existing gender inequities.
Freshwater, coastal and marine ecosystems	Appropriate representation of gender interests in ecosystem management, preservation and restoration, as well as in land tenure and concession rights.
Other ecosystems	Appropriate representation of gender interests in ecosystem management, preservation and restoration, as well as in land tenure and concession rights.
Fisheries	Attention to commercial vs. small scale and subsistence fishing and the differential accrual of benefits from either activity based on gender.
	Recognition of the needs of women and men, boys and girls for access to fishing equipment and permits.
Construction of dams	In consultation with different stakeholders, ensure that environmental impact assessments adequately address gender with attention to how livelihood systems and productive activities will be disrupted and how they can be compensated for in the resettlement plans.
	Assessment of how the benefits to be derived from the dam will accrue to both men a women,
Environmental flows	Given the gender roles in procuring and using water and environmental services, women and men may have very different stakes in water quality and environmental flows. Both men's and women's voices should be heard.
Climate change	Campaign of cleaner-burning fuel for household use to help reduce wood gathering, air pollution and harmful emissions, and benefit women by cutting their annual cooking costs by 25 %.
	Incorporation of both women and men into the decision-making framework on climate change mitigation and adaptation initiatives.
	Support for the provision of tools, including vulnerability assessments that build on local and native knowledge held by women and men and of measures to adapt to or allay the impacts of climate change.
	Integration of gender analysis and gender equality indicators into programmes and projects to identify where specific vulnerabilities to climate change lie, and where opportunities for mitigating and adapting to climate change can be found.

2.5.2 Addressing Gender Issues

The following can be used to address gender-related water issues:

- Comprehending men's and women's duties in using and affecting the environment through the gathering of data which is gender sensitive and making use of gender examination tools. The following questions will assist in this regard:
    - Whether it is male or female that is consuming the natural resources and reasons for consumption
    - What would be the effects of such practices on the eco system and water resource?
    - Who, by gender, social group and location, is benefiting from various natural resource uses?
    - Which uses and users by gender are creating negative impacts on water resources, as well as types of impacts and reasons for their generation?
    - Who of the male and female, is being impacted negatively as a result of the water uses in other sectors that affect water environment?
- Work with affected communities and stakeholders to find creative solutions that are good for people and good for the environment. Using gender-sensitive participatory methods for project management and policy development facilitates greater expression and consideration of both women's and men's voices a worthwhile effort since those most intimately involved with the problem often have good ideas for the solution.
- Capture the interests of men and women in sustainable solutions via gender-sensitive stakeholder analysis and gender-sensitive participatory methods. Participation in decisions and implementation enhances accountability, ownership and flexibility and can contribute to the decentralised management goals of (IWRM).
- Understand who is to benefit from investment, who will pay for the benefits and who will be negatively affected. Using gender analytical tools and gender-sensitive data in combination with gender economical tools, it is possible to consider how priorities for investment are determined, whether they are in line with IWRM and whether increased consultation with both women and men would yield a different result.
- Technology choice and investment decisions always require community consultation and input from expected beneficiaries. Consultation with both women and men through gender-sensitive participatory tools is essential, as experience, needs and expectations almost always differ across genders.
- Gender-sensitive consultation identifies who is in charge of each task in water management and how tasks can be better distributed to maximize efficiency, fairness and effectiveness.

Research on household income allocation can identify who pays for water services, her/his willingness and ability to pay and the best way to overcome constraints on timely payment. Additionally, a gender sensitive analysis could help understand who is best positioned to effectively solve minor and major technical problems in water services.

- Examine the distribution of benefits from water uses, services and management. Gender analytical tools, participatory methods and gender-sensitive data reveal who participates, who benefits (men, women, poor, rich) and who is most affected, and how.
- Encompass actions with poverty alleviation. Gender–sensitive analysis and gender budgeting help managers to decide on systems which allow improved access to water services for disadvantaged groups and ensure that negative impacts are allocated to users (user/ polluter pays principle).
- Promote more transparent systems of allocation and accountability that report gender-based information, allow for and promote gender sensitive participation, and analyse water budget effects on women's and men's welfare.
- Empower people by deciding on management systems that recognise, respect, promote and use the skills and expertise of both women and men.

CHAPTER 3:
CONCEPTUAL FRAMEWORK

The conceptual framework for decision-support guidelines on the development of the vulnerability assessment and adaptation requirements revolves around water security and social-ecological links (Hinkle, 2008).

3.1 TARGET AUDIENCE

The audience for the decision-support guidelines need to be clarified and this will largely determine the format of the outcomes. The decision-support guidelines will mainly be intended for local government officials and politicians. In this sense they will have to be able to address both practical project implementation related and political policy-based matters. The aim is to also make the decision-support guidelines useful for government at provincial and national scale, in the sense that they will be able to inform provincial and national policies on local needs. Local organizations, such as NGOs and CBOs, should also be able to use the guidelines for practical purposes, though the focus during development of the guidelines will be on local government officials and politicians.

3.2 RESEARCH SUBJECT

The research is focusing on rural economies and the vulnerabilities of rural communities to climate change. Rural economies and communities are situated within the larger regional, national and global systems. Even though the project will focus on impacts on local economic and ecosystem, it does not exclude all the other influences from other sectors linked to the local stakeholder.

3.3 WHAT IS A DECISION-SUPPORT FRAMEWORK?

Now that the audience of the output is defined, more clarity will be required as to what decision-support guidelines or a decision-support framework is, and what function they should fulfil. The main output will be a decision-support framework or system, as the guidelines will quite logically flow from this. Henceforth reference will be made to a “decision-support system” (DSS) as the actual output, the tool, to be developed.

A “decision support system” is quite a broad concept; it relates to both systems that is information descriptive as well as optimal approaches. However, any challenge concerning decision-making is centred on a choice between alternatives. These choices, often called “scenarios”, are assessed and

often ranked as per a set of criteria. This set of criteria is checked against goals, constraints and the expectations, or the result that one wants to achieve, which might involve trade-offs between some objectives. Simply put, the scenario that meets most of the objectives, and stays within the defined constraints would rank highest. In order to increase one's options, constraints can be removed, requirements can be removed or added, or trade-offs can be redefined. Of course, this is assuming that the range of scenarios is exhaustive (i.e. in terms of an intervention, the full range from "do nothing" to "doing the maximum" has been explored) – otherwise it is also possible to adjust possible decisions in order to achieve a scenario that ranks sufficiently high.

It must be noted that the above process is relatively simple when considering a limited number of interventions in a relatively simple system. The more complex the system and the interventions, the more difficult it will be to establish reliable scenarios, and also the more difficult it will be to define objectives and "measure" trade-offs.

In terms of outcomes, one quite specific outcome of a computerised decision-support system for natural resources management could be: "to improve planning and decision making processes by providing useful and scientifically sound information to the actors involved in these processes, including public officials, planners, scientists, and the general public" (Fedra, 1995). For this research, it is envisaged to even go a step further; to provide not just information or data, but to actually develop a system which processes linkages, dependencies and influences between data sets, enabling users to develop scenarios as a part of vulnerability assessments.

3.3.1 Proposed Approach to DSS Development

There are already quite a few decision-support systems available in relation to natural water resources management, both for groundwater and surface water, and also in the spheres of ecosystems and livelihoods. The proposed approach is to scope existing DSS's available in South Africa, while also researching the needs of end-users of the system and the development of a vulnerability assessment framework. These three outputs combined will provide the starting point for the development of the DSS.

3.3.2 Decision-Support Systems

A DSS refers to an interactive computerized system that accumulates and presents information from a number of different sources, typically for business purposes. DSSs are the applications which are systems and subsystems that help people make decisions based on the information that is culled from a number of different sources (Power, 2002).

3.3.2.1 Types of Decision-Support Systems

Communication-driven DSS: Most of the DSSs that are communication driven, are targeted at internal teams, including partners. It is for the purpose of assisting in conducting a meeting or for those who are using it to collaborate. The technology that is commonly used in deploying the DSS is a web or client server. Relevant examples for such would be chats and instant messaging software, online collaboration as well as net-meeting systems (Power, 2002).

- DSS which is data driven: This a type of DSS that has more emphasis on access to and manipulation of a time-series of the company's internal data as well as external data at times. File systems tools that provide the most elementary level of functionality are those that are accessed by query and retrieval tools. Data warehouse systems which permit data to be manipulated by tools which are computerised, a tailored for a specific task and setting by one or more tools that are general and operators to provide more functionality. DSS which is data driven with On-line Analytical Processing (OLAP).
- Document-driven DSS: They are the commonly used, and they are mainly meant for a broader base of users. The aim of this particular DSS is to look-up web pages and locates documents on a specific set of keywords or search teams. The commonly used technology in setting up such DSS is through the web or client/server systems (Power, 2002).
- DSS that is knowledge driven or "knowledgebase": They are known as a catch-all category. They cover a broad range of systems, catering for the users within the organization, setting it up, but may also serve others communicating with the organization. An example for this would be customers of the business. It is utilised essentially for the provision of management advice or for the production or service choice. The type of deployed technology used to set up system could be silent system or server system, the web, or software running on stand-alone PCs (Power, 2002).
- Model-driven DSS: are sophisticate systems that assist in analysing decisions or making choices between different options. These are used by the management, general staff members of the business or people interacting with the organization for various objectives depending on how the model is put together, scheduling, decision analysis etc. The system can be developed through software/hardware in a stand-alone computer, client/server systems, or the web (Power, 2002).

3.3.3 Millennium Ecosystem Assessment Conceptual Framework

As already outlined in this study, the framework developed for the assessment of vulnerability and adaptation requirements will revolve around the concepts of water security, eco-system services and

human well-being, i.e. the focus of vulnerability assessments will be on improving people's well-being of human and livelihoods sustainably. This means that objectives and criteria to be incorporated into the DSS will have to relate to these matters and the scoping and evaluating of previous work will focus on them also (MA, 2003).

Some of the aspects that will be explored further as part of this project segment are:

- Water security: "protection of vulnerable water systems, protection against water related hazards such as floods and droughts, sustainable development of water resources and safeguarding access to water functions and services" (UNESCO-IHE, 2010). This definition clearly links the concept of water security to human well-being and sustainable development, and touches upon vulnerability aspects ("protection of", "safeguarding", etc.).
- Ecosystem services: "the benefits people obtain from ecosystems; provisioning, regulating, supporting, and cultural services" (MA, 2003).
- Human well-being: "Human well-being has multiple constituents, including basic material for a good life, freedom and choice, health, good social relations, and security" (MA, 2003).
- Poverty: "pronounced deprivation in well-being" (MA, 2003).
- Ecosystem service valuation, and trade-offs: "Valuation can be used in many ways: to assess the total contribution that ecosystems make to human well-being, to understand the incentives that individual decision-makers face in managing ecosystems in different ways, and to evaluate the consequences of alternative courses of action" (MA, 2003). Valuation used in the latter sense usually refers to using it as a "tool that enhances the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social actions that alter the use of ecosystems and the multiple services they provide. This usually requires assessing the change in the mix (the value) of services provided by an ecosystem resulting from a given change in its management." The concept of valuation, as employed in the Millennium Ecosystem Assessment, does not only refer to consequences to humans, but also to the importance people place on considerations of intrinsic value.
- Drivers of change: "any factor that changes an aspect of an ecosystem" (MA, 2003), and distinctions can be made between direct and indirect drivers.

The Millennium Ecosystem Assessment conceptual framework, which focuses on ecosystem services, human well-being and poverty reduction and drivers of change, as depicted in Figure 3.1, is an ideal starting point for the development of a vulnerability assessment framework, and the associated decision-support system. It puts the emphasis on human well-being, resilience and sustainability, and will assist in attempting to make the various linkages that exist. The sensitivity of

systems to changes, an important component of vulnerability assessments, is captured in this conceptual framework.

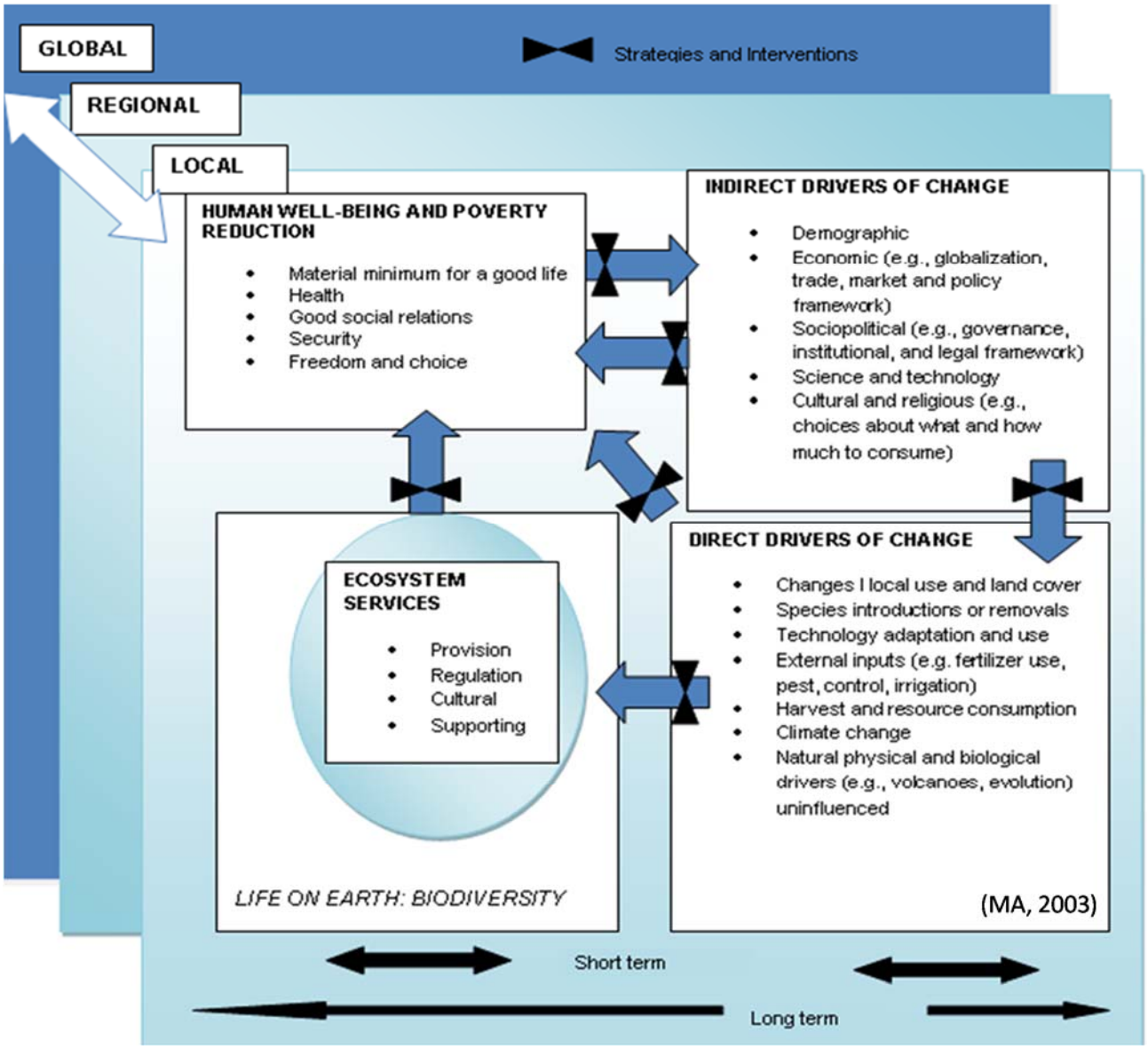

Figure 3.1: Millennium Ecosystem Assessment Conceptual Framework

The framework is laid-out in three ways, this represent the different stakeholder that are considered to make decisions. It has the global stakeholder, regional stakeholder and the local stakeholder. It is interconnected with strategies and intervention between its drivers. It is meant to address both short term and long term challenges.

There are four major drivers that help with the determination of vulnerability in communities: (1) The human well-being and poverty reduction, (2) indirect drivers of change, (3) the direct drivers of change and (4) the ecosystem services.

- Human wellbeing and poverty: It describes the things that humans want to have a decent life. Materials that are a minimum requirement for a good life, this could be a shelter, basic things

that allow them to get on with their daily life. Health is the ability to go on daily with no major things like dieses out of food shortage. Good social relation and Security can assist in feeling accepted within their community and no one can go by tomorrow without hunger. Freedom and choice, is when you don't do something because that is the only thing one can do.

- Indirect drivers of change: It describes the physicality of the situation and the governance of the area. Demographic is used to study population based on the following factors: age, race, sex, and economic status, level of education, income level and income. It is also meant to look at the socio-political, cultural and religious as well as science and technology.
- Direct drivers of change: These are the natural or human induced drivers that directly cause change in the biodiversity. Climate change may function on a global or large regional scale; political change might function on the scale of a nation or a municipal district. Socio-cultural change typically occurs slowly, on a time scale of decades, while economic changes tend to occur more rapidly. Cultural and Religious factors can be described as the values, beliefs, and things that seem normal within a group of people to share.
- Ecosystem: these are the services that are given to the communities to help them with improving their human well-being and reduce poverty. It come through constitutional regulation from either a state or a local municipality, it is seen as a mandatory to give services to the community.

By taking this approach, the project will have a very clear focus on development and poverty extermination, two major themes for rural areas in South Africa. By doing this, the subject will be of great importance to stakeholders in rural areas, and it will make it easier to mainstream climate change adaptation by being able to integrate it into existing development, planning and poverty eradication initiatives.

3.3.4 Additional Guidelines to the Decision-Support System

As it is important that adaptation options are included in existing frameworks or strategies and guidelines on how to achieve this will be developed for South Africa's most commonly used policy and implementation frameworks, such as Integrated Development Plans (IDP), Water Services Development Plans (WSDP), Provincial Growth and Development Strategies (PGDS), but also water resources management plans such as Catchment Management Strategies (CMS). Guidance will be provided on how vulnerability assessments and scenarios fit into the development of these documents, how monitoring and evaluation should be undertaken or should be integrated, etc.

Two other guidelines that will be developed in this regard relate to monitoring and evaluation and stakeholder involvement in conducting vulnerability assessments and using the decision-support framework.

3.3.5 Data Collection for the Decision-Support Framework

The main assumption for this project is that a lot of information and data is already available, either as "raw" data, or already incorporated into decision-support tools which essentially capture the sensitivity of the various systems to changes. The main challenge will be to "connect" these aspects. For example a hydrological model may outline the consequences of increased groundwater abstraction on groundwater tables: firstly, the driver that causes increased groundwater abstraction will have to be incorporated. This driver could be climatic drought but could also be socio-political, which may possibly increase water allocations to industry at the expense of rural people. Secondly, lowered groundwater tables are a driver themselves for a variety of ecological and possibly also social processes. Making these linkages will be essential for the development of a robust decision-support system, but it must be recognized that in some instances causalities might not be clearly established, in which case assumptions will have to be made. In the development of the vulnerability assessment system and the decision-support system, it is important that boundaries are identified through the development of objectives and criteria.

3.3.5.1 Water resources

Information for water resources is not available as yet but it may be available from the DWA, and the WRC, both on hydrological processes ground-water and surface water, and the impact of climate change on water resources. In addition, various universities such as the University Of KwaZulu Natal (UKZN) and the University of Cape Town (UCT), will have information on the latter topic (WRC, 2012).

3.3.5.2 Rural economies and communities in South Africa

When exploring meanings and synonyms for "rural", various options for definition crop up. There are geographic definitions, such as provincial, countrified or countryside-related (i.e. the opposite of urban), or more economically related definitions: agrarian, agricultural, pastoral, farm-related areas. More "emotional" synonyms refer to rural areas as rustic, idyllic and even simple, unsophisticated areas. Admittedly, defining rural areas and communities is problematic: Rios (1988) presents various qualitative and quantitative definitions of "rural" and highlights that even though a definition is important for demographers and policymakers, as it informs policy decisions and allocations, it is nearly impossible to "pigeon hole" rural areas and rural communities without losing the sense of complexity of these areas. South Africa's Integrated Sustainable Rural

Development Strategy (ISRDS) of 2000 also acknowledges this. In general though, rural communities are most commonly defined as those situated in the countryside, i.e. on-urban areas with a certain reliance on agricultural activities for their livelihoods. South Africa's Rural Development Framework (RDF) (1997) defines rural areas as "sparsely populated areas in which people farm or depend on natural resources, including the villages and small towns scattered across these areas" (DLA, 1997). So-called 'rural clusters' in the former homelands (large settlements without an economic base, except transfer payments) are also included in this definition. In South Africa, population density is thus not a good marker for defining rural areas, the reliance on natural resources and agriculture would be a better defining aspect. Often, rural areas are classified according to what they are not, i.e. there are relatively clear indicators as to what are urban and/or metropolitan areas, after which the remaining areas, non-urban areas, are essentially classified as rural.

As argued earlier, the emphasis on rural areas does not necessarily imply that regional, national and global influences, impacts and actions are non-existent or are to be ignored. It is intended that these will also be mapped.

The livelihood questions that are important in the light of vulnerability assessments and adaptation are reiterated below:

- The people's prioritised desire livelihood outcome as they express.
- Their access to human, social and natural capital or assets and their ability to effective use of them.
- The various strategies they use and how they make use of their assets in pursuing their priorities.
- The institutions, policies and processes that guide their accessing of assets and opportunities
- The factors affecting vulnerability to shock and stress, as well as the context in which they live.

3.3.5.3 More on gender issues

Issues related to gender will be incorporated into the vulnerability assessment framework and the DSS by ensuring that the information and data collected has a gender focus, i.e. information will be disaggregated according to gender. This would relate for instance, to unemployment figures, access to resources, HIV/Aids data, poverty patterns etc.

An important question that will have to be posed is what the desired outcome is of a gender focus and thus what the objectives and criteria of the DSS should be in relation to gender. It is proposed

that, acknowledging different perceptions and framing of problems and solutions by men and women, the vulnerability assessment framework and the DSS will aim at developing outputs that reflect those differences, ensuring that adaptation requirements and possible actions also reflect these.

3.4 CONCLUSIONS

A decision-support system is defined simply as a guideline to what must be followed in order to reach a certain target. It also informs the target audience of the vulnerability situation at hand. This set of criteria is checked against objectives and constrains the expectations, or the results that one wants to achieve, which might involve trade-offs between some objectives. The main aim of a DSS is to inform the national and provincial official and, so they can inform the local and regional authorities of the situation in their area.

CHAPTER 4:
DESCRIPTION OF THE STUDY AREA

In this chapter, the way in which the study area was selected is first discussed. Thereafter, information on the physiography and climate, as well as the geological and geohydrological conditions within the study area is provided.

4.1 SELECTION OF THE STUDY AREA

4.1.1 Introduction

Rantlhomela (2010) devised a methodology which can be used on a regional scale to determine the social vulnerability index (SVI) of South African rural communities in as far as the impact of climate change is concerned. This methodology incorporates a number of social parameters to calculate an SVI. In the current investigations, the methodology of Rantlhomela (2010) is used to select an area (the study area) where the social vulnerability is moderately high, and on which all further investigations will focus.

The section that follows presents a summary of the SVI methodology for a regional assessment to identify areas in which South African communities are likely to be vulnerable to the effects of climate change. The full methodology of Rantlhomela (2010) is presented in Appendix C.

4.1.2 The social vulnerability index (SVI)

The SVI was developed to assess the vulnerability of communities to climate change. Such an assessment could help in the development of appropriate policies for adaptation. Three social indicators were used in the calculation of the SVI (Rantlhomela, 2010), namely:

- Health,
- Loss of income, and,
- Migration.

Each of these indicators was evaluated across South Africa to determine a SVI indicating the extent to which the communities within South Africa are vulnerable to climate change. The SVI was calculated by assigning weights (W_i) and ratings (R_i) to the indicators and by using the formula:

$$\text{SVI} = \left(\sum_i R_i W_i \right) / i \qquad (1)$$

The ratings were assigned values of either 0 (insignificant risk), 1 (low risk), 2 (moderate risk) or 3 (high risk) according to the level of risk the indicator is exposed to, whereas the weights were assigned values ranging from 1 to 5 based on the estimated sensitivity of the indicator to climate change. For the indicator *Health*, the groundwater quality (TDS concentration) was used as an indicator. For the indicator *Loss of Income*, the land degradation index was used, while the current population migration trends were used to assess the *Migration* index (Rantlhomela, 2010) (see Appendix C for a more detailed explanation).

4.1.3 Results of the SVI Assessment

The results of the SVI assessment are shown in the form of a colour-coded map in **Error! Reference source not found.**. The colours represent the degree to which the communities in the specific areas are vulnerable to climate change:

- Blue denotes areas of insignificant a social vulnerability,
- Green indicates areas of low social vulnerability,
- Yellow represents areas with moderate social vulnerability, and,
- Red corresponds to areas of high social vulnerability.

It is seen that the central parts of South Africa have a low social vulnerability to climate change, while larger vulnerability is seen in the eastern, western and northern parts of the country.

4.1.4 Selection of the study area using the SVI

The social vulnerability index map was used to choose the area of study. The study area had to be vulnerable to climate change to some degree, and only yellow or red areas of the SVI map were therefore considered. Other factors that influenced the selection of the study area were: 1) accessibility, 2) the language in which communication would take place, 3) the researcher's familiarity with and understanding of the local culture, and 4) the size of the area. The size of the study area had to be small enough so that a survey could be done in a relatively short period of time.

The area chosen for the current study is the village of Tshiungani and its surroundings (refer to **Error! Reference source not found.**). Tshiungani is located in the northern parts of the Limpopo Province of South Africa, less than 19 km from the Limpopo River, which forms the border with Zimbabwe. Tshiungani lies within a yellow area (moderate social vulnerability).

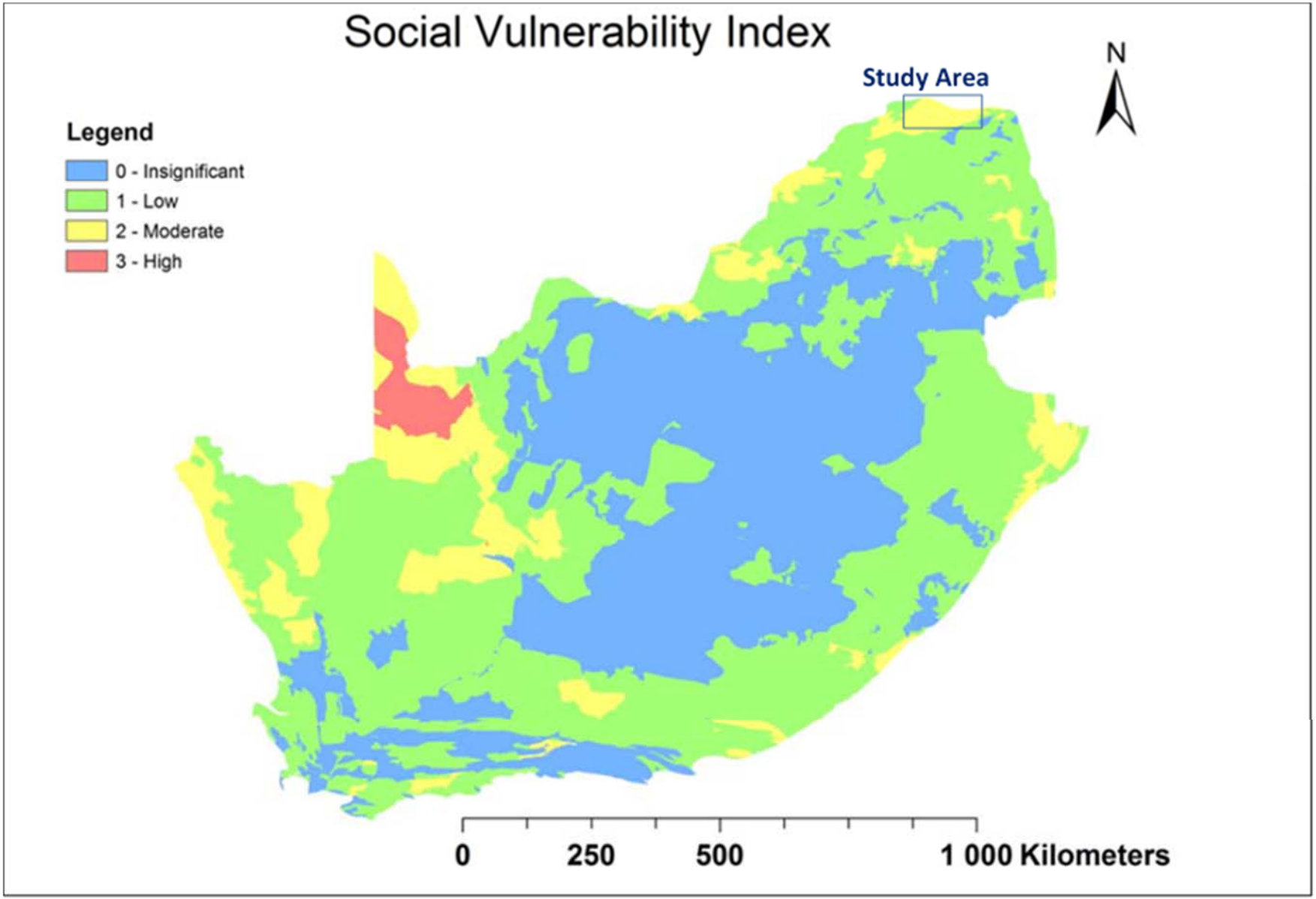

Figure 4.1: Map of the social vulnerability index across South Africa showing the location of the study area

4.2 REGIONAL SETTING

The study area is situated within the Vhembe District in the Limpopo Province of South Africa. The Limpopo Province is situated in the far north of South Africa (see Figure 4.2). The province occupies an area of approximately 123 910 km^2 and shares borders with three other countries, namely: Botswana to the west, Zimbabwe to the north and Mozambique to the east. The Limpopo Province also shares provincial borders with the following provinces: North West, Mpumalanga and Gauteng.

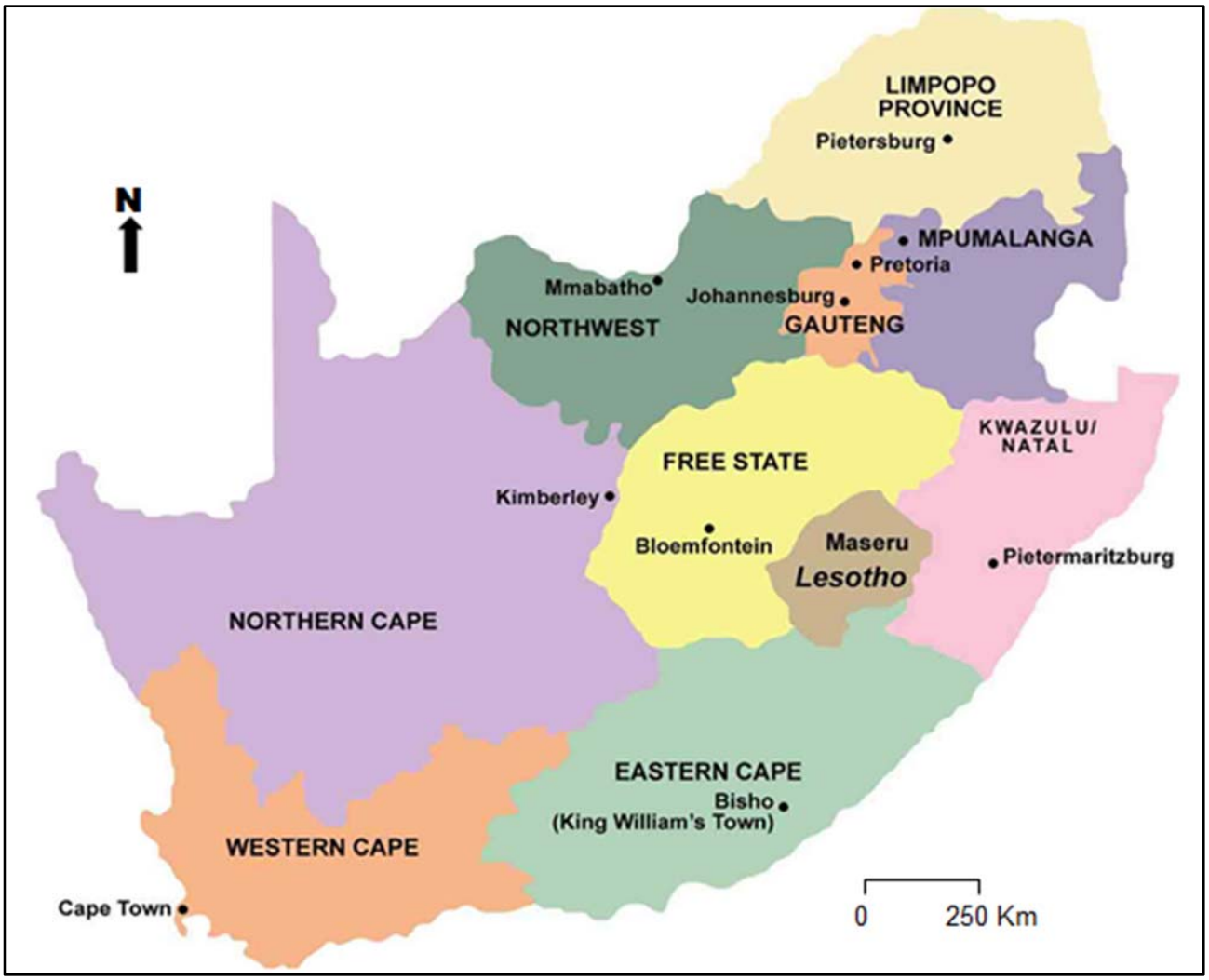

Figure 4.2: Location of the Limpopo Province in South Africa

4.2.1 Location of the Vhembe District

The Vhembe District lies in the northern part of the Limpopo Province (Figure 4.3) and is bordered in the east by the Kruger National Park, in the south-east by the Mopani District, and in the south-west by the Capricorn District. Botswana occurs at its north-eastern border, while Zimbabwe borders it in the north.

The Vhembe District covers approximately 18 569 km^2. It has a population of approximately 1 300 000 people of whom 53.3% are female and 46.7% male. The governance of the Vhembe District is both tribal and through an elected local government. The district largely relies on subsistence farming for food production and is mostly dependent on rain for agriculture.

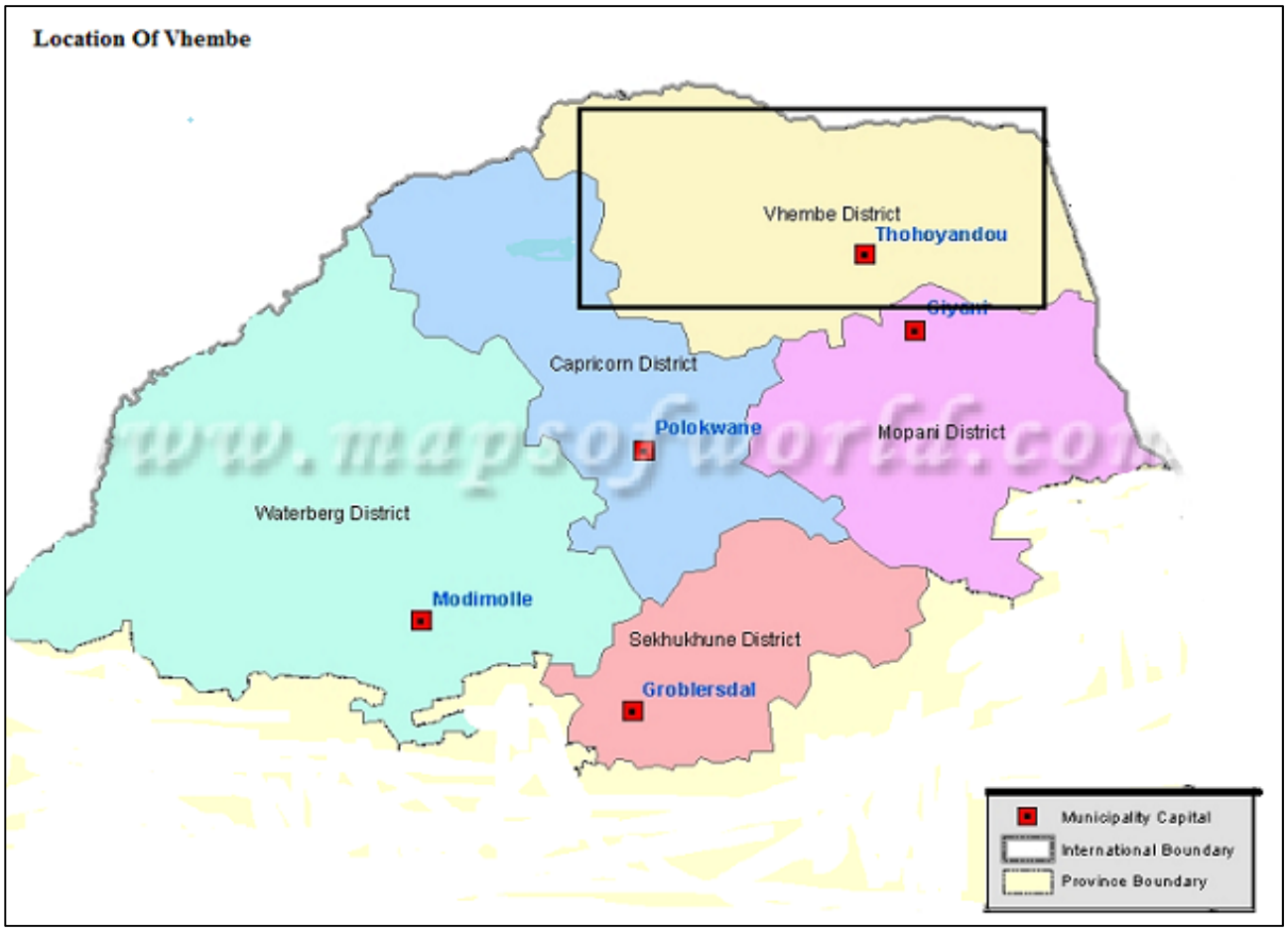

Figure 4.3: Location of Vhembe District in the Limpopo Province

Four local municipalities occur with the Vhembe District Municipality, namely: Musina, Mutale, Thulamela and Makhado. The main towns in the Vhembe District Municipality are: Louis Trichardt, Musina and Thohoyanou (see Figure 4.4).

4.2.2 Location of Tshiungani

The village selected for the current study is Tshiungani. This village is located in the north-eastern parts of the Vhembe District, less than 19 km from the Limpopo River which forms the border with Zimbabwe to the north (refer to Figure 4.4).

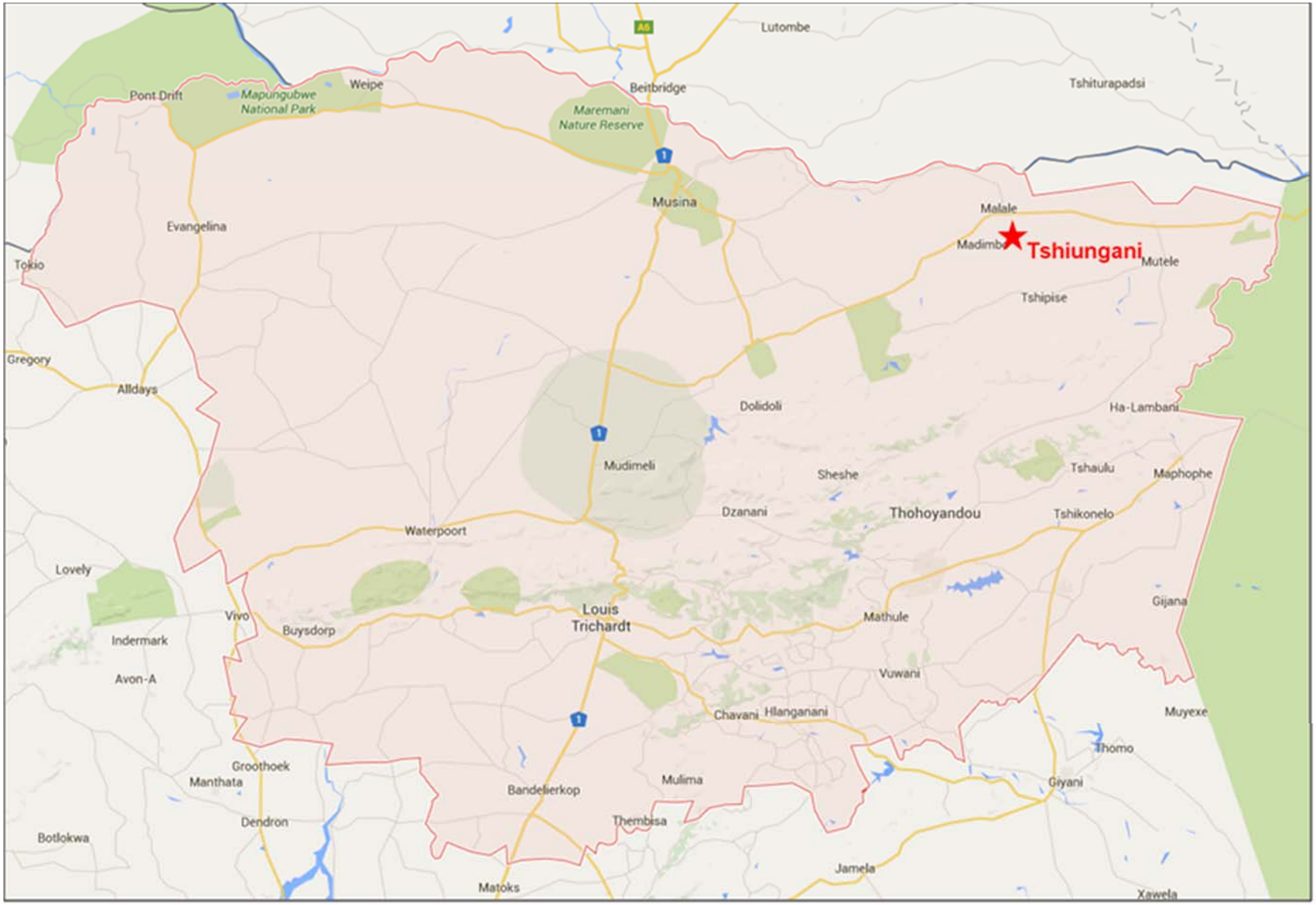

Figure 4.4: Towns within the Vhembe District Municipality

4.3 CLIMATE

4.3.1 Temperature

The annual temperatures within the Limpopo Province range from a minimum of 10ºC during winter to a maximum of up to 40ºC in summer, with the highest temperatures occurring in the Limpopo Valley, especially around Musina (Vhembe IDP, 2011). Table 4.1 lists the average temperatures recorded at selected climate stations in the Limpopo Province. A typical winter in the Limpopo Province is usually frost-free and mild.

Table 4.1: Temperatures (ºC) recorded at selected towns and climate stations within Limpopo

Station	Summer		Winter		Annual	
	Min (^{o}C)	Max (^{o}C)	Min (^{o}C)	Max (^{o}C)	Min (^{o}C)	Max (^{o}C)
Polokwane	16	27	8	22	25	12
Mara	17	29	8	25	27	12
Tzaneen	18	27	14	24	25	16
Madjadji	14	26	11	23	25	13
Levubu	18	28	12	25	27	15
Thoyandou	18	29	12	26	27	15
Giyani	19	31	11	27	2	15

4.3.2 Evaporation

In the Lowveld and northern parts of the Limpopo Province, evaporation rates vary between 1 300 mm and 2 000 mm/a. The south-western part of the province has an evaporation rate of less than 1 600 mm/a. The north-western part and the central region experience very high evaporation rates of up to 2 200 mm/a (Limpopo State of the Environment Report, 2014).

4.3.3 Rainfall

Limpopo Province falls within the summer rainfall region of South Africa. Its western part is a semi-arid region while its eastern part is largely subtropical. The western and northern parts of the province experience frequent droughts. The largest portion of the province has a mean annual rainfall of between 300 and 500 mm. The south-western part of the province has an annual rainfall of up to 700 mm. In the Lowveld, rainfall can exceed 1 000mm/a in places. The areas with the

highest rainfall are mostly the subtropical regions within the province. (Limpopo State of the Environment Report, 2014).

4.4 GEOLOGICAL SETTING

The Limpopo Province is mostly underlain by rocks of the Archaean Granites and Gneisses. However the Archaean granitoid intrusion of the Archaean Granites and Gneisses is situated on the Limpopo Belt. This belt formed between two major crustal blocks, e.g. the Kaapvaal Craton in the southern part of Limpopo Province and the Limpopo Belt in the northern part of the Limpopo Province (Brandl, 1999).

The Limpopo Belt is situated in the Eastern part of Limpopo Province; it comprises of mountainous, wedge shaped terrain. These mountains and wedge-shaped terrains extend up to 40 km wide from the east into the Kruger National Park. Limpopo and Zimbabwe are in the same formation of the outliers. The Limpopo River and Zimbabwe share the Umlali shear zone (Brandl, 1999).

The Limpopo Belt and Bandelierkop Complex host the Soutpansberg rocks. The Karoo Supergroup has been tectonically imposed onto the Soutspansberg outcrops on the eastern side of the outcrops. The later rocks of the Waterberg Group have been tectonically imposed into the Soutpansberg group (Holland, 2011).

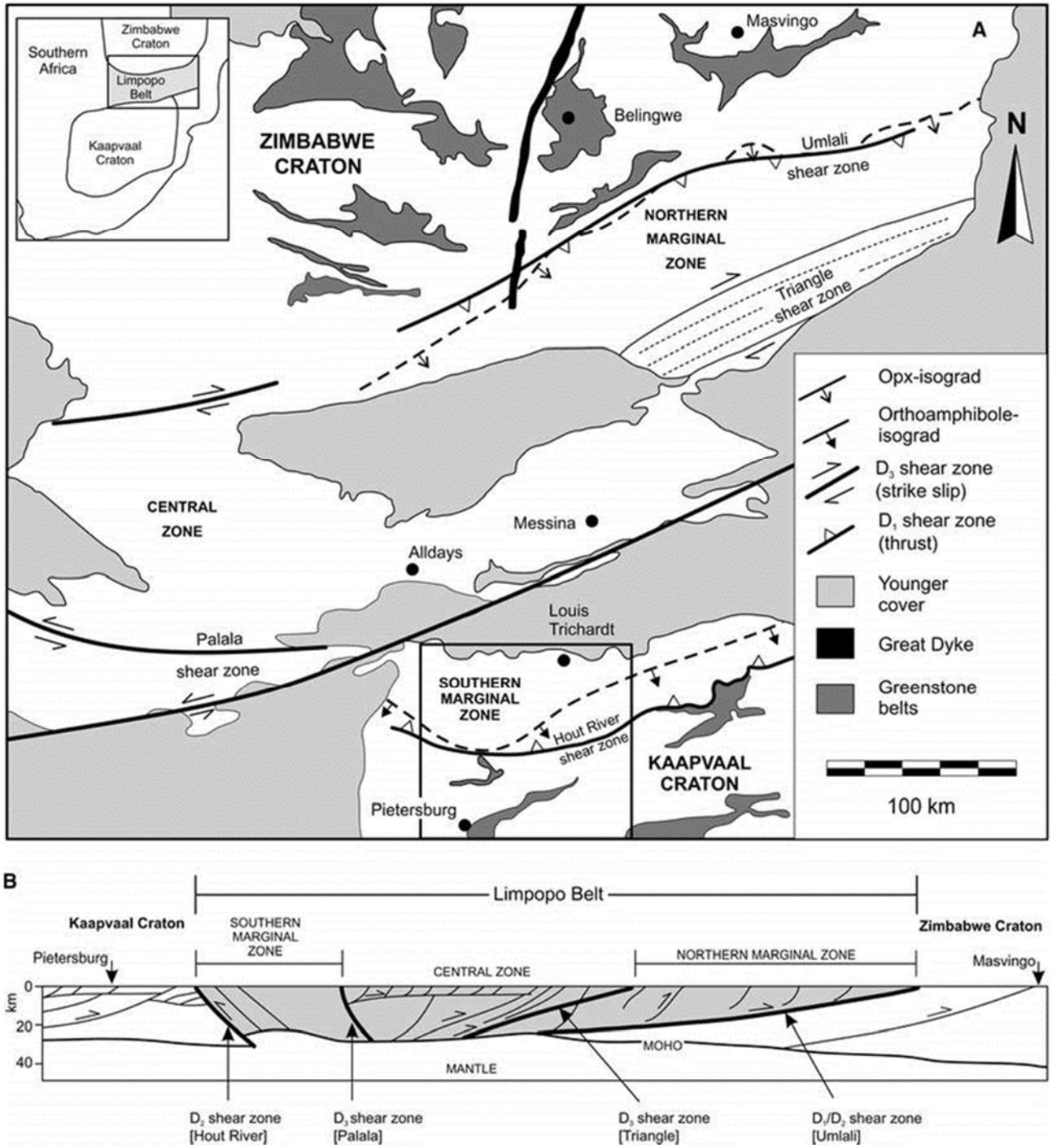

Figure 4.5: Generalized map of the Limpopo Mobile Belt indicating the major features as well as subdivisions

The Limpopo Belt covers areas from Polokwane in the Limpopo Province to Masvingo in Zimbabwe. The Limpopo Belt consists of two main cratons and three zone, The Kaapvaal Craton and the Zimbabwe Craton, the zones are Southern Marginal zone, Central Zone and the Northern Marginal Zone. This is indicated in Figure 4.5.

It has four faults situated in three main Marginal Zones, the Southern Marginal Zone, the Central Zone and the Northern Marginal Zone. The Southern Marginal zone (The Kaapvaal Craton) covers the southern part of the Limpopo and the Northern Marginal Zone (The Zimbabwe Craton) covers the northern part on Limpopo as well as the Southern Part of Zimbabwe.

4.5 LIMPOPO PROVINCE WATER MANAGEMENT AREAS

There are different water management in Limpopo Province. Each management area renders services to allocated dams and rivers. In this section a description of this management areas will be given.

4.5.1 Water Management Areas within the Limpopo Province

The province consists of four different water management regions. These are:

- The Limpopo Water Management Area (WMA). The Limpopo MWA hosts four dams and 15 rivers. The dams are: 1) the Mokolo Dam, 2) the Doorndraai Dam, 3) the Glen Alpine Dam and 4) the Nwanedi Dam. The Nwanedi Dam is found closest to the study area. Water for municipal use in the study area comes from this dam. The rivers that are most relevant to this study are the Nwanedi River and the Nzhelele River; the two rivers are located in Venda.
- The Olifants WMA includes of six rivers and two dams. This WMA is situated in the south-eastern parts of the Limpopo Province. The dams are: The Loskop and Flag Boshiela Dams. The Flag Boshiela dam feed straight from the Olifants River. The other rivers flow into Olifants River.
- The Levuvhu/Letaba WMA. This WMA includes six dams and eight rivers. These rivers flow into the Shingwedzi River which flows through the Kruger National Park.
- Lastly a small portion of the province also drains into the Komati/Crocodile WMA. This WMA includes two dams and two rivers. All the rivers in this WMA are confluent with the Mariti River.

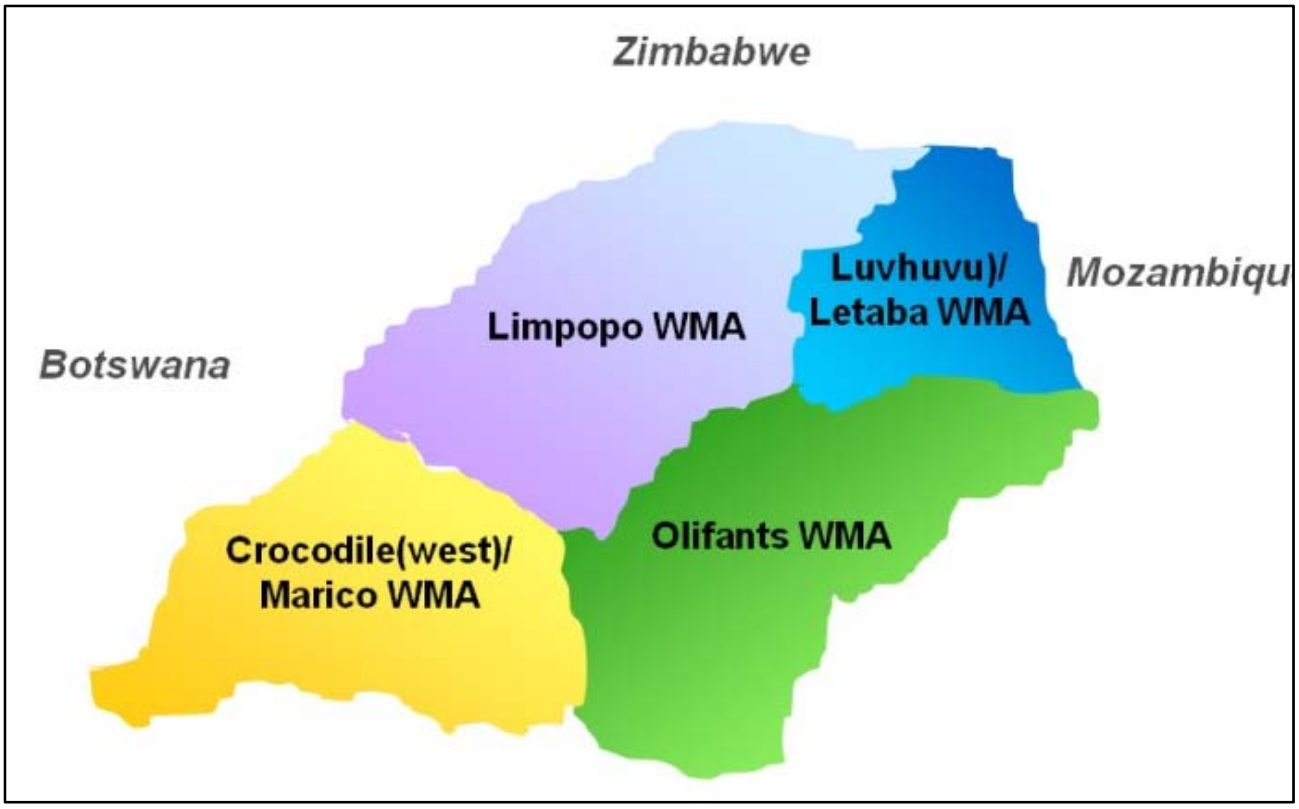

Figure 4.6. Water Management areas in the Limpopo Province

4.6 GEOHYDROLOGY

The area consists of area with fractures and weathered bedrock. The weathered bedrock consists of a confined inter-granular aquifer system. It is dominated by faults and weathered regolith and fractured aquifers. The weathered zone generally forms a poor aquifer in comparison to the inter-granular zones; this is due to its high clay content.

Aquifer systems within the Limpopo Belt can generally be classified as inter-granular and fractured. Fractures are caused by faulting and igneous intrusive rocks. Those areas with extensive fracturing, are the most favourable for the occurrence of groundwater (Sami *et al.*, 2002).

The presence of thermal springs points towards the fact that there is also deeper and longer groundwater paths within the Limpopo Belt (Sami *et al*., 2002).

4.7 SOCIO-ECONOMIC STRUCTURE

In this section the current socio-economic aspects of the community within the study area are discussed.

4.7.1 Employment

The unemployment rate is high in developing countries. In this community, unemployment is mostly high among the youth and women; the older generation of men are employed. The area itself

has no industry that can employ people; this means that the group of employed men are employed outside their town or province.

4.7.2 Education

Education forms the foundation of a person's career and ambition. In the study area, the education system consists of only a primary school. The secondary level school is found 20 km away from the village. Most of the learners do not finish matric. Some girls drop out as a result of teenage pregnancy while other learners leave school due to financial difficulties.

4.7.3 Health issues with concern to Malaria

Malaria is a big concern in the Limpopo Province, more specifically in the Bohlabelo, Mopane and Vhembe Districts where the majority of cases are reported. Table 4 provides the number of cases per district in 2003. Note that the cases from all other districts were collectively reported in the "Others" row.

Table 4.2: Malaria cases per district, 2003

District	Number of malaria cases									
	January	February	March	April	May	June	July	August	September	October
Bohlabelo	28	21	10	5	34	8	4	0	24	345
Mopane	419	162	61	133	94	17	14	14	52	448
Vhembe	1192	402	198	301	237	44	24	13	187	625
Others	46	22	6	26	7	1	2	2	15	27

4.7.4 Gender Roles

Within the study area, men are generally the earners of the families. Women are generally the primary caregivers of the households. The duties of women include everything from cooking to farming.

4.7.5 Infrastructure and facilities

The infrastructure within the study area consists of housing, water and sanitation infrastructure as well as the available energy sources.

4.7.5.1 Housing

Most of the households (69%) in the province live in formal houses or brick structures while a significant portion (20%) live in traditional houses (Limpopo State of the Environment, 2003). A

relatively small number of households live in informal dwellings (6.6%). The remaining households live in other forms of housing.

4.7.5.2 Water and sanitation

Piped/tap water in dwellings is available in 11% of households and in the yards of 34% of households in Limpopo (Limpopo State of the Environment, 2003). Community standpipes/taps within 200 m of dwellings serve 18.5% of households while standpipes farther than 200 m away from dwellings serve 28% of households. The remaining households obtain water from other sources such as boreholes, springs, rivers and dams.

The majority of households (59%) use pit latrines for sanitation. Flush toilets are available in 16% of households, most of which are connected to municipal sewage systems. A large number of households (23%) do not have access to toilet facilities. The rest use either bucket latrines or chemical toilets.

4.7.5.3 Energy

A large number of household in the village lack access to electricity. Wood is still the essential energy source for the Tshiungani village. Children and women collect wood for basic needs chores, such as cooking and warming of bathing water.

4.7.6 Cultural and Historical Background of Tshiungani

According to the inhabitants of Tshiungani, the land belongs to the ancestors, namely King Nefolovhodwe and his people. In the year 1814, there was a war between the white farmers and the tribe that was living there at the time. This tribe was the Vhatatsindi. They were ruled by King Nefolovhodwe. The king was shot and killed. His sons went into exile, leaving the land without a ruler. Whites took over the land for farming and with the advantage of the river Nwanedi, they prospered. However, this situation did not last very long.

The belief is that the ancestors became angry and caused the river to divert. The entire agricultural product of the white people was damaged and they therefore left the area. After the whites had left, people elected a new king (Netshiungani). The area was then renamed to Tshiungani to honour the new king. Most of the elderly people of Tshiungani still believe the area to be cursed when it comes to agriculture.

CHAPTER 5:
RESEARCH QUESTIONNAIRE

5.1 INTRODUCTION

There are many factors that could contribute to social vulnerability to the impacts of climate change. In order to understand the specific vulnerabilities of the Tshiungani community, a research questionnaire was compiled and face-to-face interviews were conducted with the inhabitants of the village. This was done to gain an understanding of current and potential future vulnerabilities of the community and to calculate the risks the community is currently facing and may face in future.

5.2 DESCRIPTION OF THE RESEARCH QUESTIONNAIRE

The purpose of the research questionnaire was to gain insight into the living and socio-economic conditions of the respondents and to interrogate their understanding and perceptions of climate change and its potential impacts on their lives. Questions were formulated so as to be understandable to the respondents, many of whom have a limited educational background.

5.2.1 Indicators Used in the Questions

Several indicators were identified before the research questionnaire was compiled. These indicators include: gender, education, income, lifestyle, agricultural practices, education, health quality, freedom of choice, household income, soil moisture, water supply, energy production and rainfall experienced.

5.2.2 Interview Process

In rural areas, any survey has to be approved by the cultural leaders. Tshiungani is no different, because the respondents to this questionnaire are the members of the community under the supervision the chief. The first step in the process was to write a letter to formally inform chief Netshiungani of the visit to Tshiungani and of the purpose of the interviews to be conducted. This letter was then sent from the chief to his second-in charge Mr. Malwela, who then informed the community of the survey during a community meeting. It was agreed that the research should proceed despite some members of the community being opposed to the ides. This agreement was reached on condition that the results of the water quality analyses be presented to the chief.

After the go-ahead was given by the chief, a draft of the indicators was made in order to create a list of questions for the questionnaire. Both open and closed questions were included in the

questionnaire. The interviews were conducted on a house-to-house basis. The questionnaire is included in Appendix A.

5.2.3 Challenged Faced

Challenges were faced when attempting to conduct some interviews, as many of the members of the community were resistant against the survey. As a results, community members from only 70 stands (from more than 100) took part in the survey.

5.3 RESULTS OF THE RESEARCH QUESTIONNAIRE

The results of the research questionnaire are discussed in this section by first considering the responses to the closed questions, then the responses to the open questions.

5.3.1 Closed Questions

5.3.1.1 Gender of respondents

The highest response came from women with 54% while the male response was 46%. This may be due to the fact that most of the women in Tshiungani are unemployed and were present in the village during the interviews. Of the men that responded, most were either young men in their early 20s or pensioners. The presence of the young men suggests large figures of unemployment within the community.

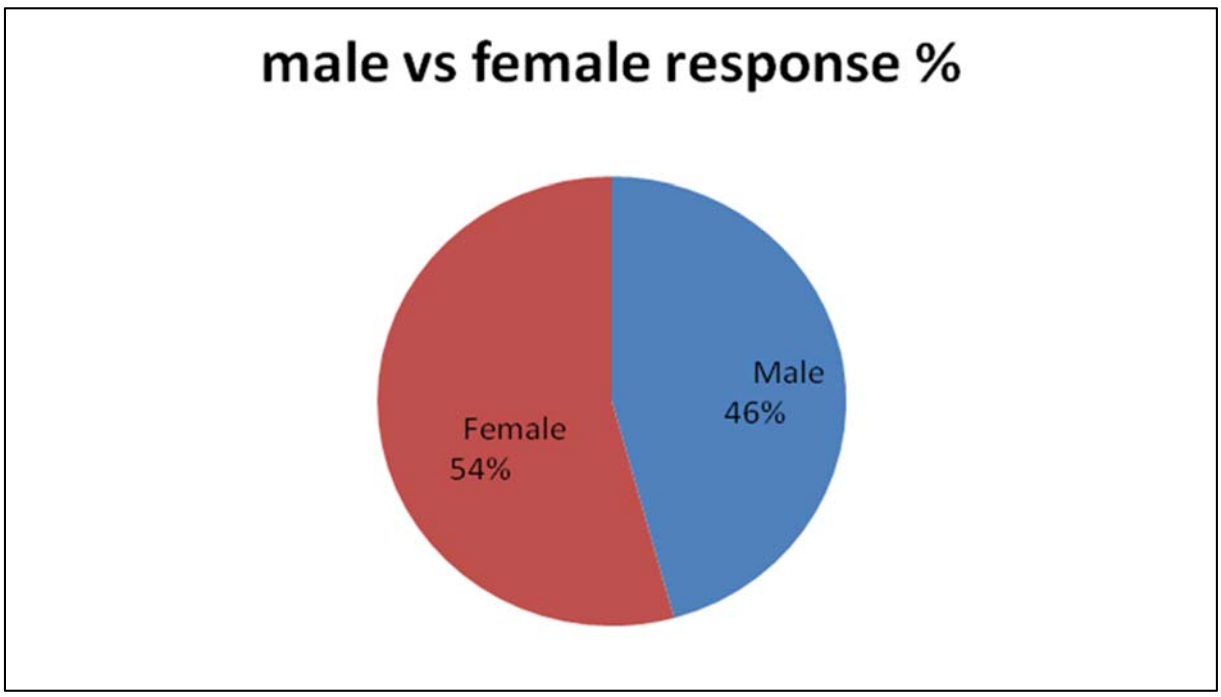

Figure 5.1: Gender of the respondents

5.3.1.2 Dependents per household

Most households (57%) in Tshiungani have two or fewer children (Figure 5.2). These households are generally younger families. Most of the families adhere to family planning, with the Department of Health providing a clinic which informs the community on family planning. Households with more than five children make up approximately 12% of the community. It is usually the older generations who have higher numbers of dependents per household.

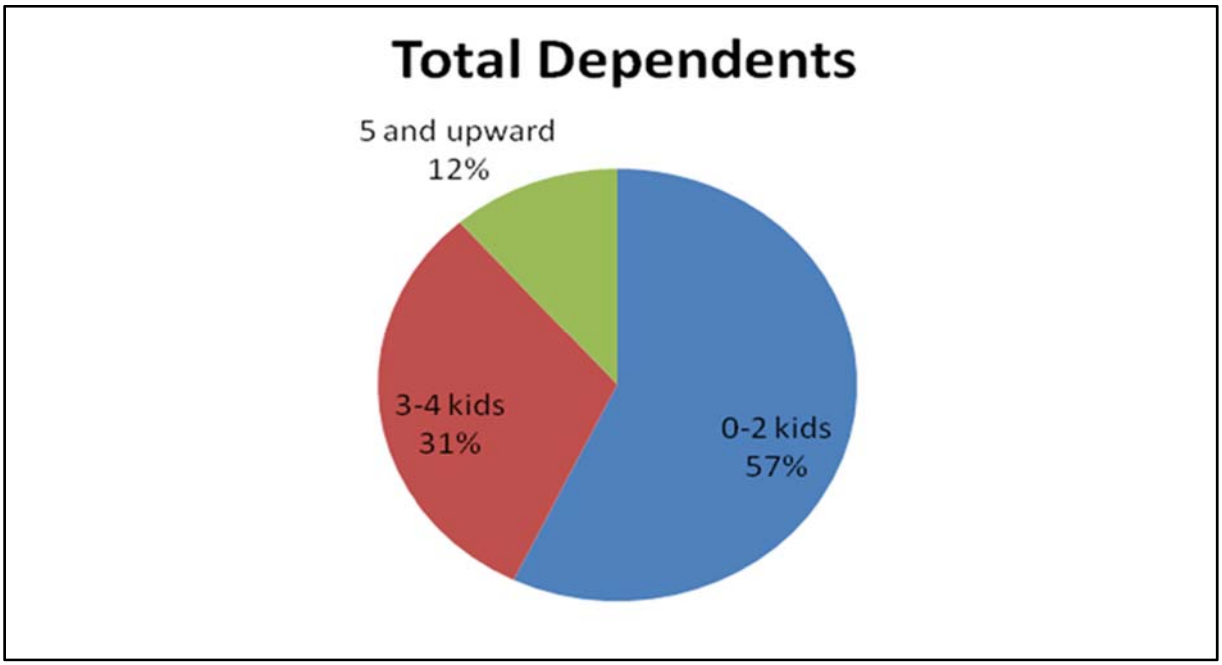

Figure 5.2: Total dependents per household

5.3.1.3 Education

Although education is essential to ensure the prosperity, for the community members of Tshiungani a primary or secondary education is considered a big achievement. Most respondents had no formal education (30%) while only 16% had tertiary education (Figure 5.3). Respondents with a tertiary education were mostly not originally from the Tshiungani area. Most of them were nurses or teachers, who were providing services to the community.

It was found that women make up a large percentage of the respondents without any formal education. With regards to education, gender plays a major role, since there are no role models of educated women within the community to inspire the younger generations. Many young women believe that their role is to take care of the household and nothing more.

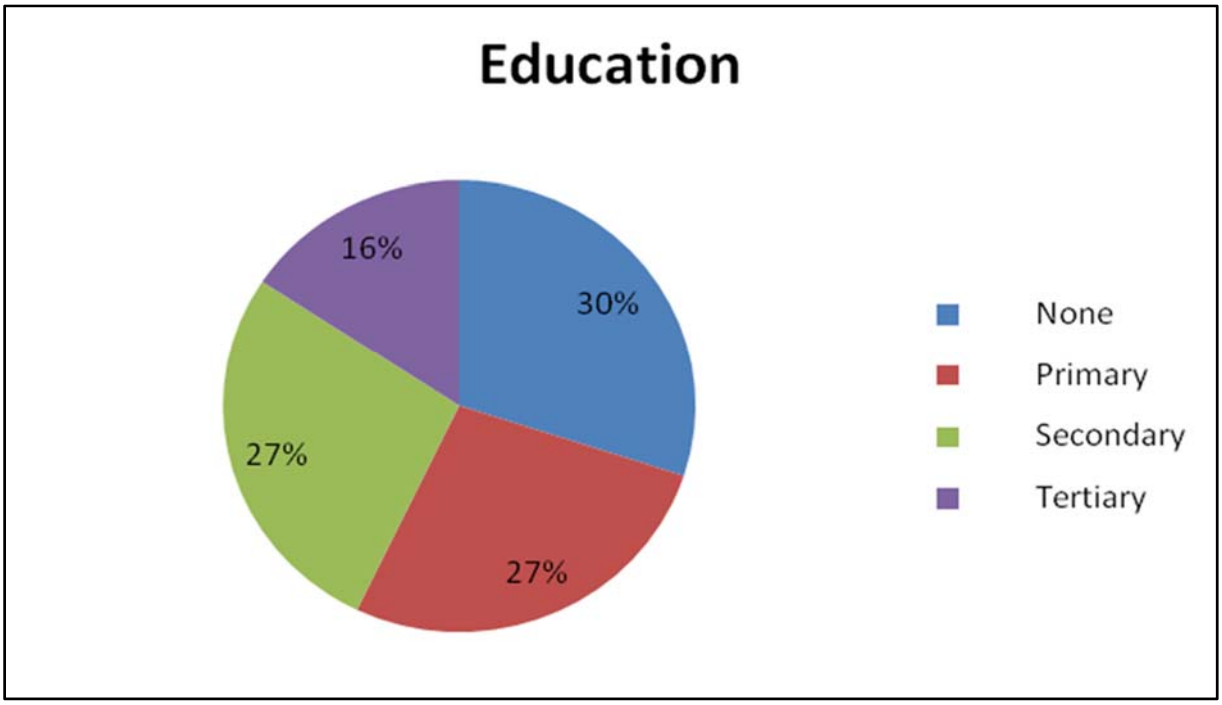

Figure 5.3: Education status of the respondents

5.3.1.4 Household income

More than 43% of the respondents earn less than R1 000 per month, some with the inclusion of grants, and only 23% earn above R3 000 per month. With most of the respondents focusing on subsistence farming there is not much opportunity to generate an income.

5.3.2 Open-Ended Questions

5.3.2.1 Stability and Security

Stability and security work hand in hand. People in this village felt that there was not much security in the area as their basic needs were not provided for. Services such as electricity had not been supplied. Many respondents were concerned about their food supply and felt that this was threatened by the heat waves that they were experiencing at the time of the interviews. The soil is often too dry to plant crops. Even when crops are planted, these crops need to be watered. This means that the community members have to fetch water from the boreholes in and near the village. In some cases, even when crops are watered, they still perish in the heat.

5.3.2.2 Agriculture

Even though agriculture could be a source of income, the Tshiungani community mostly depends on agriculture to sustain their livelihoods through subsistence farming. It is challenging to farm in this area; the soil is not fertile and is often very dry. Precipitation is often very low.

Livestock farming seems to be a successful agricultural practice. Almost all the respondents owned goats. These goats are hardy and can survive in difficult climatic conditions. Some members of the community sell goats as a means of income. Goat milk is also sold to supplement their incomes.

5.3.2.3 Conflicts

Conflicts in the community arises from land distribution. Land allocations are affected by cultural politics. The area most fertile with access to water is found close to the river, problems arise when this part of the land has to be distributed amongst the community members.

5.3.2.4 Soil moisture

The area generally experiences high temperatures and high evaporation rates. The soil in the area is therefore often dry. Strong winds often lead to dust storms and soil erosion.

5.3.2.5 Water

There are only three community boreholes that supply water to the community. This results in difficulties during water collection because the queues can be long. Of the three boreholes, two were donated by an old conglomerate mine that was situated in the area. One of the boreholes was drilled in 1996 by the municipality. The boreholes are situated within the village, closer to some members and farther from others. Groundwater is abstracted during the day and stored in tanks. Distribution of the water is done through taps that were installed after every second row of stands. Figure 6.4 and Figure 6.5 are photographs showing the collection of water by community members.

5.3.2.6 Gender equality

Gender equality has become one of the identified gaps in the rural community for climate vulnerability (Babugura, 2010). In this community, gender equality is also an area of concern.

In Tshiungani, there are customary beliefs and protocols that still need to be followed. Women are still deemed to be responsible for taking care of the households, while men are considered to be the bread winners. In this area women pride themselves on being caregivers and all household duties are carried out by women. These duties include: collecting wood, fetching water, cooking and cleaning. In addition, some of these women respondents also sell wood for an income as well. The photographs in Figure 6.4 and 6.5 show women collecting water as part of their chores.

Figure 5.4: Women collecting water at taps

Figure 5.5: Women collecting water at taps

5.3.2.7 Education

Although culturally the women of Tshiungani are still expected to take care of the family, some young girls aspire to a different life. Some of the girls would like to study further at tertiary institutions. For these girls, the lack of funding is a problem and their family members and peers tend to discourage them from enrolling for further education. Even though the men have more freedom to explore further education, finance remains a challenge.

5.3.2.8 Energy

Family members are responsibility for collecting of wood. Wood is used as a source of energy for all households. Some households also sell wood as a source of income. This dependence on wood as a source of energy is contributing to deforestation in the vicinity of Tshiungani. It also threatens education in the area, since children are often responsible for collecting wood (along with other tasks, such as shepherding the flocks). Figure 6.6 is a photograph of children collecting wood instead of attending school.

Figure 5.6: Wood collection by children of school-going age

5.3.2.9 Climate change

Approximately 44% of the older generation have an understanding of the concept of climate change. The remaining 56% are unaware of climate change. The latter respondents generally correspond to those people that left school early. Since many of the community members are poorly educated, many of the concepts of climate change are very foreign to them.

5.3.2.10 Drought and deforestation

Drought has a major impact on the community of Tshiungani. Deforestation, or the lack of vegetation, in the area is partly due to frequent droughts, but is also partly due to activities of the community. Overgrazing and overexploitation of the natural resources have contributed to deforestation. Deforestation in this area is high, as seen in Figure 6.7. It has come to a point where community members are obliged to move their livestock to remote areas for grazing.

The winter months are normally even drier than the summer months. Soil erosion due to strong winds is high and the area often suffers from dust pollution

Only community members with plots near the river have adequate access to water to grow harvestable crops.

Figure 5.7: Deforestation in Tshiungani

CHAPTER 6:
HYDROCENSUS AND WATER QUALITY

6.1 INTRODUCTION

The primary aim of this chapter is to identify and characterise the hydrological and geohydrological conditions within the study area. All water-related features within the study area are identified. These include: 1) rivers, 2) dams, 3) functioning boreholes, 4) abandoned boreholes and wells and 5) rain collection tanks, as well as potential sources of contamination (mines, abandoned mines, animal kraals).

6.1.1 Hydrocensus

A hydrocensus was conducted within the study area to identify all water users and water-related infrastructure. The area was found to have an abandoned borehole approximately 2 km from the main road. An abandoned mine also occurs within the study area. It occurs opposite the main road from the identified abandoned borehole. The borehole had no casing and was inaccessible due to the presence of dense vegetation. As a result, it was not possible to take the GPS coordinates of the borehole. The date of installation of the borehole is also unknown.

The Nwanedi River occurs in the north-west of the study area, approximately 1.5 km from the settlement. The river is confluent with the Limpopo River at a position approximately 106 km from the village. Two rain collection tanks were found in the public service areas (at the clinic and the primary school).

An active coal mine is located approximately 65 km from the village in the north-eastern side of the study area. A number of kraals are situated along the outer boundaries of the village. Five more boreholes were located within the village and they will be discussed in detail.

6.1.1.1 Borehole locations

The area was found to have a number of boreholes and a river within walking distance from the village. Five boreholes were located, three which were used by the community. Of the other two boreholes, one was found to be dry, and the other one was just abandoned. The coordinates of the boreholes were recorded using a hand-held GPS. The coordinates are listed in Table 6.1, while their positions relative to the town infrastructure are shown in Figure 6.1.

Table 6.1: Borehole coordinates

Site Name	Latitude(°S)	Longitude (°E)	Altitude(mamsl)
BH1.CLINIC	-22.49878	30.58050	465
BH2.CHIEF	-22.49944	30.58151	463
BH3.COMMUNITY	-22.50317	30.57724	459
BH4.COMMUNITY	-22.50139	30.58310	460
BH5.VHAKOMA	-22.49878	30.57743	493

6.1.1.2 Groundwater levels

Static groundwater levels were measured in each of the five boreholes located during the hydrocensus. These water levels are presented in Table 6.2.

Table 6.2: Borehole water levels

Site Name	Date and time	Water level (mbgl)
BH1.CLINIC	2011/09/26 17:00:00 PM	11.1
BH2.CHIEF	2011/09/26 17:15:00 PM	17.5
BH3.COMMUNITY	2011/09/26 17:23:00 PM	29.7
BH4.COMMUNITY	2011/09/26 17:37:00 PM	37.0
BH5.VHAKOMA	2011/09/26 17:43:00 PM	10.6

The measured groundwater levels suggested that different aquifers are present at Tshiungani. The water levels in three of the boreholes were shallow (<20 m) while deeper water levels were found in the remaining two boreholes (BH3.COMMUNITY and BH4.COMMUNITY). These two boreholes did not appear to be extracting water from the same aquifer. According to the residents of the village, abstraction from one borehole did not have any noticeable effect on the water level in the other borehole.

6.1.2 Hydrochemical Analyses

Five groundwater samples were taken from the community boreholes at Tshiungani. The boreholes were purged prior to sampling; this was done for consistency to ensure that representative water samples could be collected from all the borehole, some of which had been stagnant for months. Samples were stored in a cooler box and transported to the laboratory of the Institute for Groundwater Studies (IGS) at the University of the Free State within the recommended time of 24 hours to be analysed.

Samples were analysed for major cations and anions, pH, and metal concentrations. The results of the chemical analyses are presented in Appendix B.

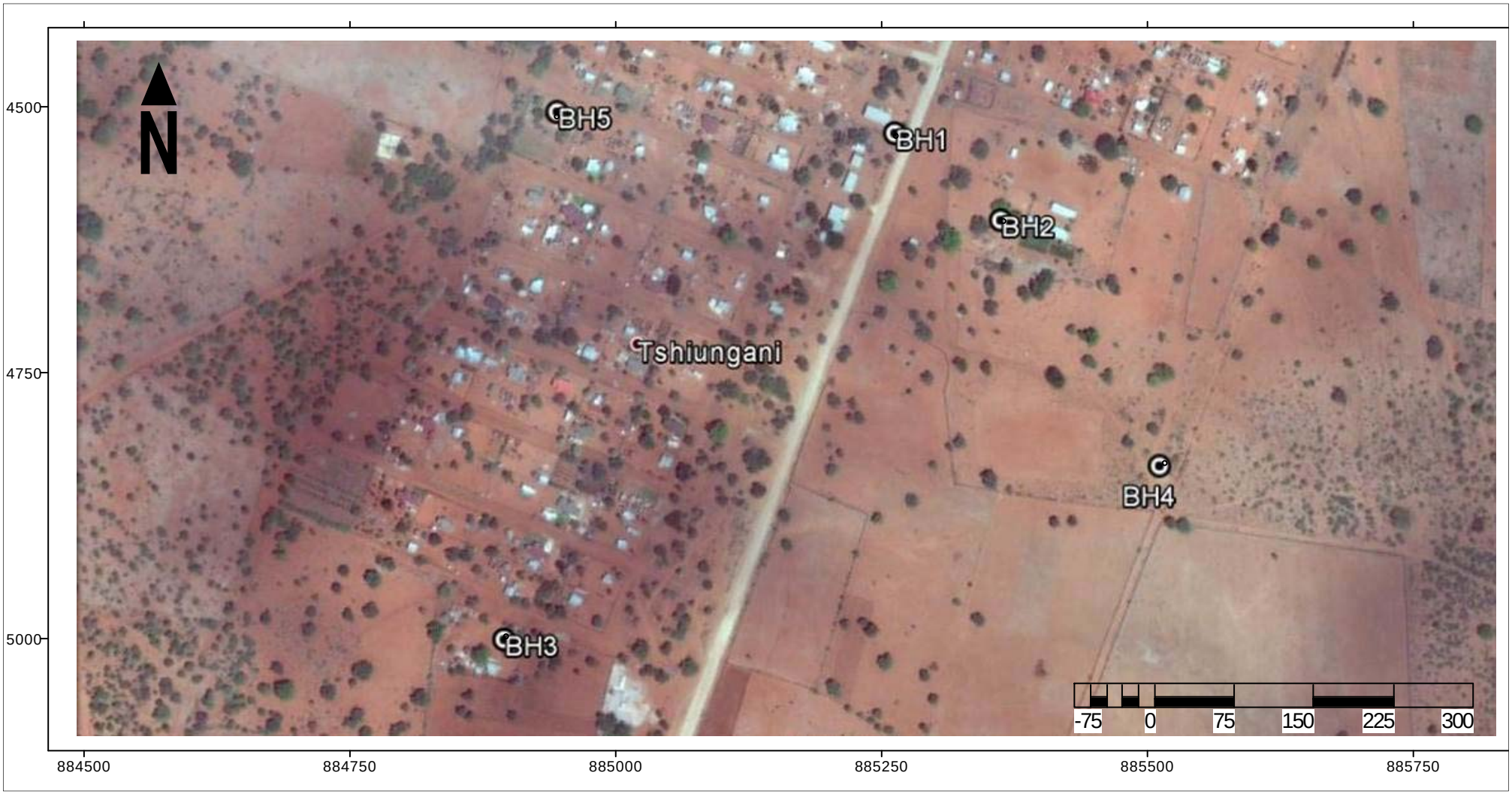

Figure 6.1: Location of boreholes relative to the surface infrastructure at Tshiungani

6.1.3 Groundwater Quality

Since groundwater is used for drinking and other domestic uses at the Tshiungani village, it is important to test the quality of the water. The quality of the groundwater from the boreholes at the village was evaluated against the drinking water standards of the Department of Water Affairs and Forestry (DWAF, 1996). The results of the chemical analyses (Appendix B) show that only the following parameters exceeded the recommended drinking water standards in some boreholes: electrical conductivity (EC), sodium and nitrate (as nitrogen). The values/concentrations of these parameters are discussed below.

6.1.3.1 Electrical conductivity (EC)

The EC values for boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY were high at the time of sampling. All three these boreholes had EC values in excess of the recommended value of the drinking water standards (170 mg/L). The EC values recorded in the different boreholes are shown graphically in Figure 6.2.

The EC values give an indication of the amount of total dissolved solids in the water. High EC values point towards large concentrations of salts in the water. High EC values are often associated with water that tastes bad, has an odour, has a colour, can become corrosive, may start foaming, and could lead to staining.

6.1.3.2 Sodium (Na)

The Na values for boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY were high at the time of sampling. The concentrations in all three boreholes exceeded the recommended value of 200 mg/L. The highest concentration value of 296 mg/L was observed in BH2.CHIEF. The Sodium values recorded in the different boreholes are shown graphically in Figure 7.3.

Sodium is absorbed after ingestion. Infants and young children are more sensitive due to their immature kidneys. In adults the sensitivity comes after long time of ingestion. This can cause high blood pressure.

6.1.3.3 Nitrate as nitrogen (N)

The nitrate concentrations recorded in boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY were high at the time of sampling. The concentrations in all three boreholes exceeded the recommended value of 11 mg/L (Figure 6.4). The highest nitrate concentration (33 mg/L) was observed in borehole BH2.CHIEF. Sewage disposal systems and livestock facilities could be the source of the high nitrate concentrations. Other point sources for nitrate contamination could include fertilised croplands and gardens.

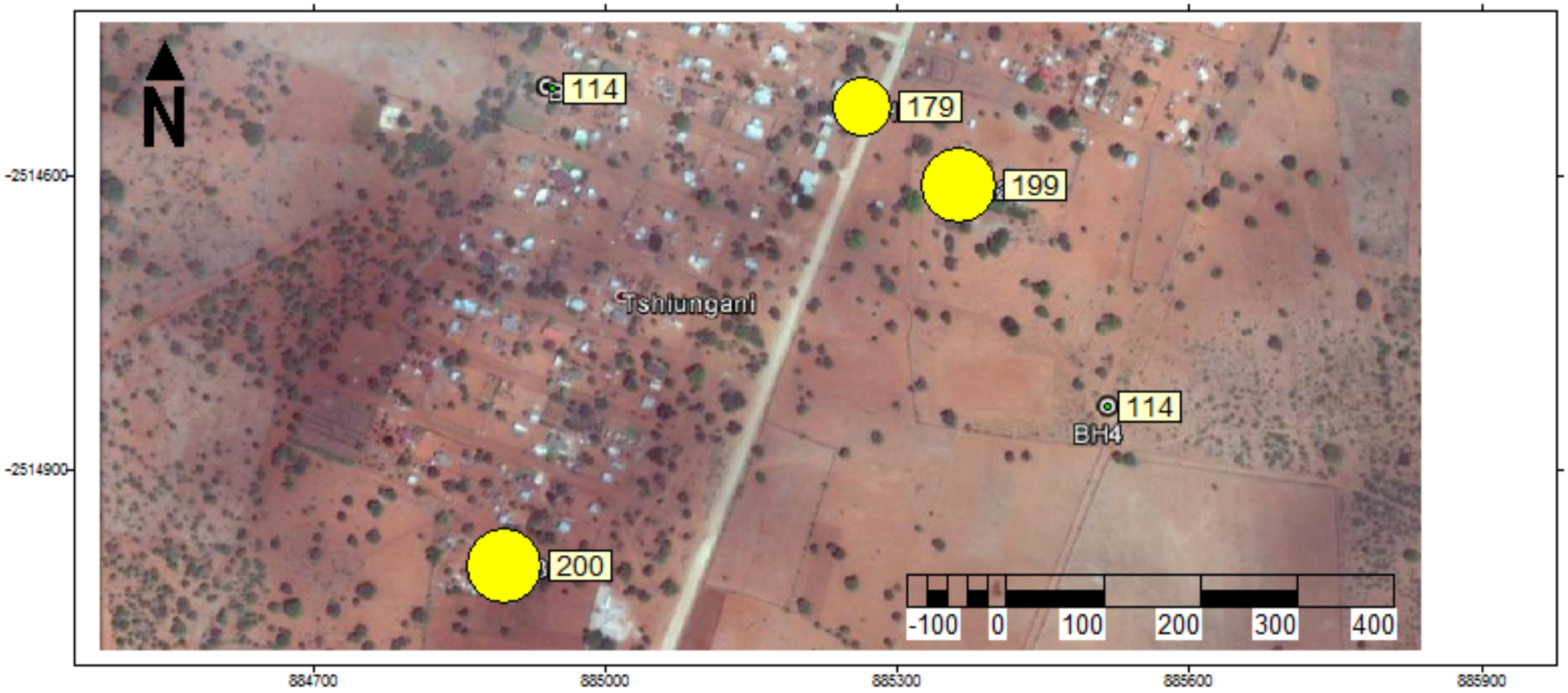

Figure 6.2: EC values recorded in boreholes within 1 km from the village

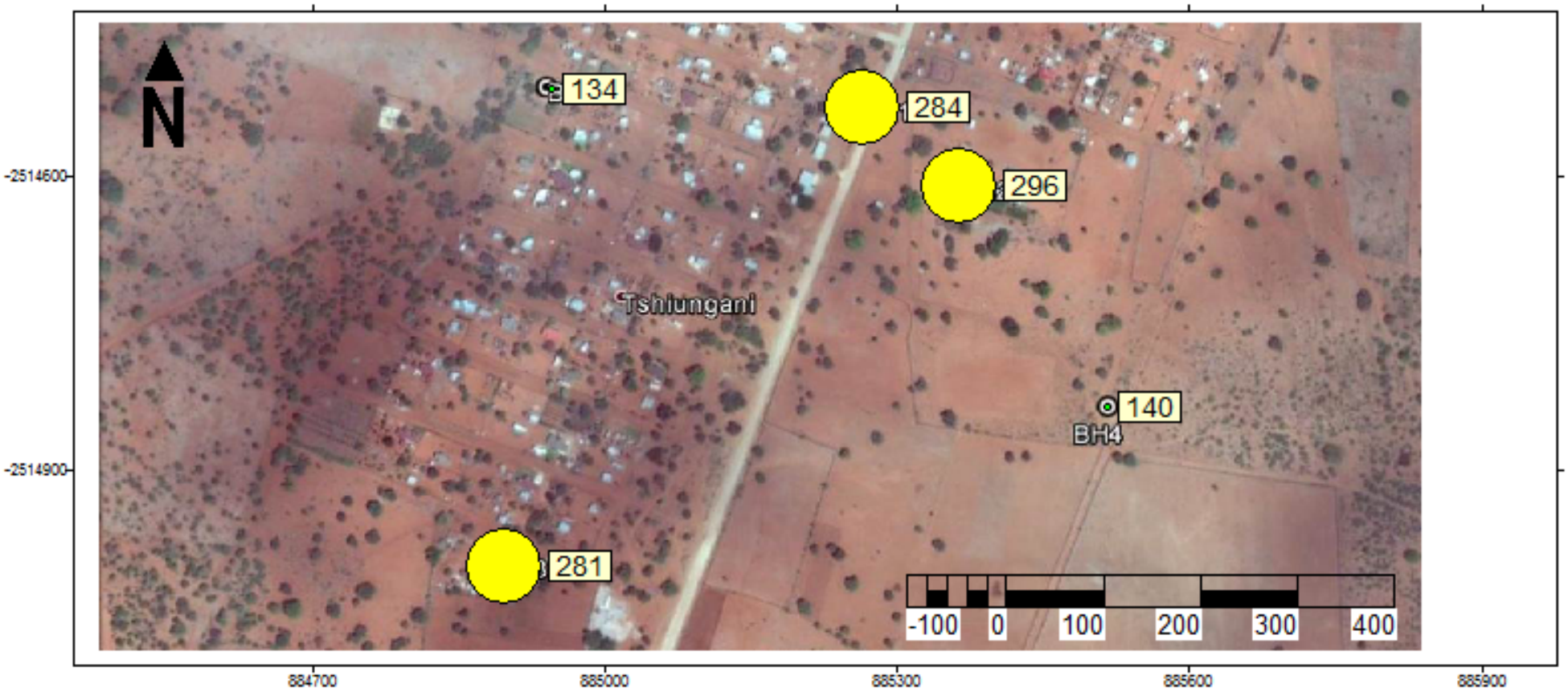

Figure 6.3: Sodium values recorded in boreholes within 1 km from the village

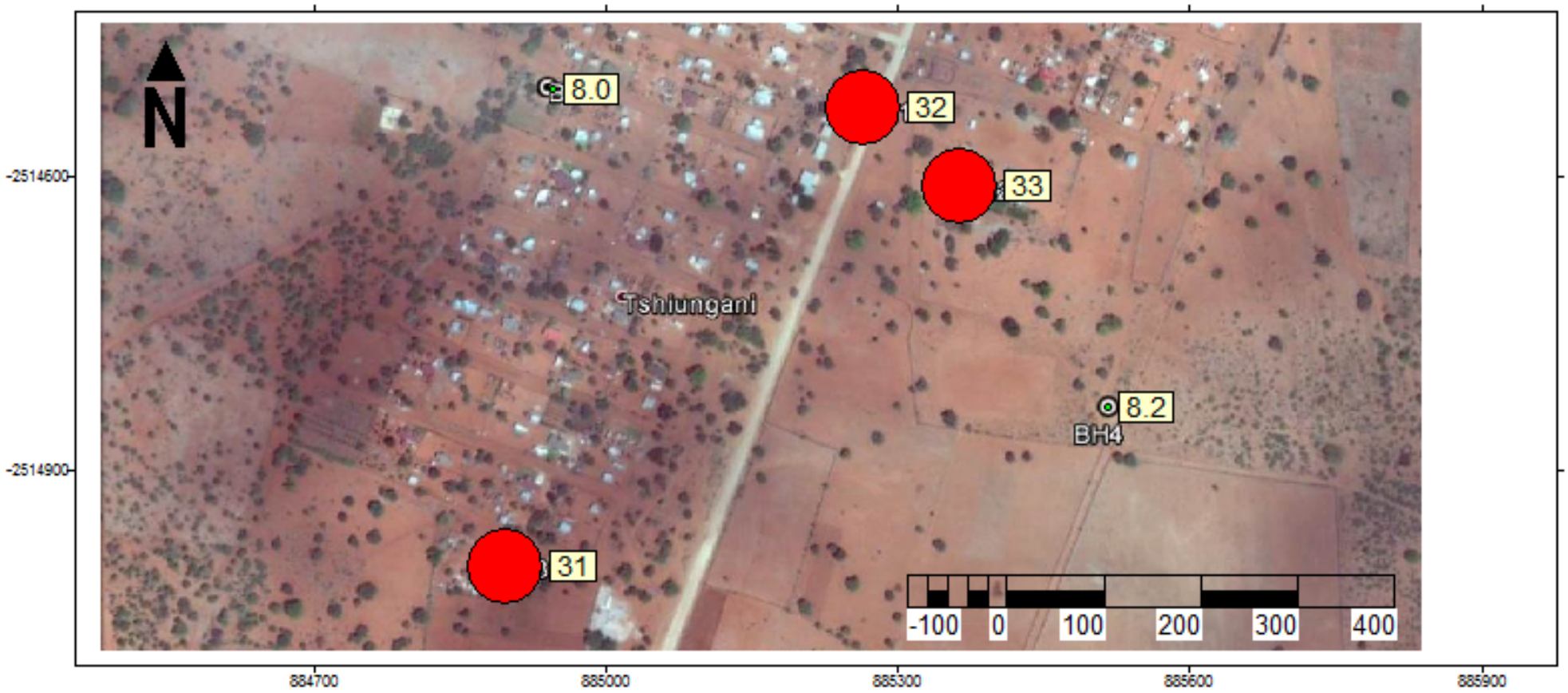

Figure 6.4: Nitrate values recorded in boreholes within 1 km from the village

When nitrate is transformed to nitrite in the digestive system, a health hazard may occur. The nitrite oxidizes iron in the haemoglobin of the red blood cells to form methemoglobin, which lacks the oxygen-carrying ability of haemoglobin. When blood lacks the ability to carry sufficient oxygen to the individual body cells, causing the veins and skin to appear blue, a condition known as methemoglobinemia (sometimes referred to as “blue baby syndrome”) is caused. This condition could lead to fatalities in infants.

6.1.4 Groundwater classification

Groundwater is found in different rocks formations. Since groundwater leaches minerals from the formations through which it flows, different minerals can be expected in groundwater occurring in different formations. Different diagnostic diagrams are available to assist in the classification of water in general and groundwater in particular. These diagrams include:

- The Piper Diagram,
- The Stiff Diagram,
- The Durov Diagram,
- The SAR Diagram, and
- The Schoëller Diagram.

The classification of the groundwater samples taken from the boreholes at Tshiungani is discussed below.

6.1.4.1 The Piper Diagram

A Piper Diagram is a graphical representation of the chemistry of water samples. The diagram consists of three areas, namely: a ternary diagram in the lower left describing the major cation concentrations, a ternary diagram in the lower right representing the anion concentrations and a diamond plot in the centre representing a combination of the two ternary diagrams. Depending on the relative concentrations of the major cations and anions, a water sample will plot at a specific position within the central diamond. The central diamond plot is generally divided into four zones, corresponding to four different water types, namely Calcium Sulphate waters, Calcium Bicarbonate waters, Sodium Chloride waters, and Sodium Bicarbonate waters.

The Piper Diagram for the five groundwater samples from Tshiungani is shown in Figure 6.5. It is seen that the groundwater from boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY Sodium Bicarbonate water, while the groundwater from BH4.COMMUNITY and

BH5.VHAKOMA are Calcium Bicarbonate waters. It therefore appears that there are at least two aquifer systems present at Tshiungani:

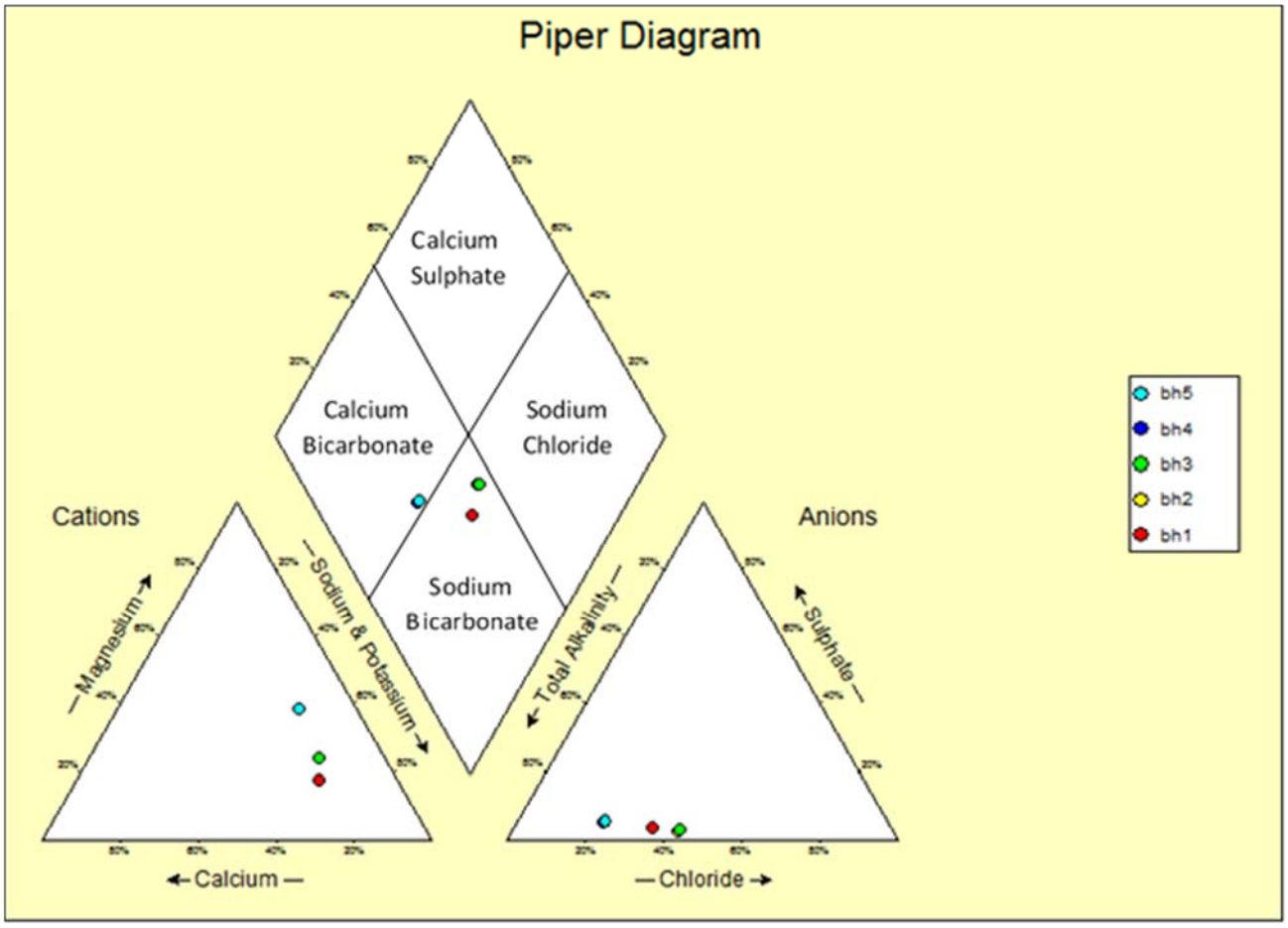

Figure 6.5: The Piper Diagram for the groundwater samples from Tshiungani

6.1.4.2 Durov Diagram

The Durov Diagram is another way the visually compare the relative concentrations of anions and cations in a water sample. The main advantage of the Durov Diagram is that it allows a graphical visualisation of the concentrations of the eight major ions. The diagram consists of two ternary diagrams where the cations of interest are plotted against the anions. It is used to visualise the cation and anion concentrations relative to the pH and the TDS concentration.

The Durov Diagram for the groundwater samples from the boreholes at Tshiungani is presented in Figure 6.6. The water samples from boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY all plot close to one another on the central square of the diagram. The samples from boreholes BH4.COMMUNITY and BH5.VHAKOMA plot a little higher in the central square. The latter two samples therefore appear to be from a different aquifer system than the other samples.

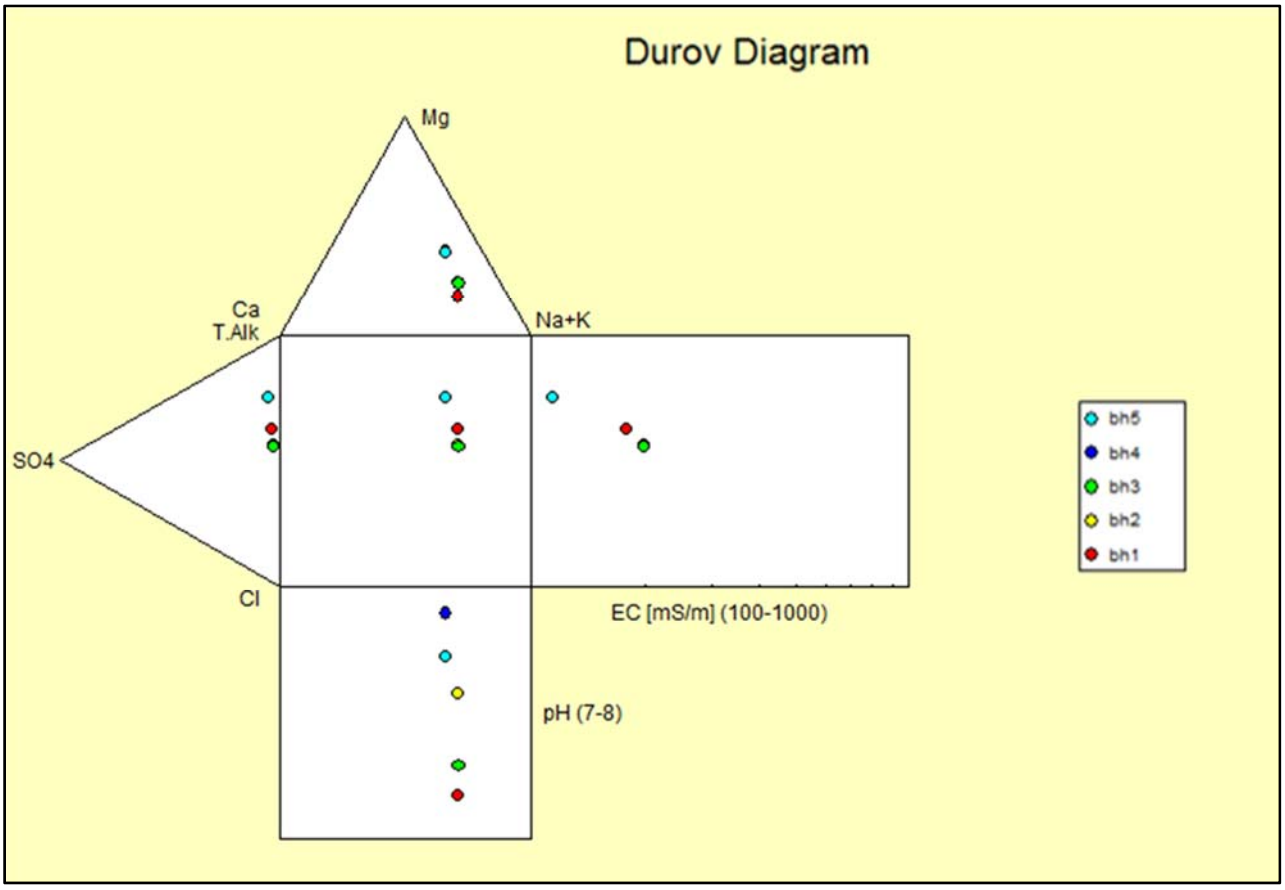

Figure 6.6: The Durov Diagram for the groundwater samples from Tshiungani

6.1.4.3 SAR Diagram

The Sodium Absorption Rate (SAR) Diagram is used to evaluate if water is suitable for irrigation purposes. From the SAR Diagram presented in Figure 6.7 it is seen that the water samples from the boreholes at Tshiungani all have low (BH4.COMMUNITY and BH5.VHAKOMA) or medium (BH1.CLINIC, BH2.CHIEF AND BH3.COMMUNITY) Sodium Hazards. This shows that the water from these boreholes is suitable for irrigation.

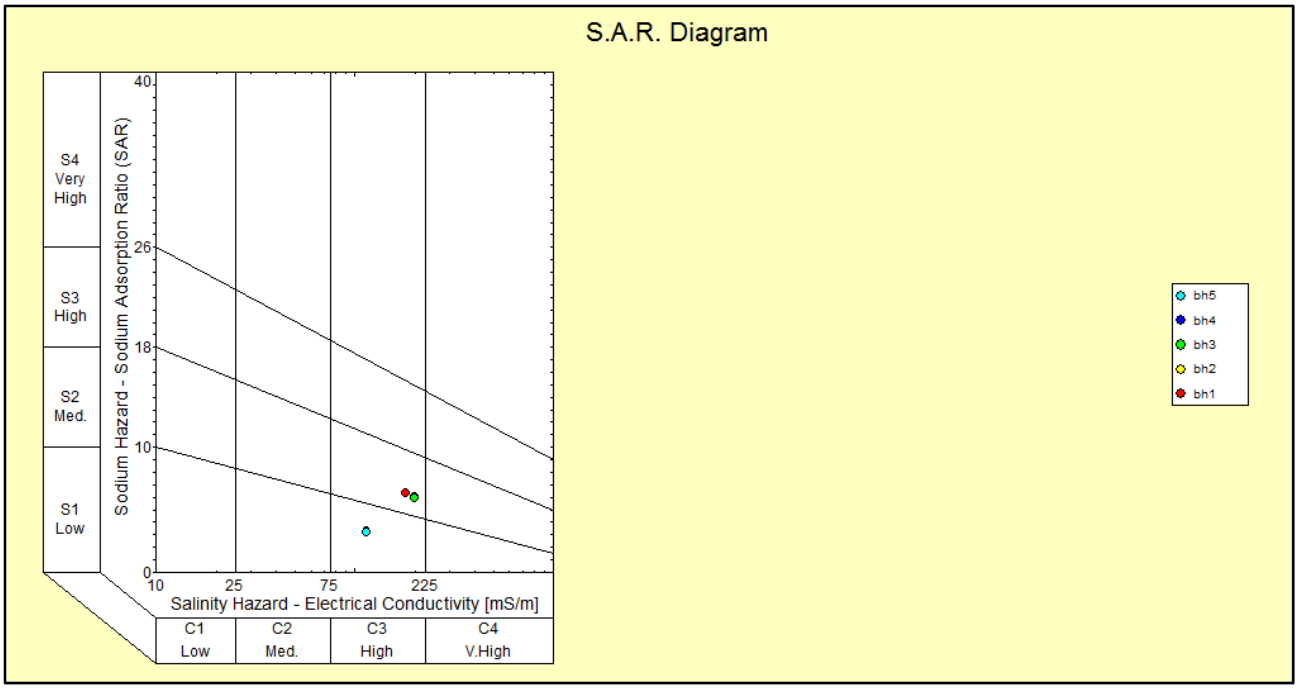

Figure 6.7: The SAR Diagram for the groundwater samples from Tshiungani

6.1.4.4 Stiff Diagram

The Stiff Diagram is particularly useful to visually distinguish between waters from different sources. The concentrations of the major anions and cations are plotted as milli-equivalents per litre (meq/L) on horizontal axes. In this way, polygons are created which give visual representations of the relative ions concentrations.

The Stiff Diagram for the water samples from the Tshiungani boreholes is presented in Figure 6.8. It is clear from the diagram that boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY have very similar water chemistries that are significantly different from the water chemistries of boreholes BH4.COMMUNITY and BH5.VHAKOMA. This observation confirms that these boreholes tap into different aquifer systems at Tshiungani.

6.1.4.5 The Schoëller Diagram

The Schoëller Diagram shows the relative abundances of the major cations and anions (expressed in meq/L) as profile plots on a logarithmic scale. From the Schoëller Diagram constructed for the groundwater samples from Tshiungani, it is seen that boreholes BH1.CLINIC, BH2.CHIEF and BH3.COMMUNITY have very similar chemical signatures that are clearly different from the chemistries of boreholes BH4.COMMUNITY and BH5.VHAKOMA.

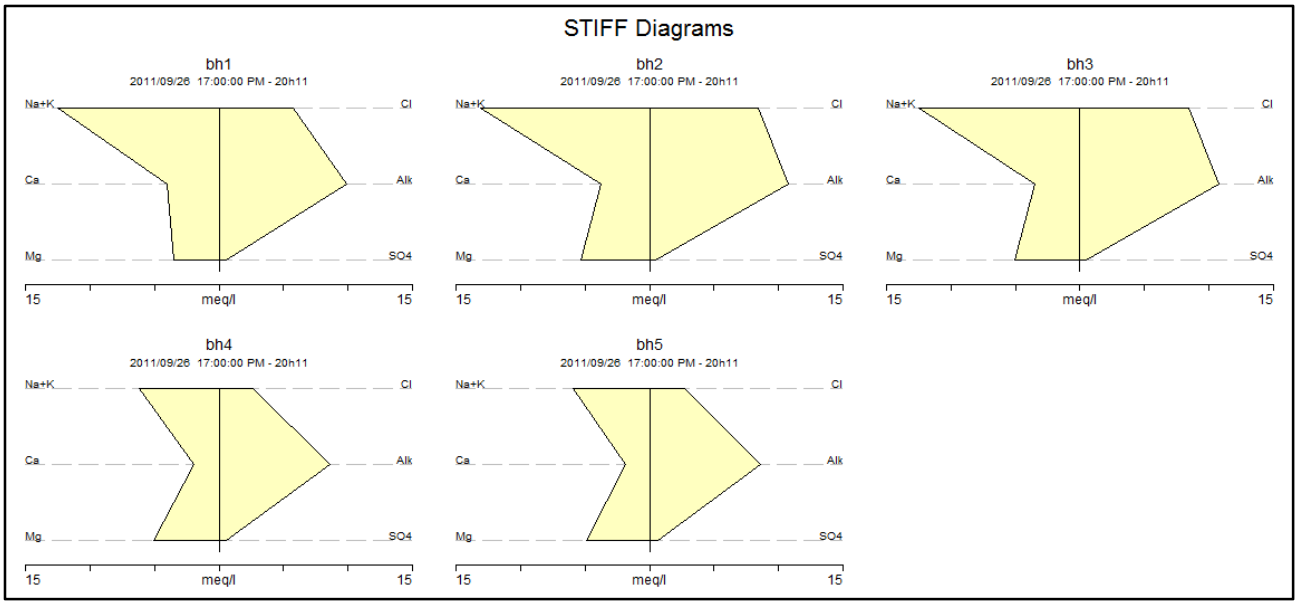

Figure 6.8: The Stiff Diagram for the groundwater samples from Tshiungani

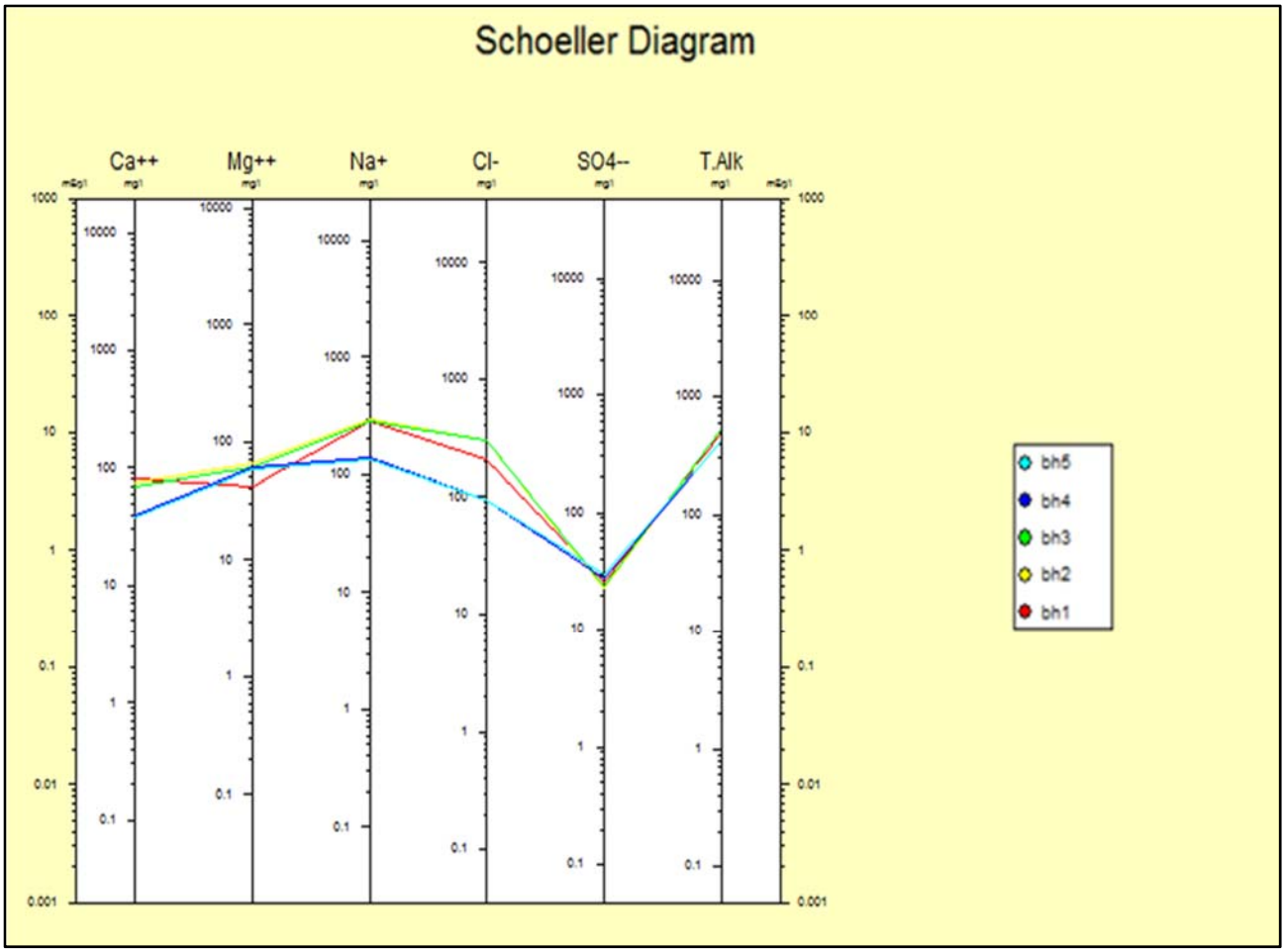

Figure 6.9: The Schoëller Diagram for the groundwater samples from Tshiungani

CHAPTER 7:
DEVELOPING A DECISION-SUPPORT FRAMEWORK FOR VULNERABILITY ASSESSMENT

In this chapter a decision-support system is developed which can be used to evaluate whether rural communities are vulnerable to the impacts of climate change.

7.1 BACKGROUND

The diversity of frameworks for conceptualising vulnerability has resulted in the diversity of methods that have evolved to measure it. There are two types of methods to assess vulnerability: outcome and contextual vulnerability (Pearsons *et al.,* 2008) (refer to Figure 7.1).

Outcome-oriented vulnerability assessments tend to lean toward reductionist approaches, focusing on a single or well-defined group of hazards or drivers of change (Pearsons *et al.,* 2008).

The contextual approach is constructivist in that it attempts to analyse vulnerability from the perspective of individuals or groups in society. Combining qualitative and quantitative approaches can provide an integrated assessment of the multiple hazards simultaneously faced by these individuals and groups (Pearsons *et al.,* 2008). Figure 7.1 shows the components of the outcome-based and contextual vulnerability assessments.

This chapter focuses on the contextual vulnerability approach. In the current study respondents in a rural community were interviewed using a research questionnaire. Face-to-face interviews were conducted with the different households in the community.

7.2 A FRAMEWORK FOR VULNERABILITY ASSESSMENT

In this dissertation, the Millennium Ecosystem Assessment Framework (Figure 7.2) will be used to provide guidance during the vulnerability assessment of the Tshiungani village. The millennium framework works in ranks, it finds links from global impact to regional and local impact. It focuses on all aspects of life, the social wellbeing, the demographics of the area, the impacts of nature on an area and the risk that could be imposed on the needs of those at risk.

The results of the research questionnaire (Chapter 5) will be used to assess the factors contributing to the vulnerability of the community. This means that not all the factors considered by the Millennium Ecosystem Assessment Framework will be included in the current framework developed to assess the vulnerability of South African rural communities to the impacts of climate change. The factors that are included in the current framework are discussed below.

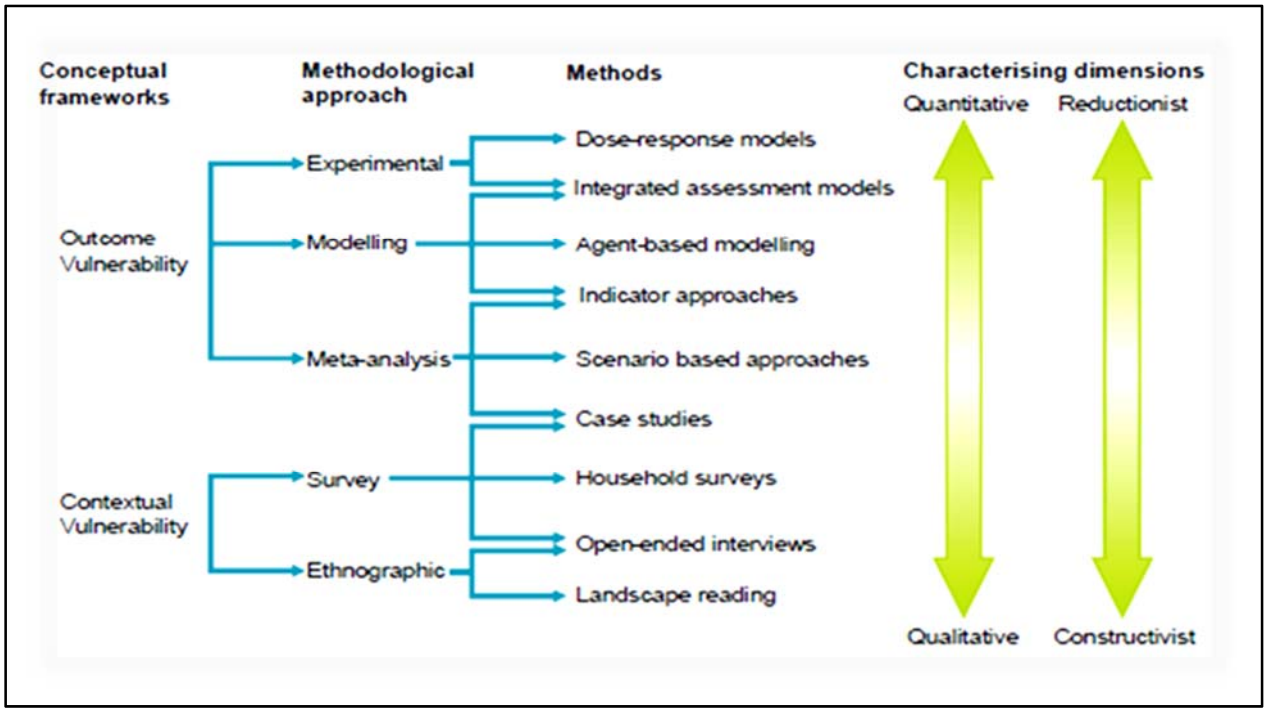

Figure 7.1: Categorisations of methodologies and characterising of outcome and contextual vulnerability (Pearsons *et al.*, 2008)

7.2.1 Human Wellbeing and Poverty Reduction

Human wellbeing is concerned with the livelihoods of people in communities and it deals with the threats that could impact on the livelihoods. The decision-support system developed in this dissertation focuses specifically on the poor in rural communities.

Life depends on access to materials and services. From the results of the questionnaire, it is clear that poverty is of great concern in the study area. This implies that the materials and services needed to sustain life are often unaffordable to members of the community. Furthermore, many of the members of the community are dependent on the local environment for their survival. The community is dependent on groundwater for their fresh water supply. Most members of the community are dependent on subsistence farming for their survival, while some households sell firewood and livestock for an income. If climate change leads to detrimental impacts on any of these resources, negative impacts on the wellbeing of the members of the community can be expected.

7.2.1.1 Education

Education is a key to productivity and without a proper education a person's livelihood is unlikely to improve. The results of the questionnaires show that the men of Tshiungani are generally more educated than the women. Men generally have more opportunity to enrol in further studies.

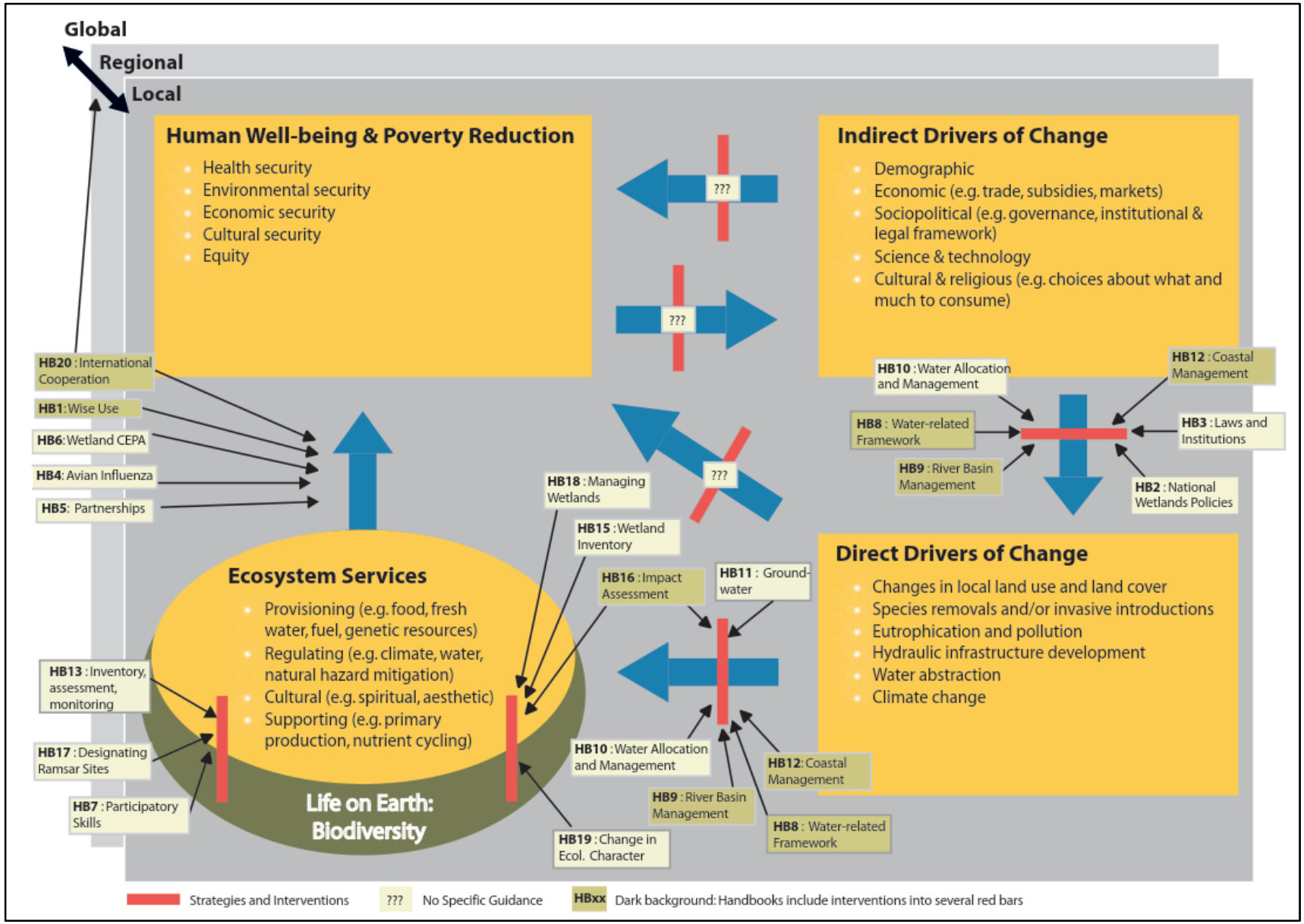

Figure 7.2: Millennium Ecosystem Assessment Frameworks (Habiba *et al.*, 2011)

The results of the questionnaire also show that children of poorer households are more likely to receive less education. The numbers of boys and girls enrolled in primary school are similar, but more girls than boys drop out of secondary school. Culturally women are still considered to be the bearers of children and responsible for the running the household, while men are considered to be the breadwinners.

7.2.1.2 Social impacts

Changes in climate could potentially lead to instability in rural communities. Instability could cause impacts on the provision of water and food. A breakdown in the social network could occur as a result of a lack of provisions, a shortage of land and greed. The research questionnaire revealed that there is a conflict between the leaders and their community in terms of land provision. Land in the Tshiungani area has become scarce and the poorest of the community in particular have little recourse to land. According to the respondents of the questionnaire, this scarcity of land is partly due to bribery. Subsistence farmers have to pay bribes to the chief to acquire land close to the river. This has led to divisions in the community between those who can afford to pay a bribe and those who cannot.

The effects of climate change could lead to increased tensions within the community. Increased water-scarcity could result in a higher demand for land close to the river. The community currently has no plan or support strategies of their own to deal with the possible escalation of conflict.

7.2.1.3 Health impacts

In terms of health considerations, the Millennium Ecosystem Framework is more concerned with the health of infants than the elderly, with infant mortality being the main concern.

Infants need to be well nourished should not be exposed to the diseases associated with malnutrition. When the natural habitat is disturbed access to food, water supply and clean air is likely to be affected. This could pose problem in terms of ensuring that infants are well nourished to develop their immune systems. However, no infant mortalities in Tshiungani were reported during the face-to-face interviews.

If climate change leads to more health problem in the community, another factor that may play a role is the lack of infrastructure. For example, more people with health problems may visit the existing clinics which may not have the capacity to deal with the larger number of people. A shortage of medical staff and a lack of medication could contribute to the problem.

7.2.2 Indirect Drivers

The indirect drivers of vulnerability to climate change considered in the current framework are water and electricity. Indirect drivers are those factors that that have to be purchased or provided by government.

7.2.2.1 Water and electricity

In rural areas, water infrastructure (dams, reservoirs, reticulation systems) is often lacking or non-existent. In such regions the collection of water from remote sources is an important activity of the members of the community. Many communities are dependent on groundwater during dry seasons when rivers, lakes and springs dry up. Access to clean water for consumption and hygiene is vitally important.

Due to their remote locations relative to the larger developments, electricity is also rarely provided to rural communities. Many rural communities are dependent on firewood as their sources of domestic energy. This wood is collected in and around the various settlements and often leads to a depletion of vegetation in the vicinities of the villages. Community members have to walk ever farther to collect wood.

Climate change could impact severely on the natural environment. Droughts will not only impact on a community's access to water, but also on the abundance of vegetation from which firewood is obtained.

7.2.3 Ecosystem Services

Humankind benefits in many ways from the ecosystem. These benefits are collectively referred to as *ecosystem services*. The ecosystem services that are vulnerable to climate change considered in this framework is soil moisture and rain. These are the factors that are vital to agricultural production which contribute in the standard of living.

7.2.3.1 Soil moisture

Rural communities depend on agricultural practices for food as well as for income. Soil moisture is one the most important factors on which crop production depends.

Changes in climate change could lead to decreases in the soil moisture content. Tshiungani is located in a very dry part of South Africa where high temperature are often experienced. During the face-to-face survey (refer to Chapter 5), the community concerns about the lack of soil moisture, as most of their vegetation had been dying. An increase in temperature would lead to increased evaporation rates, which are likely to lead to a decline in crop production.

7.2.3.2 Rain

Decreasing rainfall figures will have devastating results in semi-arid areas that are already strained for water. Climate change is predicted to impact on rainfall pattern throughout South Africa, with some areas predicted to receive much less rain than is currently recorded. Rural communities often depend on rain their livelihoods with rainwater being used for everything from drinking and domestic water to crop irrigation.

During the face-to-face survey (refer to Chapter 5), the community of Tshiungani expressed concerns about the decrease in precipitation that they had been experiencing. They had also noticed a decrease in their crop production. If decreasing rainfall patterns due to climate change continue, less soil moisture will be available for crops while less drinking water will be available to the livestock. Furthermore, since some members of the community are dependent on their livestock and firewood as sources of income, their income will also be impacted on negatively by decreasing rainfall patterns.

7.2.4 Direct Drivers

Direct drivers are important components that play a role in the livelihoods of the members of the community. Direct drivers refer to the basic needs, they are needed for survival.

7.2.4.1 Harvest

In most rural communities, agricultural is practiced for food production and for generating an income. Rural communities are therefore very vulnerable to any changes in the conditions that could lead to decreased agricultural production. Some of the factors that may contribute to a decrease in the harvest include: increased temperatures leading to higher evaporation rates and a decrease in the rainfall figures leading to a decrease in the soil moisture.

The people most directly affected by a decrease in agricultural production are the farmers who are reliant on agriculture for the provision of food and for generating an income. The face-to-face interviews conducted with the members of the Tshiungani community (Chapter 5) showed that the community was concerned about the decrease in agricultural production. If climate change leads to a decrease in the rainfall figures, less agricultural production is to be expected.

7.2.4.2 Livestock Mortality

Climate change may impact on the food and water resources of an area and may therefore threaten the lives humans and livestock. Under conditions of decreasing natural resources in an area, humans may start to consume some of the resources that would otherwise have been available to animals.

This could lead to the migration of animals to other areas where water and food is more readily available.

Apart from the direct impacts of increased temperatures (more evaporation; less drinking water) high temperature may also contribute indirectly to the mortality of animals. Veld fires are more common during dry periods. When strong winds blow, fires may spread rapidly and animals may be killed.

7.3 DEVELOPED DECISION-SUPPORT FRAMEWORK FOR ASSESSMENT OF VULNERABILITY

The millennium framework system targets social vulnerability. The responses to the research questionnaire (Chapter 5) were used to develop a framework to assess the human vulnerability of the community of Tshiungani to the impacts of climate change.

The indicators used to develop the framework were adapted from the questionnaire. Indicators were selected by looking at the importance they pose to the livelihood of the community of Tshiungani. The answers from the questionnaire show that community of Tshiungani are most vulnerable to the impacts of climate change in terms of the following parameters:

- Education,
- Income,
- Water supply,
- Electricity,
- Social Impacts,
- Health,
- Agricultural productivity,
- Soil moisture, and,
- Precipitation.

These indicators are included in the decision-support framework presented in Figure 7.3.

7.4 APPLICATION OF THE FRAMEWORK TO CALCULATE VULNERABILITY

The framework was used to assess the vulnerability of the community of Tshiungani to the impacts of climate change. The different parameters used in the framework were evaluated in terms of the magnitude of the risk posed.

7.4.1 Risk

In order to assess the vulnerability, risks had to be assigned to the different indicators. The way in which risks were assigned for the different indictors is described below and summarised in Table 7.1Table 7.3.

7.4.1.1 Income

Based on the needs of the community and the cost of living, different income brackets were considered to be associated with different degrees of risk. For a family of four, a total income of R3 000 or more was considered to be adequate to provide for food and other basic needs. An income of R1 000 – R3 000 was considered to be enough to cater for most needs, but could exclude some of the essential. R1 000 or less was considered to be inadequate to meet the basic needs of a family of four.

7.4.1.2 Education

For the assessment of risk, a tertiary education was considered to be associated with no risk; this choice was based on the fact that a tertiary education would likely lead to proper employment and a decent income. Having only a primary education was considered to be a high risk, since a decent income is unlikely for an individual with low levels of literacy.

7.4.1.3 Water supply

Being dependent on borehole water or rivers was considered to be a high risk. These water sources may be depleted during dry spells brought on by climate change.

7.4.1.4 Agricultural, Rain and Soil Moisture

The food production and income of the members of the Tshiungani community are largely dependent on rainfall and soil moisture. If agricultural production decreases due to lack of rain and dry soils, income and food supply will be affected. Rainfall figures lower than 300 mm were considered to be associated with high risks, as was a lack of soil moisture.

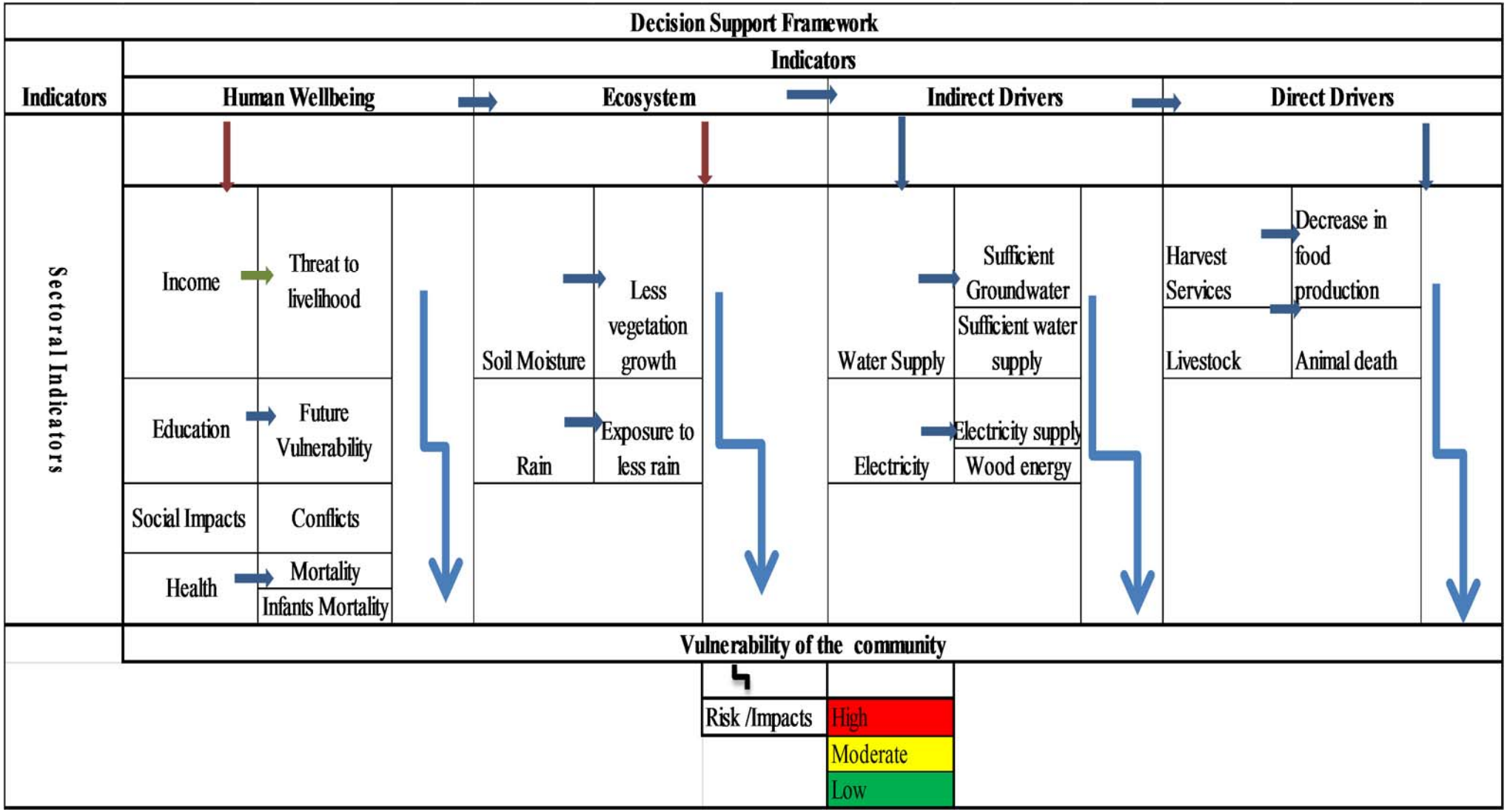

Figure 7.3: Schematic representation of proposed framework

7.4.1.5 Livestock Farming

If the health and number of livestock are affected by the impacts of climate change, income and food supply will also be affected. Mortalities among the livestock are therefore considered to be a high risk factor.

Table 7.1: Decision-support framework – risk allocation

Indicators			
Human Wellbeing		**Indirect Drivers**	
Income		**Water supply**	
>R3,000	No Risk	Borehole water	High Risk
R1,000 - R3,000	Moderate Risk	Tap water	Moderate Risk
<R1,000	High Risk	River water	High Risk
Education			
Tetiary	No Risk		
Secondary	Moderate Risk		
Primary/ None	High Risk		
Ecosystem		**Harvest Services**	
Rain		**Agricultural activities**	
≥500mm	No Risk	Increased production	No Risk
300mm	Moderate Risk	Decreased production	High Risk
≤300mm	High Risk		
Soil Moisture		**Livestock Farming**	
Moist	No Risk	Death	High Risk
Dry	High Risk	More livestock production	No Risk

7.4.2 Rating Scale

In the assessment of the vulnerability of the community of Tshiungani to the impacts of climate change, a rating scale was used to assign numerical values to the risks as identified from the responses received during the face-to-face interviews. These numerical values were calculated based on the number of respondents who gave specific answers to closed questions. The responses were grouped into responses that suggested either *no*, *moderate* or *high* risks for the indicator. The rating is therefore based on stakeholder perception.

For closed questions with a choice between insignificant, moderate or high risks, the numerical value of the risk rating was calculated from:

$$\begin{aligned}\text{Risk rating} = [&(0 * fraction\ of\ answers\ indicating\ no\ risk)\\ &+ (1 * fraction\ of\ answers\ indicating\ imoderate\ risk)\\ &+ (2 * fraction\ of\ answers\ indicating\ high\ risk)]/2\end{aligned} \quad (2)$$

For closed questions with a choice between no or high risks, the numerical value of the risk rating was calculated from:

$$\text{Risk rating} = [(0 * fraction\ of\ answers\ indicating\ no\ risk) + (2 * fraction\ of\ answers\ indicating\ high\ risk)]/2 \quad (3)$$

This way of calculating the risk rating results in numerical values that range from 0 to 1. The risk ratings calculated for the various indicators at the Tshiungani village are shown. Once the risks were rated, weights were applied to the different indicators. These weights correspond to the relative importance of the different indicators in the vulnerability of the community to the impacts of climate change. For example, if the community is deemed to be more vulnerable in terms of the lack of soil moisture than in terms of livestock deaths, the former indicator will receive a larger weight in the final calculation of the vulnerability. Weight values ranging from 0 (unimportant) to 1 (very important) were applied.

To calculate a numerical value representing the degree to which a community is vulnerable to climate change, the following formula can be used:

$$\text{Vulnerability} = \left(\frac{1}{N}\right)\sum_{i=1}^{N} w_i r_i \quad (4)$$

where r_i and w_i are the risk ratings and weights for indicator i, and N is the number of indicators included in the assessment. The numerical values assigned to the vulnerability can therefore range between 0 (not vulnerable) to 1 (very vulnerable).

For the assessment of the vulnerability of Tshiungani, all the indictors were deemed to be important. Weights of unity were therefore assigned to all the indicators. With this choice of weights, the numerical value representing the vulnerability of Tshiungani was calculated to be 0.50, as shown in Table 7.2.

To evaluate this vulnerability value in terms of the actual vulnerability of the community, a vulnerability scale was used. This scale is shown in Table 7.3. Comparison of the vulnerability value calculated for Tshiungani (0.50) with the vulnerability scale, shows that Tshiungani can be considered to be moderately vulnerable to the impacts of climate change.

Table 7.2: Risk rating for the indicators at Tshiungani

Indicators	Sensitivity	Risk	Number of respondents	Risk rating (r_i)	Weight (w_i)	$r_i \times w_i$
Income	>R3 000 R1 000 - R3 000 < R1 000	No Moderate High	12 26 32	0.64	0.85	0.55
Education	Primary Secondary Tertiary	High Moderate No	40 25 5	0.75	0.85	0.64
Rain	More rain Less rain No rain	No Moderate High	7 20 43	0.76	1.00	0.76
Soil Moisture	More moist Less Moist Dry	No Moderate High	2 58 10	0.56	1.00	0.56
Source of Domestic Water	Tap Borehole River	Moderate High High	0 70 0	1.00	1.00	1.00
Livestock	More births More deaths	No High	55 15	0.21	0.80	0.17
Agricultural Production	Increase in production Decrease in production	No High	42 28	0.40	0.95	0.38
Health	Infant Mortality Healthy babies	High No	1 69	0.01	0.10	0.00
Social Impact	Conflicts No Conflict	High No	9 61	0.01	0.10	0.00
Energy	Wood Electricity	High No	64 6	0.91	1.00	0.91
Vulnerability $[\Sigma(r_i \times w_i)]/N$						**0.50**

Table 7.3: Scale used to assess vulnerabilities

Vulnerability value	Vulnerability rating
0.00 - 0.20	Insignificant vulnerability
0.20 - 0.40	Low vulnerability
0.40 - 0.60	Moderate vulnerability
0.60 - 0.80	High vulnerability
0.80 - 1.00	Very high vulnerability

7.5 DISCUSSION

The decision-support framework developed in this study was uses the results of face-to-face interviews with community members to rate the risk associated with different indicators of vulnerability. This rating is based on the perceptions of the persons interviewed and is therefore subjective. However, since many members of the community are interviewed, individual subjective

responses are averaged to obtain a response that is representative of the community. Furthermore, the assigning of weights to the different indicators is a subjective process. The person assessing the vulnerability subjectively chooses which indicators are more important in the assessment of vulnerability.

Despite these limitations, the developed framework provides a simple process to assess the vulnerabilities of rural communities to the impacts of climate change. It is likely to find application when comparing the vulnerabilities of different rural communities in South Africa in order to allocate funds and resources when combatting the societal effects of climate change.

CHAPTER 8:
SUMMARY AND RECOMMENDATIONS

More than 19 million or 39% of South Africans live in rural areas. Small subsistence farming and homestead food production takes place in rural areas, with approximately 1.3 million small-scale farm units in South Africa. People in rural areas often face economic difficulties and frequently rely on urban allowances and social welfare grants for survival. Natural resources such as wood and surface water are used extensively in rural areas where basic services have not yet been provided.

Most vulnerable and poor communities are already starting to be impacted on by climate change around the world. The effect that extreme weather conditions, such as an increase in droughts, extreme heat, tropical storms, sea level rises and high rainfall causing floods, may have on most portions of Africa, could have adverse effects on poor rural communities.

In this study, a decision-support framework was developed to assess the vulnerability of rural communities in South Africa to the impacts of climate change. This framework was based on the Millennium Ecosystem Assessment Conceptual Framework, but incorporated the results of face-to-face interviews with members a specific community to determine the indicators of vulnerability in this community. The risks associated with these indicators were rated based on the responses of the people interviewed. Furthermore, weighting of the importance of the each indicator in the vulnerability of the community was done.

To demonstrate the application of the framework, it was used to calculate a numerical value representing the vulnerability of a selected community. In the same way, the framework can be applied to other rural communities in South Africa to assess their vulnerabilities and to prioritise those communities where funds and resources should be allocated when combatting the impacts of climate change.

Although this framework could have wide application in the assessment of the vulnerabilities of rural communities in South Africa to climate change, further work is warranted to improve the framework. To this end, the following recommendations are made:

- The framework developed in this study was based on the Millennium Ecosystem Assessment Conceptual Framework. However, other frameworks should also be considered to better understand climate change impacts on rural communities and to strengthen and improve the assessment of the vulnerabilities faced by rural communities.
- The decision-support framework developed in the current study focused on one rural village. The framework could be significantly improved by expanding the study to include more rural

villages. This will allow a better understanding of how other rural communities are affected by climate change. Furthermore, expanding the study will help to establish recommendations which could assist in finding solutions for rural communities that are affected by climate change on a wider scale.

- In the current study, community vulnerability was assessed by considering those parameters that support community livelihood. However, adaptation measures to protect biodiversity and ecological parameters that support the livelihood of the community were not considered. Future studies or assessments which integrate adaptation in the decision-support framework should be considered.
- The current study focussed on the development of a decision-support framework to assess the current vulnerabilities of rural communities to the impacts of climate change. No projections of future climatic conditions were incorporated in the development of the framework. By including long-term projection of the changes brought on by climate change, the framework can be refined and improved. Such an improved framework will assist in the planning of adaptation strategies for rural communities and will allow better allocation of funds and resources to those communities facing the largest impacts.

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ABSTRACT

Climate change is likely to affect the way in which people live. Natural resources such as groundwater, surface water and wood form a vital component of the livelihood in rural communities and are used extensively in rural areas where basic services have not yet been provided. The effect of climate change on all these natural resource may impact the lives of those in rural communities. Climate change is already starting to affect some of the poorest and most vulnerable communities around the world.

The aim of the dissertation was to develop a framework to assess the vulnerability of rural communities to climate change. This framework used the Millennium Ecosystem Assessment Conceptual Framework as a guideline, but also incorporated the results of face-to-face interviews conducted with members of a selected community. The purpose of the interviews was to interrogate the communities' level of awareness on climate change and to gain an understanding of the parameters influencing the community's vulnerability to the effects of climate change.

The developed framework allows the calculation of a numerical value which represents the vulnerability of a community to climate change. To illustrate its application, the framework was used to assess the vulnerability of a selected community. In the same way, the framework can be applied to other rural communities in South Africa to assess their vulnerabilities and to prioritise those communities where funds and resources should be allocated when combatting the impacts of climate change.

Further work to improve the framework developed in this study is recommended. These recommendations include:

1) considering other existing frameworks to better understand climate change impacts on rural communities and to strengthen and improve the assessment of the vulnerabilities faced by rural communities,
2) expanding the study to include more rural villages in order to better understand how other rural communities are affected by climate change and to establish recommendations which could assist in finding solutions on a wider scale for rural communities that are affected by climate change,
3) including in the framework adaptation measures to protect biodiversity and ecological parameters that support the livelihood of the community, and,

4) including long-term projection of the changes brought on by climate change to refine and improve the framework.

OPSOMMING

Klimaatverandering sal waarskynlik die manier waarop mense leef affekteer. Natuurlike hulpbronne soos groundwater, oppervlakwater en hout vorm ‘n intrgrale deel van die lewensbestaan van landelike gemeenskappe, en word intens gebruik in landelike areas waar basiese dienste nog nie verskaf is nie. Die effek van klimaatverandering op al hierdie natuurlike hulpbronne mag impakteer op die lewens van mense in landelike gemeenskappe. Klimaatverandering is reeds besig om die armste en mees kwesbare gemeenskappe te affekteer.

The doel van hierdie verhandeling was om ‘n raamwerk te ontwikkel om die kwesbaarheid van landelike gemeenskappe tot klimaatverandering te assesseer. Hierdie raamwerk gebruik die *Millennium Ecosystem Assessment Conceptual Framework* as riglyn, maar inkorporeer oof die resultate van aangesig-tot-aangesig onderhoude met die lede van die gekose gemeenskap. Die doel van die onderhoude was om die gemeenskap se bewustheid rondom klimaatverandering te toets en om ‘n begrip van die parameters te kry wat die kwesbaarheid van gemeenskappe tot klimaatverandering beïnvloed.

Die ontwikkelde raamwerk laat die berekening van ‘n numeriese waarde toe wat die kwesbaarheid van die gemeenskap to klimaatverandering verteenwoordig. Om die toepassing van die raamwerk te illustreer, is dit gebruik om die die kwesbaarheid van ‘n geselekteerde gemeenskap te assesseer. Op dieselfde manier kan die raamwerk toegepas word op ander landelike gemeenskappe in Suid-Afrika om hul kwesbaarhede te assesseer en om daardie gemeenskappe te prioriseer waar fondse en hulpbronne toegeken moet word om die impakte van klimaatveradering te beveg.

Verder werk om die raamwerk wat in hierdie studie ontwikkel is te verbeter word aanbeveel. Hierdie aanbevelings sluit in:

1) inagneming van ander bestaande raamwerke om die impakte van klimaatverandering op landelike gemeenskappe beter te verstaan, en om die assessering van kwesbaarhede deur landelike gemeenskappe getrotseer te versterk en te verbeter,

2) uitbreiding van die studie om meer landelike dorpies in te sluit sodat beter verstaan kan word hoe klimaat verandering landelike gemeenskappe affekteer en om aanbevelings te maak wat kan help om oplossings op ‘n groter skaal te vind vir landelike gemeenskappe wat geaffekteer word deur klimaatverandering,

3) insluiting in die raamwerk van aanpassingsmeganismes om biodiversiteit, asook die ekologiese parameters wat die lewensbestaan van die gemeenskate ondersteun, te beskerm, en,

4) insluiting in die raamwerk van lang-termynvoorspellings van die veranderinge deur klimaatverandering teweeg gebring om die raamwerk te verbeter en te verfyn.