Urban Households' Vulnerability and Adaptation to Climate Change in Mopani District, Limpopo Province, South Africa

By

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Supervisor	:	Professor Peter Bikam
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2022

DECLARATION

I, JIMOH Musa Yusuf, student number 17003332, hereby declare that this thesis titled **"*Urban Households' Vulnerability and Adaptation to Climate Change in Mopani District, Limpopo Province, South Africa"***is my work in design and execution and has not been previously in whole or part submitted to any University for any degree.

Signature ………………………………………….. Date 15 January, 2023

CERTIFICATION

This is to certify that this research Thesis titled "Urban Households' Vulnerability and Adaptation to Climate Change, in Mopani District, Limpopo, South Africa", submitted to the Department of Urban and Regional Planning, by Mr Jimoh M. Yusuf, a PhD Student with registration number 17003332, is a product of the author under our thorough supervision.

Supervisor **Date**

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Associate Professor

Head, Department of Urban and Regional Planning **Date**

18 January, 2023.

Dr. Emaculate Ingwani

Dedication

This work is dedicated to my parents:

Late Hon. Jimoh Amuda Yusuf, (Father) and

Alhaja A. Abake. Yusuf (Mother)

And

My Family, Alhaja Asmau Folashade Yusuf (Wife),

Faridah, Yusuf & Sultan (Children)

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RESEARCH OUTPUTS

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ABSTRACT

The surreptitious impact of climate change on human society is a recurrent issue among scholars and policy makers in the 21st century. While the literature is replete with theoretical discussion and empirical analysis, particularly studies focusing on the major cities of developed economies, there is dearth of empirical studies on the cities of developing economies generally, and South Africa in particular where current dimension of human vulnerability, adaptation and response pattern are very abnormal and pathetically problematic. This thesis therefore examines Urban Households' Vulnerability, adaptation and response to Climate Change in Mopani District, Limpopo Province, South Africa. It assesses the households', communities' and spatial planning coping strategies in response to extreme climate change events in both spatial planning policies and households' practices.

Purposive method was used to select six towns (Giyani, Hoedspruit, ModjadjisKloof, Nkowankowa, Phalaborwa, and Tzaneen) in the Mopani District as case studies. Using Multistage sampling techniques, 500 respondents, proportionally distributed among the selected towns were randomly chosen for the purpose of questionnaire administration to elicit information on socioeconomic characteristics and adaptation strategies. 60 years records (1958 to 2017) of rainfall and Temperature were obtained from monthly gridded and high-resolution satellite dataset from the global data to detect climatic trends and cycles in annual and monthly Temperatures and Rainfall during the period. Google earth pro and 'gps visualizer' are used to conduct topographical analysis to assess the influence of terrain on the occurrence of climate related disasters. The use of geospatial analysis of available LandSat imageries was adopted for the examination of Land use and Land Cover Changes to monitor the trend in land and land resources consumption as an influencer of exposure to rainfall and temperature. Household Vulnerability Index (HVI) developed by United Nations (UN) Habitat was used to examine Households' and communities' degrees of exposure, sensitivity, and adaptive capacity. Ordered Logit Regression Model was used to examine the contributions of factors to HVI and Principal Component Analysis (PCA) was employed in weight assignments. Pearson's Correlation Coefficient was used to measure the strength of association that exists between the Households vulnerability Index and some selected socioeconomic attributes (such as age, gender, income, highest qualification) in the selected towns. Livelihood Diversification Index (LDI) was calculated, using the Herfindahl index of diversification to scrutinise the influence of diversification of households' Livelihood on their overall vulnerability level in Mopani. A mobile

application and web-based technology and tools are employed to design and develop the Disaster Hotspot Reporting and Monitoring System, for timely reporting and record keeping of climate related incidences.

The results reveal that the selected towns across the Mopani District have exhibited increasing warm Temperature (with varying heat waves) throughout the period under examination. Upward correlations that imply increase in the variations in both mean minimum and mean maximum Temperatures are observed over the period, with seasonal variations recorded from year to year. However, the trend in rainfall shows a reducing trend during the same period with yearly seasonal variations in precipitation. Most towns are characterised by gentle slopes, thus flash floods occur in varying intensities and frequencies across the selected towns. Developments (buildings, roads, asphalts, floor tiles etc) consistently invade vegetation, water bodies and bare land. Household exposure and adaptive capacity are observed to be high in the district with about 92% households in exposed category; Nkowankowa town claims the highest proportion (96.58%), while ModjadjisKloof town accounted for 60%, being the least. The HVI is equally high in these towns with Tzaneen being the town with the highest (over 78%) Community Vulnerability Index (CVI), while Hoedspruit town is the most resilient, with the least CVI of 55.56%. The high vulnerability levels observed in these towns were attributed to poor housing conditions, lack of access to essential services, and lack of insurance cover (of any form) among the households, among other factors. However, a point increase in LDI instigates a reduction of HVI by 0.729 points. A point increase in household age has increased HVI by 0.333, while that of educational qualifications significantly decreases the impacts on HVI by -0.0706. Other factors such as physical, statutory, and system failures contributed to high HVI in the study area. The result further reveals that tree planting and fans/air conditioners were the most popular with adoption by 100% respondents as coping strategies to deal with increasing Temperature in the District. In contrast, water treatment and storage tanks in homes were the most commonly embraced adaptation strategies for changes in water levels by 100% and 81% respondents respectively. The findings further show that, local municipalities' plans and policies recognised the impacts of climate change on urban households and the roles urban planning plays a central role in responding to climate change impacts. However, there is little evidence to indicate substantial efforts to pragmatically and coherently address the problems; the municipalities still rely on the national government for urban-related and climate change disaster response policies and strategies.

While emphasising greening (in homes and at the city centres) to reduce heat waves and curtail surface runoff, the study led to the development of a framework with an incorporated disaster hotspot reporting and monitoring system for sustainable adaptation planning in the district.

Key words: Urban households, vulnerability, adaptation, climate change, Mopani, South Africa

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CHAPTER ONE

INTRODUCTION AND STUDY BACKGROUND

1.1 Introduction

Climate change has become a reality, according to Carter *et al*., (2015); IPCC (2012), because of its significant 'social, economic, and environmental consequences occasioned by life-threatening weather condition and climate events (Olivier *et al*., 2011; Oloke *et al*., 2013). Its consistent prediction to further stimulate significant risks to life, livelihoods and ecosystems indicate its ability to leave no facet of human endeavour immune (Parry *et al*., 2007; McElroy and Baker, 2012). The current frequency of its occurrence, particularly in the post-1990 era, is described as more than normal and globally worrisome, particularly for cities of developing countries (Adeniji and Ogundiji, 2009). With the increasing global roles of the urban centre, cities in the world are observed by 2050, will play host to more than two-thirds of the global population (UN Habitat, 2013). Therefore, these signal negative consequences for the global city, its dwellers, and its components especially in emerging economies (Hamilton, 2010; Meghan *et al.,* 2016). This trend can continue because majority of the world's future population growth is expected to occur in the cities of Africa, Latin America, and Asia, which are already rapidly manifesting (UN Population Division, 2008). According to the IPCC (2012), this has far-reaching societal implications to exceed mere alterations in temperature and precipitation but constitutes a looming threat, making the existence of humanity highly vulnerable. The magnitude of the vulnerability appears to be more grievous in Africa and other developing nations because of their (environmental, weak social, and economic) peculiarities (IPCC, 2007; Adeboyejo *et al*., 2011; Phokele and Sylvester, 2012).

Urban planning is not limited to the arrangement of buildings and the supporting infrastructure and utilities, but it also encompasses creating an environment that promotes liveability and sustainability (Baycan-Levent, and Nijkamp, 2009). Climate change is inextricably interwoven with the process of urbanization because of the increasing importance of urban areas in the global economic, social, governance, cultural, and environmental spheres (Sánchez-Rodríguz *et al*. 2005). Furthermore, it is essential to note that most climate change factors that worsen the vulnerability of urban households are related to physical, political, economic, social, and in-migration issues. This is true, particularly in South Africa (Moyo *et al.*, 2018).These circumstances have caused a continuous invasion of the city periphery, resulting in deforestation and households' exposure to flooding and heatwaves, abject poverty, as well as inadequate access to a sound health system, safe water, and quality education (Agbola, 1995; 2006). As a result, these towns are characterised by slums and informal settlements, social exclusion, and a weak socioeconomic base (Egunjobi et al, 2004; Ogundipe, 2006; Mabogunje, 2008). The common phenomena with this informal settlement include incompatible land uses, disregard for development control and physical planning regulations, overcrowding, ill-serviced dwelling units, and poor construction materials (Anand, 1999). Resultantly, poor urban dwellers are subjected to higher risk; couple with a weak coping capacity to climate change consequences make them more vulnerable (Anand, 1999; Nsiah-Gyabaah, 2010). Hence, the need for appropriate and urgent urban planning with other strategies is apt, to safeguard the United Nations Agenda 21 for environmental sustainability.

Like most developing economies' urban population, South Africa presents a similar scenario with 60.62% in cities in 2007 and about 65.36% of the urban population in 2018 (World Bank, 2018; Plecher 2019). This trend can threaten sustainability if the annual urban population growth rate which is put at 2.1% by 2018, is not contained (World Bank, 2018), as it is currently experiencing significant impacts of changing climate, especially in urban areas (Kreft *et al.,* 2017). The urban population is prone to a higher risk of being vulnerable because of high densities, high poverty rate, insufficient drainage (channels), high solid wastes volume, and poor urban management practices. In addition, informal settlement sites and hard concrete surfaces aggravate the consequences of climate change in cities (Adeniji and Ogundiji, 2009). These phenomena are primarily responsible for increased hazards that continually stretch local planning authorities' capacity with limited resources and infrastructure to respond with sustainable adaptation strategies.

The case of the Mopani District of South Africa shows a similar scenario, with extreme weather events impacting pipe-borne water provision, windstorms, intense floods, and droughts (Phokele and Sylvester 2012). Mopani is a water-stressed district that was nationally declared a climate disaster area alongside other municipalities in South Africa in 2016 (Manderson *et al*. 2016; MDMIDP, 2016; Mopani District Disaster Management Centre Report, 2017). In line with these concerns, scholars like Phokele and Sylvester (2012) have indicated that in Limpopo Province, the Mopani and Vhembe Municipalities constitute the districts most affected by climate change. These partly explain the motivation for this study, which is buttressed by the concerns raised by the Mopani District Disaster Management Centre regarding the character, magnitude, as well as the extent of climate change vulnerability in the district (MDDMC Report, 2017). Further complimented by the multiple scientific and practical research conclusions that has advanced the need for more climate change research attention on cities due to neglect in favour of rural areas (Thomas *et al*.

2009; Jörn *et al*. 2010). Despite that, global warming and growing heat-related ailments are becoming more prevalent in urban areas (Adeboyejo *et al.,* 2012; 2015), thus subjecting the urban population to higher risk (Adeniji and Ogundiji, 2009). Against this background, this study does investigate the households' vulnerability and coping strategies to the comsequences of climate change and suggest sustainable strategies to strengthen their coping capabilities.

1.2 Statement of the Problems

The environment undoubtedly is a basic requirement for human existence and survival (IPCC 2012). However, consequent to human actions, human-induced disturbances in history have compromised the environment's security. The well-being, health, and economic prosperity, most importantly, human survival, have been affected, especially for future generations, through environmental alterations, with changing climate (McElroy, 2012).

Climate is changing and has impacted human activities with far-reaching societal implications (IPCC 2012). The potential to exceed mere alterations in temperature, precipitation, and other climate parameters constitutes a threatening threat to humanity's existence, especially in Africa and other developing countries, because of their peculiarities (IPCC, 2007).

The studies mentioned below have reported significant evidence of disappearing rivers and other water bodies'encroachment (resulting from bush burning and tree felling). Fluctuations have arisen in the frequencies and intensities of rainfall, heightened temperatures, and sanitation problems, shortage of essential services coupled with increasing climate-related hazards with limited resilience and adaptive capacities of towns and their inhabitants. This has been especially true in the Southern African countries Wilbanks and Kates, 1999; Adelekan and Gbadegesin, 2004; Archer and Tadross, 2009; World Bank, 2010).

South Africa has a significant share of this phenomenon in Africa, and it is projected that 250 million Africans could be exposed to climate change disturbances in few years to come. In this business-as-usual scenario, the phenomenon is becoming increasingly severe. This explains why Mopani and twenty other Municipalities in South Africa were declared climate change disaster zones in 2016 because they had to deal with disasters like floods, drought, heatwaves, as well as the spread of climate-sensitive illnesses like malaria (Congedo and Macchi, 2015; Manderson *et al*., 2016; Mopani District Municipality Integrated Development Plan, 2016; Mopani District Disaster Management Report, 2017).

The Mopani District's population is becoming increasingly sensitive to the growing frequency of extreme climate occurrences, with risks to health and livelihood. This is exacerbated by high unemployment and poverty rates, increasing rates of dependency, as well as limited resource access and essential services. It is leading to households getting polluted domestic water supplies from the Greater Giyani, and Thabina rivers due to climate change (Christensen *et al*., 2007 and UNDP, 1999; Nkondze *et al*., 2013).

In the South African context, with respect to the climate change adaptation strategy, the policy response is lacking, and institutional arrangements in combating the phenomenon are weak with overlapping and conflicting solutions. This is coupled with the paucity of monitoring skills and equipment for disaster mitigation and adaptation in the Mopani District Municipality. These shortfalls have influenced the plummeting of households' adaptive capacity in the district and have equally frustrated attempts at appropriate interventions to enhance adaptation and increase cities' resilience to climate change disasters (McKinney and Schoch, 1998; Okunmadewa, 2000; MDMIDP, 2016).

Therefore, a knowledge gap currently exists in the spatial planning system regarding climate change uncertainties. Vulnerability and adaptation to climate change have ironically been appreciated in research, programmes, and projects, as a rural phenomenon, despite that, the importance of the urban centre in the world (social, economic, cultural, political and environmental spheres) keep increasing (Sanchez-Rodriquez *et al*., 2005), because it is home to half the world's population (Satterwaite, 2009) and the stress occasioned by these developments, Jörn *et al.* (2010). However, the current planning practices, particularly in Mopani District (like other most African municipalities) do not have the prerequisite understanding of the underlying factors of climate change vulnerability with respect to small and medium towns' socioeconomic components and other relevant influencing indicators of household vulnerability and adaptation strategies. (Clark 2009; 2010; BNRCC, 2012; MDMIDP, 2016).

Consequently, this study is challenged with these incidental phenomena to:

i. Identify how variations in temperature, precipitation, and extreme events are impacting urban households;
ii. Unpack the specific populations which are vulnerable due to their exposure and sensitivity levels as-well-as their capacity to adapt; and
iii. How, in turn, the households as-well-as various levels of government have responded, adopting various coping strategies to the phenomenon.

No doubt, a well-planned and resilient urban centre is most desirable but not limited to proper arrangement of buildings and the complementing utilities and infrastructure; it equally incorporates the promotion of an environment that stimulates comfortability, safety, liveability and sustainability (Baycan-Levent, and Nijkamp, 2009). Proper attention on the process of urbanisation and climate change with interwoven inextricability that results from the increasing social, economic, cultural and political roles of urban center is required (Sánchez-Rodríguz *et al.,* 2005). This will require paying special attention to the essential climate change factors that worsen the vulnerability of urban households, which are physically, politically, economically and socially inclined. It is therefore thought timely and topical for a comprehensive system-level analysis to address the climate change influence on vulnerability and adaptation and to ascertain its extent and magnitude in the selected small and medium towns in Mopani district, South Africa.

1.3 Research Questions

This research is an attempt to present a countering view to the most favoured discourse on climate change vulnerability and adaptation which is dedicated to rural areas and big cities, particularly in Africa. The drive is to articulate questions about the past, present as well as the future about how small and medium-sized towns and their dwellers can face climate change consequences in Africa. Addressing and clarifying such questions are believed to be an urgent task for Africa's researchers, cities' dwellers, policymakers, civil organisations, academics, and planners.

These questions for the selected study areas are as follows:

i. What is the trend and pattern of temperature and rainfall between 1958 and 2017 in Mopani District?
ii. What is the magnitude and spatial scales of households' vulnerability?
iii. Are there spatio-temporal variations in households' vulnerability, and what are the relationships with the households' characteristics?
iv. What are the individual households', communities' and urban planning response strategies to the impacts of climate change?
v. What are the decision-support tools upon which sustainable planning strategies can be built?

1.4. The aim and objectives

1.4.1 Aim

The study examines the vulnerability and response pattern to climate-related impacts among households in six towns (Giyani, Hoedspruit, ModjadjisKloof, Nkowankowa, Phalaborwa, and Tzaneen) in the Mopani District, with the view to suggesting practicable and sustainable strategies capable of enhancing households' adaptive capacity and resilience in the towns.

1.4.2. Thus for the chosen towns, objectives are to:

i. Examine the trend and pattern of temperature and rainfall during 1958-2017, in Mopani District.
ii. Assess the magnitude of households' vulnerability (with regards to exposure, sensitivity, and adaptive capacity levels) in the selected towns;
iii. Analyse the spatio-temporal variations in households' vulnerability in the selected towns of the District;
iv. Examine households', communities' and urban planning response to the impacts of climate change in the selected towns; and the district; and
v. Propose adaptive measures and decision support tools upon which sustainable planning strategies will be built.

1.5 The Study Area

The study area for the research is the Mopani District Municipality in Limpopo Province, the northern-most province in the Republic of South Africa. It comprises five local Municipalities which are, Greater Giyani, Maruleng, Greater Letaba, Ba-Phalaborwa, and Greater Tzaneen. The Province shares international borders with Zimbabwe, Botswana, and Mozambique. It also borders the province of Mpumalanga in the south, Gauteng and the North West in the South-west. It covers an area of 13,948.418ha (10.2%) of the surface area of South Africa. The province has Mopani as one of its five district components, others being Bohlabelo, Capricorn, Sekhukhune, Vhembe, and the Waterberg District Municipalities.

The Mopani District according to South African municipality classification is a "Category C municipality, located on a global view, between the Longitudes: 29° 52´E to 31° 52´E and Latitudes: 23° 0´S to 24° 38´S, with 31° E as the central meridian" MDIDP 2017/18. The district is sited in the Degree square 2431 Topographical sheets, within the north-eastern quadrant of Limpopo Province, see Fig. 1.1.

Mozambique borders the district to the east, while the Vhembe District Municipality, which contains the municipalities of Thulamela and Makhado, borders it on the north. It is bordered on the south by the province of Mpumalanga through the Ehlanzeni District Municipality (Bushbuckridge, Thaba-Chweu and Greater Tubatse). The Capricorn District Municipality (Molemole, Polokwane, and Lepelle-Nkumpi) lies on the west, and the Sekhukhune District is on the south. The district encompasses the Kruger National Park from the Olifants River to the Tshingwedzi camps or the Lepelle River to the Tshingwedzi rivers, covering a total area of 2 001 100 acres (20 011 km2). There are 125 Wards, 16 urban areas (towns and townships), 354 villages (rural settlements), and 16 urban areas (towns and townships) in total (towns and townships) (MDMIDP, 2019). The administrative and territorial headquarters of South Africa's northern most Districts are shown in Figure 1.1

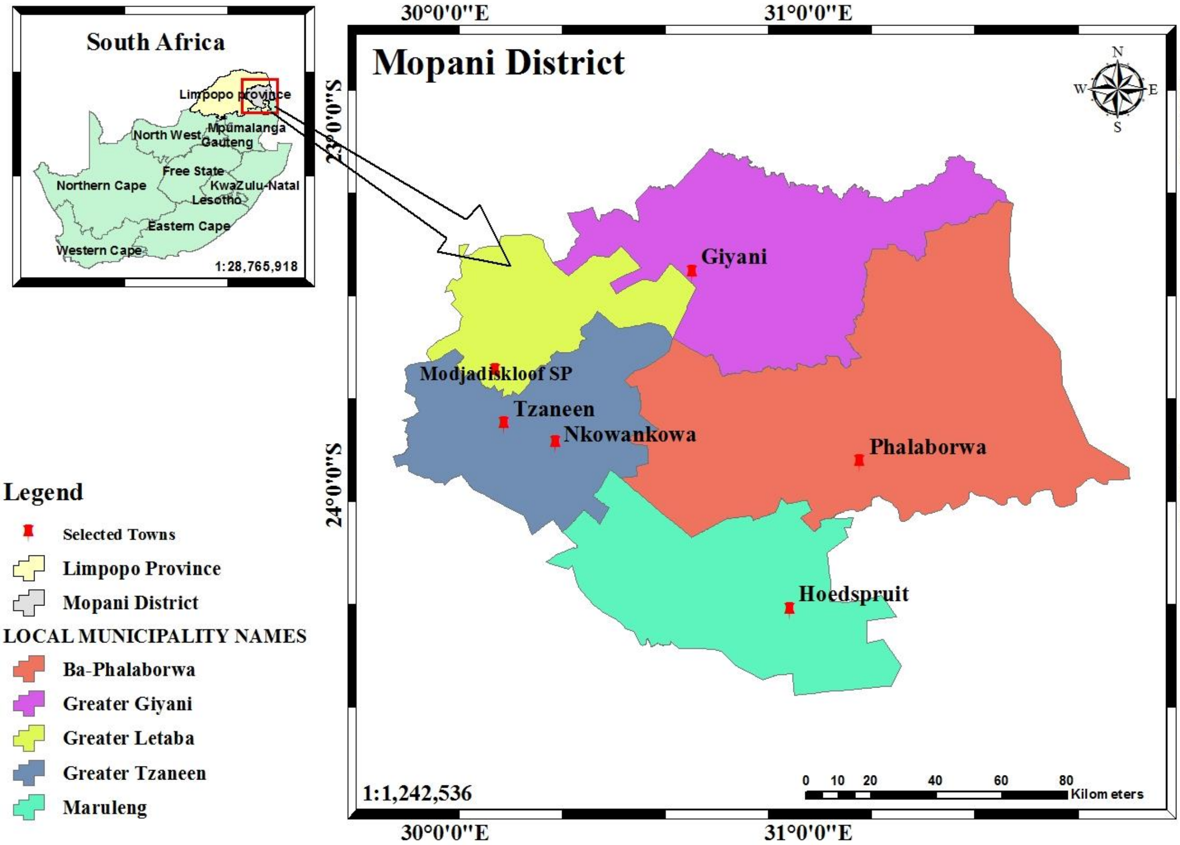


Figure1.1: Mopani District Map indicating the Local Municipalities and the selected towns with in the context of Limpopo Province and South Africa

The district consists of five local municipalities: Ba-Phalaborwa, Greater Giyani, Greater Letaba, Greater Tzaneen, and Maruleng with the seat of Mopani being the Giyani Township. The most important economic sectors in the district are Mining (30.1 %), community services (22.6%), trade (14.6%), finance (14.6 %), trannsportation (8.2%), agriculture (3.2%), power (2.8%), and construction (2%). are the most important economic sectors in the district. According to the Mopani District Municipality National Council of Provinces' Report of 10 September 2014, Agriculture is the second-highest creator of jobs after social and infrastructure projects within the district of Mopani.

Generally, most parts of the Mopani District receive about 85% of their rain recorded in summer. There are variations in the rainfall received ranging from the mountainous zones of the district with about 2000mm/a in the mountainous region of Drakensberg (2000 mm/a), and the Kruger National Park (the dry low veld) having a share as low as 400mm/a. On the other hand, in the high Mountainous zone of Mopani the temperature ranges on average from 21°C to 25°C on average in the Kruger Park's arid low veld sections. The district is located inside the Letaba Catchment area, which encompasses around 13 779 km2 and has an average annual precipitation of 612mm (Environmental Management Framework for the Olifants and Letaba river catchment areas, Report, 2009)

The district is predominantly characterized by plains and undulating plains, with the southwestern boundary formed by the high mountains of the escarpment. Elevations range from around 200m above sea level on the plains to more than 2,200m above sea level at the highest points of the escarpment. The Olifants River catchment (including the Letaba and Shingwedzi catchments) is a sub-catchment of the Limpopo Basin and is the largest tributary of the Limpopo River.

The reconciled total population of the Mopani District Municipality has increased from 1,068,569 (Statistics South Africa Census 2007) to 1,092,507 (Statistics South Africa, Census 2011) i.e. with an average annual rate of 1.35%. The attendant consequences of the phenomenon are already becoming more apparent, couple with the climate phenomenon in the district. This population will not only contribute to carbon footprint of the region but equally be confronted with climate-related challenges, (Congedo and Macchi, 2015).

Climate change related disaster such as flash and extreme floods events, drought, heatwaves and the spread of climate-sensitive diseases constitute the most common and devastating environmental event affecting the Limpopo province (Manderson *et al.,* 2016; MDMIDP, 2016; Congedo and Macchi, 2015). These impacts are obvious in economic, social and environmental sphere (Leira *et al*., 2002; Buckland, Eele and Mugwara, 2000). Unreliable and unpredictable precipitation have resulted in episodic (with few days of) rainfall occurring in a complete season (FAO 2004), making Limpopo province higher in drought susceptibility than the other parts of South Africa (Leira *et al*. 2002). With strong indication, the occurrence of drought in the Southern Africa is cyclical, though the prediction of the event is marred with less degree of certainty indicating the influence of the El Niño Southern Oscillation (ENSO) (Chikoore, 2016).

The impacts of these extreme climate events are extensive and pertinently manifesting significantly in human livelihood (Vogel, Laing and Monnik 1999). In the year 1992, South Africa, lost about 50,000 jobs in the agriculture sector, and additional 20,000 in associated sectors to Droughts, affecting roughly 250,000 people (AFRA, 1993), with 1.8% ($500,000) loss to GDP during the period (Pretorius and Smal, 1992).

Moreover, as a result of high poverty coupled with low literate level, with limited job (economic) opportunities, the communities of Mopani District Municipalities have a high possibility of being vulnerable to the impacts of climate change. The future projection of climate change, as interpreted and described in IPCC AR5 has shown severe upsurge in temperature and dangerous temperature events in the Limpopo province including the Mopani District in the period of 2030-2050 (under low mitigation) (Khwashaba 2018). In specifics, drastic increase in the occurrence of heat-wave and high-fire danger days are very likely in the district, with possible occurrence of more often seasons of drought. Such variations will have effects on human health, lives and livelihood in the district in decades to come. The district's population, characterized by high rates of poverty, poor living conditions with regards to paucity of services, waste management, health services and facilities and housing infrastructures, with conflicting land management systems, and weak and conflicting institutional arrangements may further compromise the households vulnerability to the earlier mentioned climate stressors in the district (Nkondze *et al.*, 2013; MDMMR, 2016), especially among socially vulnerable groups (Bazrkar *et al*., 2015). It is already evident in climate related disasters record (Musyoki, Thifhufhelwi and Murungweni, 2017; Nkondze *et al,* 2013) that the district's population is becoming increasingly vulnerable to the increasing incidences of extreme climate events, with increasing associated risk.

Notwithstanding the above assertions, climate change impacts are location-specific, hence for effective spatial planning for effective adaptation programming to climate change, an assessment of local vulnerabilities is required, to cater for the peculiar needs and priorities of the local community (Piya *et al* 2012). This justifies the need to examine the spatial variations in the patterns and degrees of occurrence of climate change and the vulnerability levels and response patterns across some small and medium-sized towns in the Mopni District.

1.6 The Study Scope

This study examined the variability of climatic paramers particularly, rainfall and temperature, as well as establishing the magnitude and the influencing factors of household vulnerability and the coping strategies that are employed to reduce the negative components of the phenomenon. The existing connections between these climatic parameters and household exposure as well as the prevalence of climate-related diseases were examined.

The study focused on the varying levels of household vulnerability and response strategies to climate change in the Mopani District in the Limpopo Province of South Africa, with attention paid to the main town(s) in the five Local Municipalities, (Giyani in Greater Giyani Municipality, Hoedspruit in Maruleng, and Modjadjiskloof in Greater Letaba, Phalaborwa in Ba-Phalaborwa and Nkowankowa and Tzaneen Towns in Greater Tzaneen Municipalities). It investigated temperature levels in line with historical climate data (during the period of 1958-2017) at the District Municipality level, with varying rates and frequencies. The study focused on selected towns in the District, and how climate change has affected households' susceptibility, based on their socioeconomic characteristics and community assets base.

The study unpacked the various coping strategies employed by individual households and various agencies of government in charge of planning, disaster management, and other related responsibilities. The study further reflected on the variation in human susceptibility and respective vulnerability components across the selected towns. Households' socioeconomic characteristics and livelihood diversification were also analysed.

The study proposed a "Disaster Hotspot Reporting and Early Warning System" (Hotspot Reporter) to provide for an instant account of hazards/disasters for prompt response by designated agencies of government to address climate change-induced effects. The spatial planning dealt with heat mitigation and flood reduction-related strategies to facilitate adaptation.

1.7 Rationale of the Study

The environment is no doubt the fundamental requirement for human well-being and health as well as for economic prosperity, particularly for societal survival. However, the recent increased human-induced disturbances (especially climate-related) are worrisomely compromising the environment, with far-reaching potential implications for society in the 21st century (IPCC, 2019; McElroy, 2012). This development has created and aggravated scenarios of an unsecure environment for future generations. It has though over time, particularly in recent times, triggered considerable policy interests locally and globally. The attention as drawn by the consequences of these human actions has resulted in some conclusions that triggered this study.

In recent times, most developing countries (particularly Africa) are rapidly becoming urbanized. This is characterized by informality, with the dangers of extreme changing climate related catastrophes appearing in expanding frequencies and difficulties of flooding, dry spells, water contamination, heat pressure and the spatial spread of vector-borne infections (Adeboyejo *et al*., 2011). The metropolitan populace is at a higher risk because of concentrated densities, insufficient seepage channels, high volumes of strong squanders and never-ending sprawl as well as risky sites occupation (flood plains) and impervious surfaces among others (Adeniji and Ogundiji, 2009). Several hundreds of thousands of these people are already affected globally by meteorological disasters, about 280 million in 2010 alone. This number is projected to rise to 375 million in the future, thus implying intensified meteorological disaster soon. (Birkmann and Von Teichman, 2010).

Equally buttressing the submission were the climate change models proposed by Hulme *et al*., (2005); Tadross *et al*., (2009); IPCC (2020). These have clearly indicated the imminent possibility of the globe facing increased and varying climate change-related challenges as projected; this applies particularly to the developing countries including South Africa. For instance, the 43 years of climatic data analysed from 26 South African weather stations, as indicated by Kruger and Shongwe (2004), showed that South Africa's temperature increased by an average of 0.13° C per decade; the projection indicates a further increase by 1.2°C by 2020, 2.4°C by 2050 and 4.2°C by the year 2080. On the other hand, rainfall was projected to decrease by 5.4% by 2020, 6.3% by 2050, and 9.5% by 2080 (Masego, 2010). The recent recurrent droughts, floods, and other extreme climatic events are clear manifestations of these predictions (Moyo *et al*., 2012); hence the need for appropriate data-driven (informed) urban coping policies and strategies.

The choice of Mopani for this study was informed by the phenomenon of climate becoming more worrisome, especially when the Mopani District and twenty others were declared national climate change disaster zones in 2016 (Manderson *et al*., 2016; MDMIDP, 2016). Mopani is confronted with extreme events of floods, drought, heat waves and the spread of climate-sensitive diseases (UNHABITAT, 2011; Wamsler, Brink and Rivera, 2012; Phokele and Sylvester, 2012; Congedo and Macchi, 2015). It is also characterized by a sensitive population exposed to those extreme climate events. This is compromised by high rates of poverty, a high proportion of female-headed families, conflicting land management systems, a high infrastructure deficit, and many other social issues (Christensen *et al*., 2007; Nkondze *et al*., 2013; MDMMR, 2016).

Moreover, concerns are occasioned by the lack of the District adaptation policy and programmes, weak and conflicting institutional arrangements as well as the paucity of climate change knowledge and over-reliance on government among households, which aggravate the situation. As well, threats of climate change to reverse millennium development gains are looming, and they are expected to have the most significant impacts on key sectors of the economies and threaten livelihoods, especially among socially vulnerable groups (Boko *et al*., 2007; Bazrkar *et al*., 2015).

The need to explore climate-smart urban planning and management has never changed, because African countries are always in search of sustainable urban management strategies particularly in the face of climate uncertainties. Instead of using the conventional approach of macro-level policies and programmes, this study unpacks a household/community-based (micro) vulnerability assessment to inform effective climate-smart spatial planning. The study is an in-depth analysis of the indicators of urban household vulnerability. It examines how these indicators act to undermine the capacity for self-protection, delay recovery from exposure, and heighten the sensitivity of households in the Mopani District, South Africa. Being a boundary-spanning issue, the study embraces both natural and social sciences and the application of technology while advocating for indigenous skills and knowledge-based adaptation in addressing the identified vulnerability challenges.

1.8 Layout of the Thesis

The first chapter deals with the introduction and background of the study and articulates the research problem as well as the research questions. It further highlights the aim and objectives of the study, the study rationale and its scope and limitations, as well as a brief description of the study area. In the second chapter, relevant conceptual and theoretical issues that are specific to climate and climate variability, disaster management, urbanisation and sustainable development among others were examined. Issues reviewed in the literature include the trends in climate change in South Africa, and the Limpopo province and Mopani District with respect to development/spatial planning and other relevant legal frameworks. It identifies vulnerability assessment methods. The chapter concludes by summarising the identified gaps in the literature.

Chapter three deals with methodological issues by narrating the details of the procedures employed. The chapter emphasizes the types and sources of data, analytical, as well as the methods and instruments used. The chapter further details the choices, definitions and measurement of variables, as well as general data analytical techniques.

Chapter four addresses objective one, by analysing the trends in the Land Surface Temperature of the Mopani District as well as the six selected towns on one hand, while the fifth chapter contains the analysis with respect to complimenting objective two. The examination of the topographical characteristics, land use, and land cover change, households' demographic characteristics as well as their access to basic services in the selected towns in Mopani District is assessed in chapter five.

Chapter six is the analysis with respect to research objectives two and three which deal with the examination of the magnitude and spatial variations of household and community vulnerability to climate change hazards in the six selected towns in Mopani District. And Chapter seven deals with research objective four with respect to the households' and urban planning adaptation response strategies and policy implementation.

While chapter eight addresses objective five by presenting the proposed disaster hotspot reporting and monitoring system, with the highlights of the summary of findings, the study's contribution to knowledge and planning implications as well as recommendations and decision support tools for sustainable urban planning.

1.9 Chapter Summary

This section has presented the background to the study and has highlighted the statement of the problem from where the research questions, the aim, and specific objectives were drawn. The concluding part of the chapter briefly discussed the main characteristics of the study area, the study scope and the rationale of the study and the highlights of the contents of the chapters. The succeeding chapter deals with conceptual issues, a theoretical overview, and a literature review of current studies to analyse the scope of the study with respect to urban household vulnerability and adaptation in general.

CHAPTER TWO

LITERATURE REVIEW ON CONCEPTUAL AND THEORETICAL OVERVIEW OF CLIMATE CHANGE

2.1 Introduction

This chapter reviews the literature on various conceptual issues relating to changing climate, susceptibility, and coping. Relevant theories relating to urbanisation, Climate change, population growth, disaster, and vulnerability as well as the risk/hazards model are equally reviewed. It briefly describes the selected towns while examining the trend of natural disaster as well as an overview of the trends of climate variability at national, provincial and district levels in South Africa. It reviews also the South African legal framework on climate change, spatial planning and development and concludes with reassessment of literature on changing climate and the need for urban planning.

2.2 Conceptual Issues

This subsection discusses the relevant issues that form the framework upon which the concepts of climate change are anchored. This is intended to provide the background understanding of the basic terminologies.

2.2.1 Climate Systems, Variability and Change

Climate is generally considered the normal atmospheric conditions at a given area over the long run or the average weather of a place over many years (National Research Council, 2012). It can be further characterized as the factual portrayal as far as the mean and inconstancy of temperature, precipitation and wind over a period going from months to thousands or millions of years; it however has a defined classical period of 30 years (World Meteological Organisation (WMO), 2003). Climate differs from weather which only describes short-term conditions of these variables in a given region. It generally describes an area’s long-term weather patterns, that is, the long-term manifestations of weather and other atmospheric conditions in a given region or country.

"Climate" is gotten from the Greek word klima, which alludes to the point of frequency of the sun. This is fitting, considering that sun powered radiation is a definitive energy driving the environment frameworks. Processes inside the world's framework convert approaching sun powered radiation to different types of energy and rearrange it over the globe from one pole to another and all through the upward spreads of the air and sea. This energy warms the climate and seas as well as energizes winds and sea flows, initiates stage changes of water, drives substance changes, and supports natural movement (Princeton, 2009). It is this global framework comprised of the environment, the seas, the ice sheets (cryosphere), living creatures (biosphere) and the soils, residue and rocks (geosphere), which all effect, in without a doubt, the development of hotness around the Earth's surface and which is known as the environment framework. Therefore, environment is characterized as a mind boggling framework comprising of five significant parts: the climate, the hydrosphere, the cryosphere, the land surface, and the biosphere and the collaborations among them (WMO, 1989).

Figure 2.1 depicts the basis of the climate system showing the important elements in controlling the climate such as flows of energy, water vapour and carbon dioxide. Sun based energy drives the global environment yet plants, mists, volcanoes, ice and the seas all assume significant parts in directing the world's ozone depleting substances which ingest the hotness transmitted from the surface and afterward re-emanate the hotness back to the surface. This interaction keeps up with the world's temperature at an agreeable level.

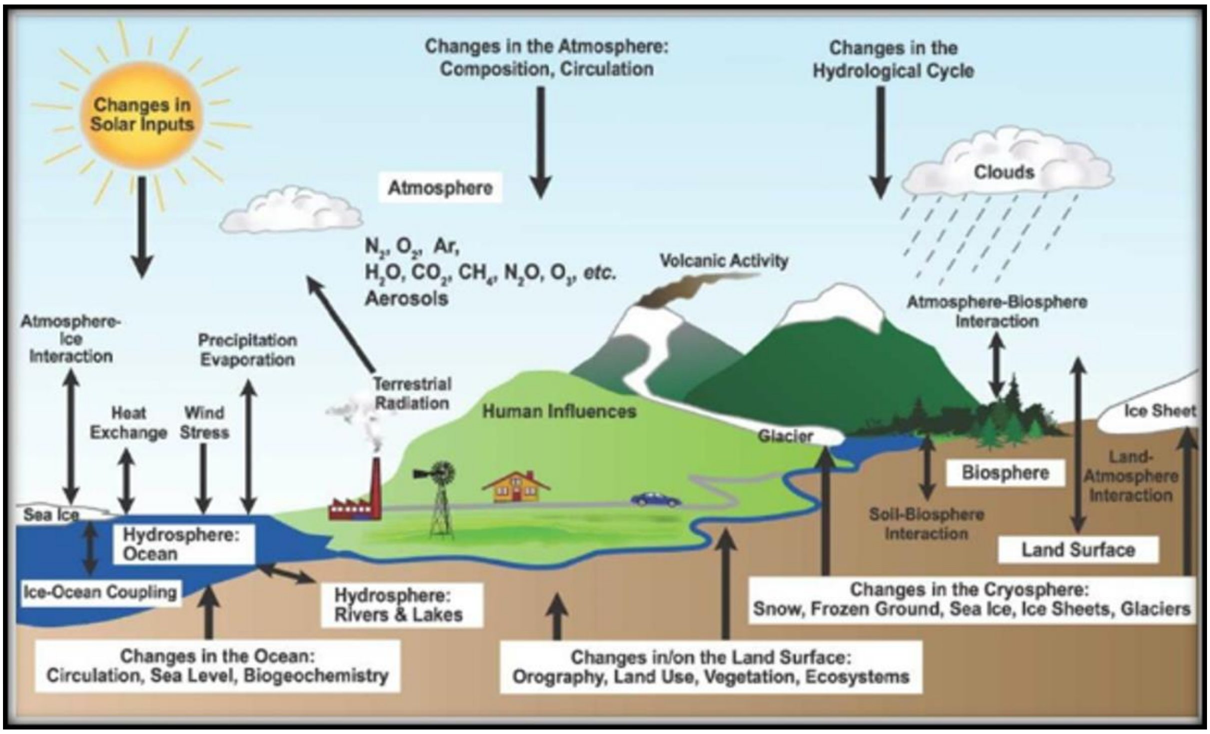


Figure 2.1: Schematic representation of the Components of the Global Climate System
Source: IPCC (2001)

2.2.2 The Causes of Climate Change

Climate change is a global phenomenon that affects the natural environment. There is an increasing cause of concern all over the world because of the realization that human activities are changing the climate. Humans are accustomed to weather conditions that vary on daily, monthly, seasonal and inter-annual time-scales. However, accumulating evidence suggests that in addition to this natural variability, average climatic conditions measured over extended times (conventionally 30 years or longer) are also changing, above the natural variations observed on decadal or century time-scales (McMichael *et al*., 1996). Climate change, according to the IPCC, refers to a change which can be identified (e.g. using statistical tests) in the means and/or variability of its properties which persists for an extended period, typically decades or longer (1PCC, 2001).This is however different from the definition by the United Nations Framework Convention on Climate Change (UNFCCC). This is a more commonly adopted definition, where climate change is attributed directly or indirectly to human activity which alters the composition of the global atmosphere and in addition to natural climate variability observed over comparable time periods (UNFCCC, 1992).

A staggering logical agreement keeps up with that environmental change is expected fundamentally to artificial constraining. Regular elements, for example, volcanic emissions can make normal worldwide temperatures change over time yet can't make sense of the drawn out warming pattern throughout the course of recent years (NRC, 2012). As a matter of fact, a large portion of the noticed expansion in worldwide normal temperatures since the mid-twentieth century as indicated by the IPCC (2001) is because of the observed increase in anthropogenic ozone depleting substance (GHG) emissions. Green house emission is a beneficial natural phenomenon without which Earth's climate would be too cold for most living organisms to survive. It alludes to the catching of hotness by specific gases in the climate. These gases, fundamentally water fume, carbon dioxide, methane, nitrous oxide and ozone happen in just follow sums, however they block huge measures of hotness from getting away out into space, accordingly keeping the earth warm, Figure 2.1.

2.2.3 Effects of Greenhouse Gases (GHG)

Human activities have continued to propagate the concentrations of the heat-trapping greenhouse gases in the atmosphere. Temperatures are rising, ultraviolet radiation is increasing at the surface, and pollutant levels are increasing. Many of these changes can be traced to industrialization, deforestation, and other activities of a human population that is itself increasing at a very rapid rate (Henderson-Sellers, 2006).

Other examples would be excessive burning of fossil fuels like coal and oil which are the major factors producing carbon IV oxide. Deforestation also causes large amounts of carbon IV oxide (CO_2) in the atmosphere. Plants play an important role in regulating the climate as they absorb carbon dioxide from the air and release oxygen back into it. However, with the clearance of vast areas of vegetation around the world for farming, urban and infrastructure development, the stored carbon is released back into the atmosphere as CO_2. Other industrial and agricultural activities also contribute to the proliferation of greenhouse gases which cause climate change. Methane is emitted during the process of oil drilling, coal mining and from leaking gas pipelines; a large amount of nitrous oxide emission is attributed to fertilizer application. Chlorofluorocarbons (CFCs) are chiefly a result of various industrial processes and refrigeration. These gases are playing a negative part in increasing the havoc of global warming, as they are continuously causing an increase in the earth's temperature (Riphah, 2015).

Researchers have been taking inescapable estimations of Earth's surface air temperature since around 1880. These information have consistently improved and, today, temperatures are recorded by thermometers at a huge number of areas, both on the land and over the seas. Discoveries, as displayed that there was predictable expansion in the focus ozone harming substances (GHGs) in 2019 and 2020 (Friedlingstein, *et al*., 2020). Notwithstanding the circumstances of La Niña in the last option part of the year, in 2020, the mean temperature of the globe was one out of the three hottest on record (Figure 2.2). This reflected around 1.2 °C more than pre-modern levels. The most recent six years, from 2020, were the six hottest years recorded (IPCC 2020).

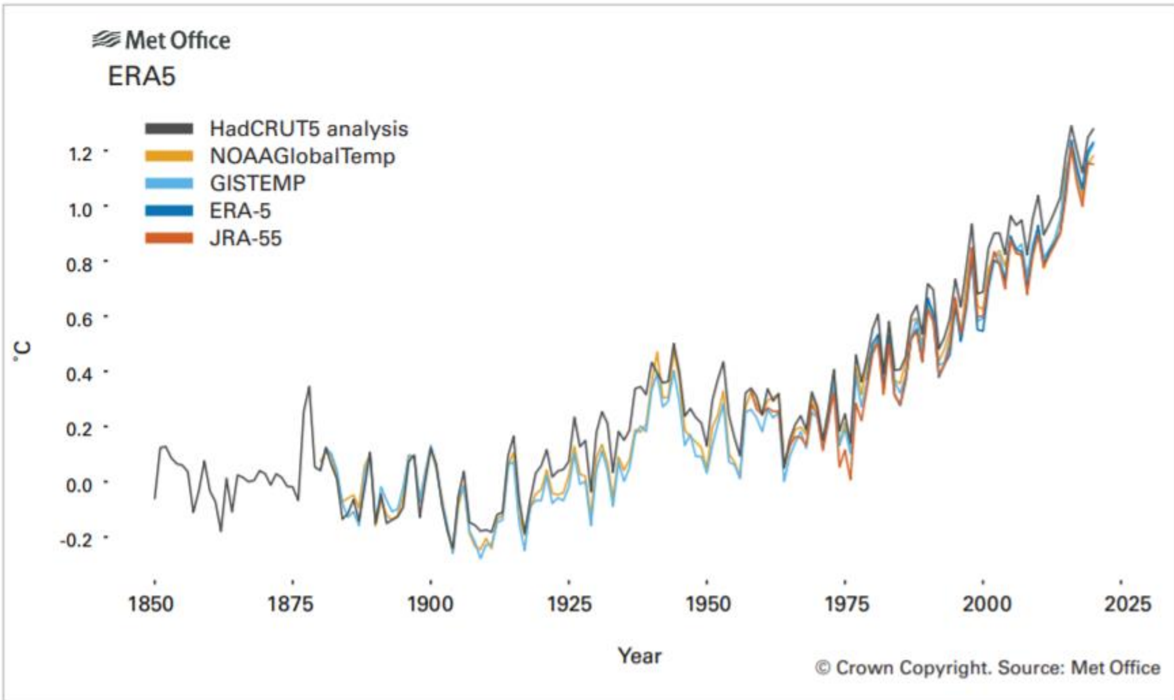


Figure 2.2: Global annual mean temperature difference from pre-industrial conditions (1850–1900) for five global temperature data sets. Source: Met Office, United Kingdom cited from WMO 2020

The increases that are seen in the centralizations of very much blended GHG since around 1750 are "unequivocally brought about by human exercises" IPCC (AR6). As announced in IPCC (AR5), fixations have reliably expanded in the air beginning around 2011, focuses have kept on expanding in the climate, achieving 410 ppm on yearly midpoints for "carbon dioxide (CO2), 1866 ppb for methane (CH4), and 332 ppb for nitrous oxide (N2O) in 2019". Record shows that there has been a progressively warming pattern in every one of the most recent forty years, with the succeeding many years hotter than the first ten years starting around 1850 (IPCC, 2020). In this same report, global surface temperature recorded during 2001-2020 (the initial twenty years of the 21st century) was 0.99 [0.84-1.10] °C higher than 1850-1900. The temperature was 1.09 [0.95 to 1.20] °C higher in 2011-2020 than 1850-1900, with land recorded a bigger increment (1.59 [1.34 to 1.83] °C) than over the sea (0.88 [0.68 to 1.01] °C). The assessed expansion in worldwide surface temperature since AR5 is primarily because of additional warming starting around 2003-2012 (+0.19 [0.16 to 0.22] °C) (Climate Change 2019). Moreover, strategic advances and new datasets contributed around 0.1ºC to the refreshed gauge of warming in AR6.

According to IPCC (2019), the global surface temperature has been on the increment quicker starting around 1970 a bigger number of times than in some other 50-year time frame for over at least 2000 years (high certainty). In the latest time frame temperatures (2011-2020) surpassed that of the latest multi-century warm period, around 6500 years prior [0.2°C to 1°C comparative with 1850-1900] (medium certainty). "Before that, the following latest warm period was around 125,000 years prior when the multi-century temperature [0.5°C to 1.5°C comparative with 1850-1900] covers the perceptions of the latest ten years (medium certainty)" (IPCC 2021).

increase in compound extreme events which are a mix of a few drivers or potentially dangers that add to cultural or ecological risks, for example simultaneous heatwaves, dry seasons, compound flooding (a tempest flood in mix with outrageous precipitation and additionally stream), compound fire weather patterns (i.e., a mix of warm, dry, and windy circumstances), or simultaneous limits at various areas, have likely been impacted by human since the 1950s (Climate Change and Land 201; WCRP Global Sea Level Budget Group, 2018).

In a near-surface (2m) average air temperature across the continent of Africa in 2020, according to WMO, 2020 was between 0.45 °C and 0.86 °C more than what was recorded in 1981–2010 average. This puts the 2020 ranking between 3rd -8th warmest period ever Fig 2.3. This depends on the set of data used though. The temperature recorded for Africa shows a faster warming than that of the global average temperature (land and ocean

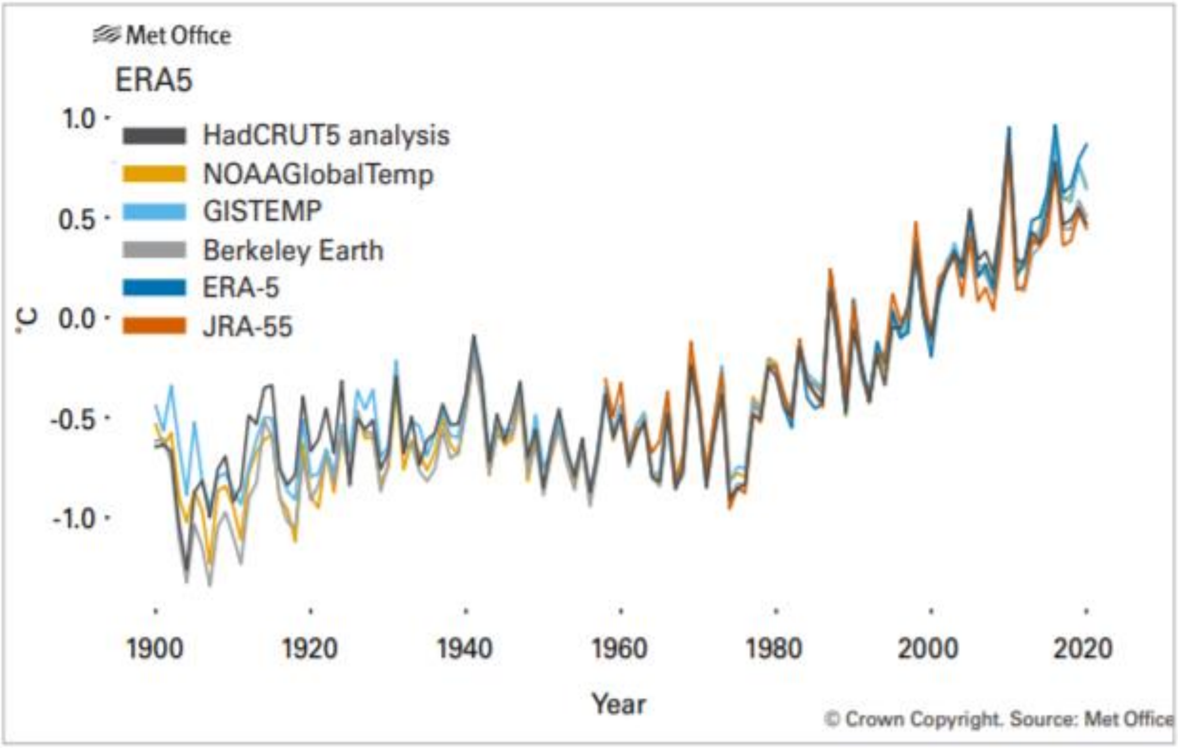


Figure 2.3: Area average land air temperature anomalies in °C relative to the 1981–2010 long term average for Africa (WMO Regional Association I) based on six temperature data sets. Source: Met Office, United Kingdom

combined). This findings of WMO, 2020 is consistent with the IPCC extraordinary report on climate change and land (IPCC 2019, based "on six informational collections - HadCRUT5, NOAAGlobalTemp, GISTEMP, Berkeley Earth, JRA-55 and ERA5 - approved sometimes with in situ perceptions"

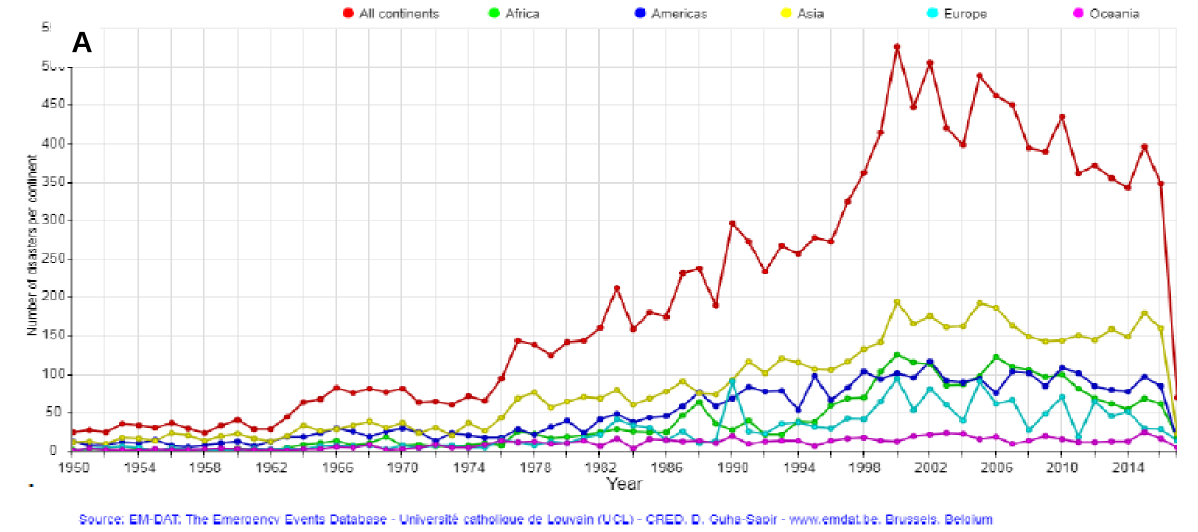
Run-off water is on the increment at high scopes and in a few wet tropics and diminishing over a significant part of the mid-scopes and dry tropics, for example, Limpopo Province, which is as of now water-stressed regions (Congedo and Macchi, 2016). There are changes in normal precipitation designs, for certain Mopani district encountering drying. More extraordinary and longer dry spells have become tenacious. Drought-affected areas are on the increment, and extreme precipitation events, which are probably resulting to increment in recurrence and power, will expand flood chance and many individuals are projected to be presented to expanded water pressure (Adeboyejo *et al.*, 2016). Coasts are presented to expanding chances, including waterfront disintegration, because of environmental change and ocean level ascent. These impacts will be exacerbated by expanding human-initiated pressures on beach front regions, especially coastal towns. A large number of individuals are projected to encounter extreme flooding consistently because of ocean level ascent by the 2080s. Those thickly populated and low-lying regions are particularly in danger, where versatile limit is somewhat poor and as of now face different difficulties like typhoons or neighborhood waterfront subsidence (United Nations Human Settlement, 2011).

2.2.4 Natural Hazards

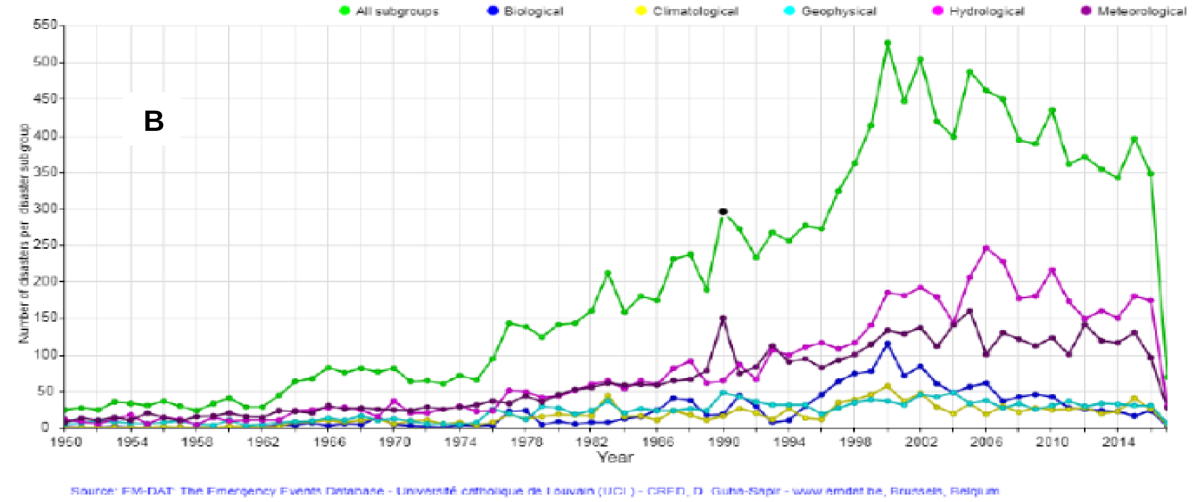
Globally, numerous natural hazards are significantly influencing the living states of people both in the rural and urban centres and transforming the condition of the natural environment. According to UNISDR (2009), tremendous changes have occurred in the status of the typical habitat, which is sometimes erratic. The unpredictable, extraordinary transformation from the normal state result in unpredicted natural hazards resulting in social, environmental and economic disturbances and devastations of living and environmental conditions of both rural and urban communities (UNISDR, 2009; IPCC, 2012; Brooks, 2003

These natural hazards can be classified as climatological (i.e. wild forest of land fires and drought), Geophysical (i.e. lava flow, earthquakes-ash fall, rockfall, ground movement and tsunami), Hydrological (includes riverine flood, flash floods, landslide), Meteorological (such as extreme temperatures- severe winter, cold wave and heatwaves storms-convective storms and tropical cyclone) are referred to as natural hazards. The attributes of hazards such as their magnitude or intensity, regularity, length, and degree vary concerning the geographical setting of that specific area (IPCC, 2007 cited in Khiwashaba, 2018).

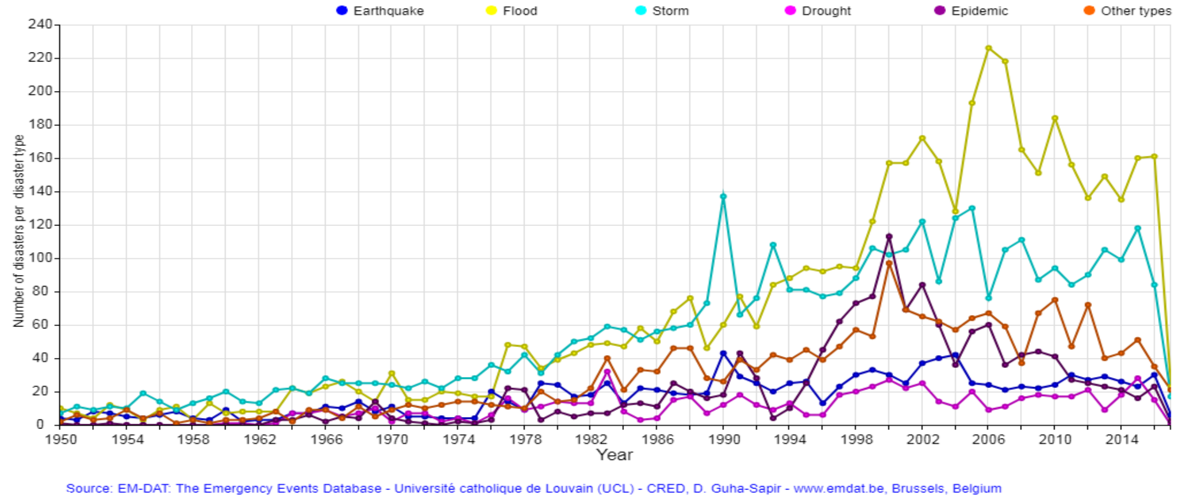
Man-made hazards in a particular geographical areas or settlements have the potentials to worsen the extent of natural hazards (Tsultrim, 2012; Novelo-Casanova, 2011). While the effects of natural hazards of any form on humans are referred to as natural disasters, their occurrence can either be spontaneous (fast), large-scale and violent and can equally be continuous and long-term (Pawson, 2011). Those events that are fast and in large scale frequently occasioned huge damage and devastation (for instance, severe storms, tornadoes and thunder storms).



A: Total number of natural hazards recorded across continents



B: Occ



C

Total number & typology of natural hazards recorded from 1950-2017

Fig. 2.4 A-C: Occurrence of hazards 1950-2017
Source: EM-DAT.bet (The International disasters database, 2017).

Several global communities across countries in different continents are affected by natural disasters. Records of the events are captured in the International disasters database (EM-DAT) that was created in 1988 by the Centre for Research on the Epidemiology of Disasters (CRED). The centre with the supports from the World Health Organisation (WHO) and the Belgian Government, harnessed data from sources like UN agencies, NGOs, Private sector, research-based institutions and media outfits.

Based on the records from EM-DAT (Fig 2.4 A-C) we captured the various disasters that occurred from 1950- 2017 across the continents with attention on those that were recorded in South Africa, including that of Limpopo province. The data base of *EM-DAT (The International disasters database, 2017)* as shown in Figure 2.4 indicates the trends of disasters in different continents of the world for over six decades (1950 to 2017). The records indicate an increasing trend in the occurrence of natural disasters through the years, with the year 2000 being the year that every continent experienced the peak of disasters. The succeeding years witnessed fluctuating trends but averagely on a decreasing trend till date. Figure 2.4A further depicts an increasing trends in disaster occurrence across the countries of Africa from the year 1950 through to 2006. The continents equally recorded a decreasing trend throughout post year 2006. The case of the Americas disasters occurrence was consistent with that of African continent with increasing trend from 1950 but experienced a downward but shifting undulating trend during the years 1986 to 1998, the scenario is similar to what is obtainable in Asian continent but the increasing trend in the occurrence remains till 2017.

Figure 2.4C classifies the global occurrence of natural disasters by typologies during the year 1950-2017. According to the table, the globe started experiencing biological disasters from the year 1964 with an increasing trend till year 2000 being the peak. The table further shows that the trend in the occurrence assumed a declining trend from the year 2000 till 2017. Similarly, Climatological events have been on the rise right from 1950 till 2017, while Geophysical events equally intensified during the 1950-2004 but maintained a declining trend henceforth till 2017. Likewise, hydrological disasters increased to 2017. Similarly, Meteorological events equally maintained increased trend during the year 1950 – 2004 but decreased during post 2004.

In Figure 2.4C, the occurrence of every event gradually increased, though fluctuated during 1950-1990 until it finally dropped in 2017. Floods being the most occurring disaster from 1950, it increased through to 2006 when it started to decline till 2017. Similar scenario was recorded for events such as Drought, but showing lower level of occurrence throughout the period of examination with slight increase until 1995. Table 2.1presents the Republic of

South Africa reported cases of natural hazards' occurrence according to the International disasters database in 2017.

Table 2.1: List of natural hazards that occured in South Africa 1920s - 2016

Climatological hazards	Geophysical hazards	Meteorological hazards	Hydrological hazards	Biological hazards
Drought 1964, 1980, 1982, 1986, 1988, 1991, 1995, 2004, and 2015	**Earthquakes** 1920, 1969, 1982, 1987, 1988, 1990, 1997, 2005, 2014	**Extreme temperatures** 1996, 2007, 2016	**Floods** 1959, 1968, 1974, 1977, 1978, 1981, 1987, 1988, 1993, 1994, 1995, 1996, 1997, 1999, 2000, 2001, 2002, 2003, 2004, 2006, 2007, 2008, 2009, 2011, 2012, 2014, 2016	**Epidemic** 2000, 2002, 2003, 2004, 2008
Wildfires 1991, 1998, 1999, 2000, 2001, 2002, 2007, 2008		**Storm** 1952, 1983, 1984, 1990,1993,1994, 1998, 1999, 2000, 2001, 2002, 2003, 2008, 2009, 2010, 2011, 2012, 2013, 2017	**Landslide** 1996	

Source: EM-DAT.bet (The International disasters database, 2017) - Universite Catholique de Louvain (UCL), (2017)

The above highlighted disasters have occurred in different magnitudes and extents and have significantly impacted on the ecosystem, human, livestocks, infrastructure and livelihoods in Limpopo province generally, as well as across small and medium sized towns. Paucity in access to potable water, low level of literacy, polluted and high infrastructure deficit in the district (Author's field survey, 2017; MDMIDP, 2016), suggest the district's population becoming increasingly vulnerable to the increasing incidences of extreme climate events, with increasing associated risk to life and livelihood (Musyoki, Thifhufhelwi and Murungweni, 2017; Nkondze *et al,* 2013).

2.2.5 The Concept of Vulnerability in Climate Change

The concept of vulnerability has been a familiar vocabulary for over 50 years, especially among disaster management experts, development and economics specialists, sociologists, anthropology professionals, geographers, health practitioners, global change, and environmental scientists (Bergstrand *et al.,* 2015; Cutter, 1996; Timmerman, 1981; O'Keefe *et al.,* 1976).

The term "vulnerability" has diversified meanings which are specific to disciplines, for instance in social work and psychology (Furedi, 2004). However, vulnerability is the key to understanding impacts in disaster studies, (Birkmann, 2006). Similarly, there is clearer understanding of natural, technological, social as well as intentional hazards since late 1970s as triggering a set of complex responses informed by the social, economic, cultural and physical vulnerability of society (Hewitt, 1983). Hence, the realization is obviously increasing of the need to understand and reduce human vulnerability to disasters in its many different forms.

Vulnerability of human and regular frameworks to environmental change and fluctuation and their capacity to acclimate to environmental change peril is as of now a field of try that is getting consideration around the world. It fills in as a combining point for improvement specialists, environment researchers, organizers, disaster managers, and a large group of others. This has achieved unique theoretical models for the investigation of weakness and variation, through resolving comparative issues and cycles, yet with various vocabularies. As the collection of writing develops on vulnerability, and transformation, it achieves a confounding arrangement of phrasings with hazy connections. For instance, similar terms might be utilized, however addressing various ramifications, particularly when the setting of use is unique (IPCC, 2001; Adger, *et al*., 2002; Burton *et al*., 2002).

Thus, what is apparently clear about vulnerability is variability in geography, time, and space and among social groups (Cutter *et al.,* 2003). This presents to scholars and researchers alike, the essential questions underlying vulnerability analysis which include how societies are affected by natural hazards, particularly the critical processes and outcomes of hazards risks and disasters in society (Collins *et al.,* 2015). Hazards can only be mitigated but cannot be totally abolished or regulated (Solangaarachchi *et al.,* 2012). However, through what Timberlake (1984) refers to as a "shift from the hazard to the vulnerability paradigm", reduction of the hazard-related risks can be achieved by human efforts. Record has it however, that many regions till today have paucity of efforts for profiling the bottom-up vulnerability of socio economically poor hazard-affected places. There are various profiling factors which have already been proved to influence vulnerability at different geographical and socio-political scales and contexts; these are noted to be complex as well as multi-dimensional and differential in nature (Birkmann, 2006; Solangaarachchi *et al.,* 2012). Apart from being spatially different between and within social groups, vulnerability is equally scale-related, with respect to spatiotemporal and units of analysis. These include individuals, communities or systems as well as the dynamic characteristics of those influencing forces which drive changes in vulnerability over time (Fekete *et al.,* 2009; Tapsell *et al.,* 2010).

Despite the divergence in the definitions of vulnerability in climate change literature, two distinct classifications stand out. On one hand, Jones and Boer (2003) identify vulnerability in terms of the magnitude of (likely) damage caused to a person or system by a climate-related event; they emphasize hazards and their impacts, with the mediating role of the human system reducing the outcome of hazardous events. The focus here is more on the hazard rather than on the ability of people or systems to cope. The hazard and impact approach emphasizes the vulnerability of the human system as a function of the kind of physical hazard(s), how frequent the occurrence of the event is, the extent of its exposure, and the sensitivity of such a system to the impacts of the hazard. This appears in the IPCC Third Assessment Report which describes vulnerability as a product of hazard, exposure, and sensitivity. This clearly implies a physical or biological vulnerability. The work of Jones and Boer (2003) thus emphasizes the indicators of outcomes rather than that of the state of a system which precedes the incidence of the hazard.

Because of the dynamism in the vulnerability conceptualizations, three basic forms can be identified: (i) "vulnerability as hazard exposure; (ii) vulnerability as social response; and (iii) "vulnerability of places" (Cutter, 1996); these reflect the "biophysical, social and spatially expressed vulnerabilities" (Emmanuel, Bernard, Andrew 2017). Borrowing from the conceptualization by the IPCC, vulnerability is a function of the character, magnitude and rate of climate change and the variation to which a system is *exposed*, its *sensitivity* and its *adaptive capacity* (IPCC, 2007). In other words, the key elements of exposure, sensitivity and adaptability are imperative for understanding the concept of vulnerability. This clarification is of great importance, for in the past climate change vulnerability was narrowly understood as exposure to climate hazards and in some literature interchanged with sensitivity. But today as posited by Bachofen and Cameron (2011), a more complete picture of vulnerability, encompassing exposure to risk; sensitivity to these risks; and adaptive capacity is informing our understanding of climate change impacts and shaping policy approaches. These three dimensions to vulnerability require proper clarification to afford a holistic understanding of the concept of vulnerability in climate change. These include:

a. Exposure is the presence of individuals, vocations, species or biological systems, natural capacities, administrations, and assets, framework, or financial, social or social resources in spots and settings that could be unfavorably impacted by environmental change
b. Sensitivity addresses how much a framework is impacted, directly or indirectly, positively or negatively by climate change

c. Adaptive capacity is the competence of a system to adjust to environmental change, to direct expected harms, to make the most of chances, or to adapt to the consequences (IPCC 2014).

In view of this background, this study will adopt the UN approach for climate change vulnerability assessment, where climate change vulnerability is presented as an outcome of the interrelationships among the above components (hazard exposure, sensitivity and adaptive capacity).

2.2.6 Urbanization and Sustainable Development

Urbanization and sustainability are two independent, well-known concepts each with a variety of definitions. The relationships between them have been a subject of many discussions and the focus of many studies. The current study examines and clarifies the meaning of urbanization and its implications for our contemporary world, before relating it with the concept of sustainability.

2.2.6.1 The Concept of Urbanization

Urbanization is not a new concept, but there is considerable confusion over what it really means. For instance, to say a country or region is urbanizing implies that it is becoming more urban which seems quite simple enough, except that there is no clear definition of an urban area. Ofem (2012) logically describes urbanization as a process that agglomerates people, and their socio-economic activities in settlements referred to as urban centres. The issue anyway is that there is no worldwide agreement on the best way to the determination of the limits of metropolitan regions or to distinguish when a settlement is 'urban' (McGranahan and Satterthwaite, 2014).

Urban areas are defined with a variety of criteria including population size, population density, administrative or political boundaries, or economic function (Cohen 2006) and these definitions vary with different countries. For example in Sweden with respect to population, the most widely adopted criterion is that, as few as 200 people can form an urban settlement. However, it is a minimum of 40,000 in Mali (McGranahan and Satterthwaite, 2014), at least 5,000 in Botswana (United Nations, 2002) and 50,000 in the United States (USDA, 2008), 20,000 in Nigeria, (Babalola, 2012and Aluko, 2010). In South Africa, before 1996, regardless of physical features, urban area are defined as areas with local authorities. In 2001, smallholdings, mining towns and residential peri-urban areas were covered, considering spatial forms and land use (StatsSA, 2001)

When treated simply as a demographic phenomenon, urbanization is often erroneously used synonymously with population growth. For instance, conceiving it as “an increase in the extent and density of urban areas" (Uttara, *et al.,* 2012) or "as the increasing number of people living in urban areas" can be misleading. When urban populations grow, this is not really urbanization. As rightly pointed out by McGranahan and Satterthwaite (2014), only about half of global urban population growth can be ascribed to the increasing share of the population that is urban (i.e. to urbanization rigorously defined); the other half are the result of natural population growth. It is even more confusing when urbanization refers to the expansion of urban land cover because the rate at which urban land cover is expanding is about three times the rate at which the urban share is growing (McGranahan and Satterthwaite, 2014).

Hence the question remains, what is urbanization? Amao (2012) sees it as population increase and migration from rural to urban areas and growth-centres; it is generally accepted that urbanization involves the shift in population from rural to urban settlements (McGranahan and Satterthwaite, 2014). An urban centre in this context however, refers not just to an area with rapidly increasing population, but also one characterized by the processes of modernization, industrialization and development of space economy. Thus, urbanization can be said to be characterized by such self-evident factors as;

a. Mobility of population from agricultural to nonagricultural areas;
b. Concentration of populace in a new place of habitation or a place characterized by a new way of life; and
c. Variety of professions other than agriculture, and continued mobility in these occupations, mobility both - vertical and horizontal;a mode of habitation and non-agricultural (i.e., industrial, commercial etc.) pattern of economy.

Hence, the degree of urbanization is not merely judged by the percentage of the total population living in an urban community, or the number of urban places in any political or administrative territory, but also by the influence which an urban place or community exerts on the cultural, political and economic life of its own hinterland and abroad. Soubbotina (2000) aptly summarizes urbanization as a course of relative growth in a country's urban populace joined by a much quicker increase in the monetary, political, and social significance of urban areas comparative with rustic regions.

2.2.7 Urbanization Trends

Recently, there has been a tremendous growth in many urban areas as a result of population increase and transformation in the world's economy. Around 3 billion people or nearly half of the world's total population live in urban centre (United Nations, 2004; Cohen, 2006; and UNCHS, 2007). Globally, more people live in urban areas than in rural areas with 54% of the world's population residing in urban areas in 2014. In 1950, 30% of thr world population was urban, by 2050, 66% of this was projected to be urban (UN, 2014). In most countries, these urbanisation trends are natural cconsequences andstimli of economic development and industrialisation and reflect economic success. Thus, as measured by the share of a country's urban population in its total population,the level of urbanization, is highest in the most developed, high-income countries and lowest in the least developed, low-income countries (Soubbotina, 2000).

People concentrate in urban areas, because this is where new investments and new jobs are created. Further, urbanisation reflects the increasing proportion of GDP generated by industry and services and the increasing proportion of the labour force working in industries and services. The world's most urbanised cities are undoubtedly the most prosperous; all the wealthiest nations are highly urbanized and most of the poor countries are predominantly rural. All the most successful economies in Africa, Asia and Latin America are urbanizing. There is considerable theory and empirical evidence supporting the view that urbanization is integral to economic growth (Spence, Annez and Buckley, 2009; Strange 2008). Therefore, the fact that urbanization is economically advantageous is therefore not in question.

It is not all facets of urbanization that are economically beneficial and urban crowding or congestion equally have their consequences. Urbanization has always and continues to raise a number of environmental concerns. From inception, the 19th century industrialization and urbanisation in Europe and North America brought along unhealthy environmental conditions of cities which promoted the spread of diseases such as cholera and other waterborne pandemics. Moreover, ambient urban air pollution became the scourge of many cities during this period. Today, deforestation, noise, water pollution, erosion, poor air quality, the urban heat island effect, and climate change are all issues amplified by urbanization with serious implications for health and livability. Added to this is the rapid and unprecedented rate in urbanization which has become alarming. Recently the number of megacities with populations over 10 million grew from 2 in 1950 to 10 in 1990 to 23 in 2010, with their share of the world's urban population growing from 3.2 per cent to 6.7% to 10.3% over this period (UN Population Division, 2014).

2.2.7.1 Urbanisation and global environmental change

The process of urbanisation and the anthropogenic global environmental change in recent times has received extensive documentation and these trends are acknowledged to be in parallel, and intractably interwoven, a reality that the majority of scientists recently faced as development cannot be separated from its attending environmental impacts (Conradie, 2012). Urban areas have increasingly become more important than the world's social, economic, cultural, political and environmental spheres (Sanchez-Rodriquez *et al.*, 2005). Half of the world's populace of approximately 6.4 billion human beings presently lives in city regions, as compared to much less than 15% in 1900 and 30% in 50 years ago (UN population Division, 2008; Satterwaite, 2008; 2009). The world's urban population has increased more than tenfolds during the twentieth century. But unlike what was obtainable at the beginning of the twentieth century, the most rapid urban change is currently taking place in middle- and low-income countries. These countries host closely three out of four of the world's urbanized population (Satterthwaite, 1997; De-Sherbinin *et al.*, 2007; Bazrkar *et al.,* 2015).

This might also additionally account for why towns consume as high as eighty percent of energy globally and account for a more or less same share (of approximately 70 to eighty percent) of Global Greenhouse Gas (GHG) emissions (World Bank Report, 2010). The record in addition showed that the GHG emissions could be driven less by industries, but pushed much by energy that are required for lighting, heating, and cooling driven by population increase. The International Energy Agency (IEA, 2008) estimates that city regions presently account for over 67% of energy-associated international greenhouse gases, that's anticipated to rise to 74% by year 2030. When taken into consideration as regards to climate change, the roles performed through city regions is huge being the host of the population, in addition to the monetary activities, cause them to a maximum exposure and susceptible to the growing share of threat from intense climate events (Bazrkar *et al*. 2015).

2.2.8: The Concept of Sustainable Development

The concept of sustainability is a relatively new idea unlike the subject of urbanization. It can be traced to the 1980s when the United Nations in 1983, tasked former Norwegian Prime Minister, Gro Harlem Brundtland to run the new World Commission on Environment and Development (United Nations, 2013). Often tagged as the Bruntland Commission, it eventually published its report in 1987, titled "Our Common Future" in an effort to hyperlink the issues of financial improvement and environmental stability. In doing so, the record provided the broadly noted definition of sustainable development as achieving "the desires of the community with out compromising the posibility of future generations to fulfill their personal desires" (Cerin, 2006 and Dernbach, 2003). Sustainability in different phrases is meeting the desires of the existing with out compromising the ability of coming generations to fulfill their personal desires. Several definitions of sustainability exist, it essential to note. This is confirmed through the studies of Parkins (2000) which highlighted over two hundred definitions of sustainability.

Sustainability is thus a terminology used by many individuals and organisations to put in place their policies, programmes and projects within their areas of activities. Sustainability can be conceptualized on the tripod of environmental sustainability, economic sustainability and social sustainability. Only when all three pillars are balanced and effectively integrated can true sustainability be achieved, as shown in Figure 2.5. For instance, achieving the Sustainability requires the balance of environmental, economic and social factors. Practically

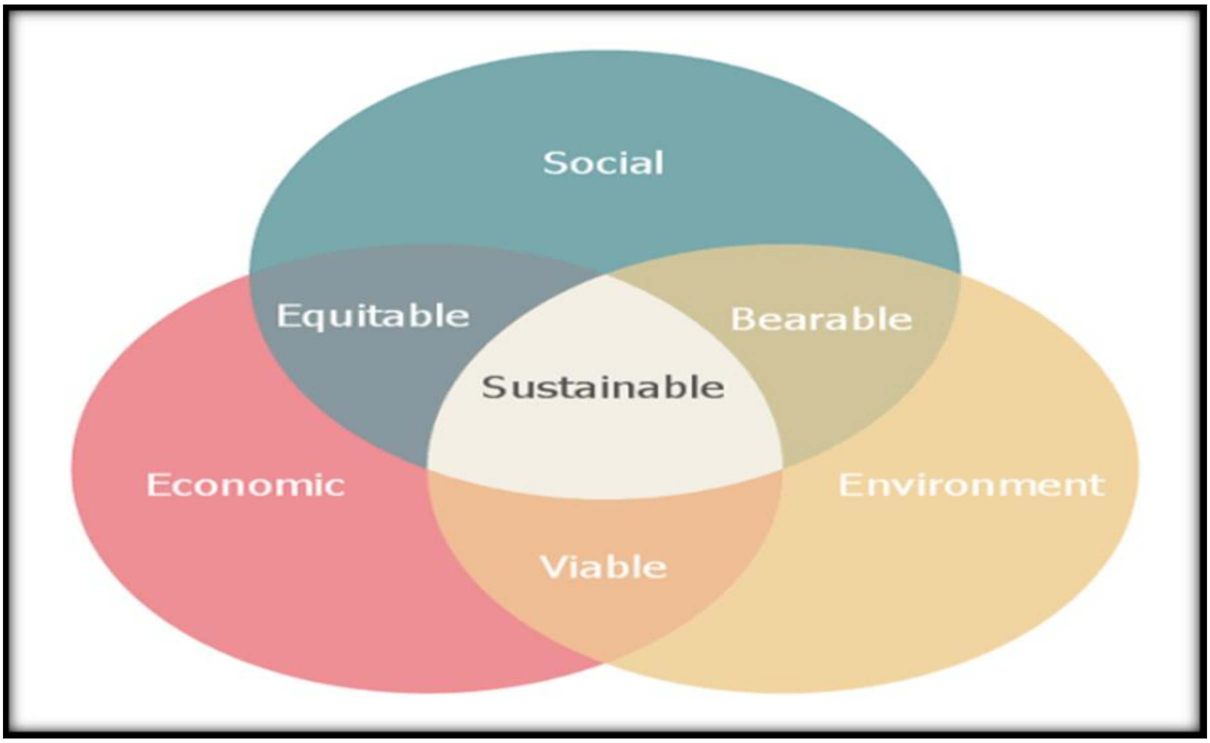


Figure 2.5: Sustainable Development Model
Source: Adams (2006)

though, trade-offs are sometimes unavoidable with one or two objectives capable of being maximized at a point in time. As Norgaard (1994) points out, it is impossible to define sustainable development in an operational manner in the detail and with the level of control presumed in the logic of modernity. Despite these complications, the three principles outlined are logical, and drawing on the principles, the core themes of sustainability are identifiable and the explanation below highlights it lucidly (Harris, 2003).

First, financial sustainability calls for that unique types of capital that make economic production feasible should be maintained or augmented. These consist of manufactured capital, natural capital, human capital, and social capital. Some substitutability can be feasible amongst those types of capital, however in broad terms; they're complementary so the preservation of all 4 is critical over the lengthy term. Next, the conservation of ecosystems and herbal assets is critical for sustainable economic production and intergenerational equity. From an ecological perspective, both human population and total resource demand must be limited in scale and the integrity of ecosystems and diversity of species must be maintained. Market mechanisms frequently do now no longer function successfully to preserve this natural capital however generally tend to burn up and degrade it. Lastly, social equity, the fulfilment of primary fitness and educational needs, and participatory democracy are critical factors of development, and are interrelated with environmental sustainability. Taken together, those observations crystalize the essence of sustainability which seems to be the antithesis of urbanization issues and may be compromised with the aid of using the extreme events of climate change. This is possible through accelerated exposure, excessive sensitivity and decreased adaptivity which in the end bring about excessive vulnerability amongst households.

2.2.9 Urbanisation and Climate Change and Sustainable Cities

Urbanisation, cities, and climate change are intricately connected. Cities, without a doubt, have the greater propensity to contribute to GHGs that lead to climate change. Peoples' activities generate Greenhouse Gases – automobiles and industries use fossil fuels, buildings are built in cities and the construction industry has a huge impact on the environment and climate (Chan, 2017). The Urban Heat Island effect occurs in cities, particularly the city centres which are the hottest spots in the cities (Huang and Lu, 2015) and all these contribute one way or another to global warming. As noted by Chan *et al.,* (2016), if cities are unsustainable, they contribute more towards global warming as cities themselves warm up. The ecological habitat is greatly challenged because the urbanized landscape profoundly affects the related ecological processes and services (Dempsey *et al.* 2009). Hence, sustainability is no longer a luxury but a basic need if cities are to survive and flourish.

2.2.9.1 Urbanisation and climate change

The relationship between urbanisation and sustainability has long been the focus of numerous studies (Roders, 2013; Gohar, 2016: Goel, R.K. and Vishnoi, S., 2022). Some scholars regard urban sustainability as an oxymoron while others believe that urbanization is the key to regional and global sustainability. For example, according to (Wu, 2010), cities are not necessarily inimical to sustainability but can be a positive driving force towards it. This has led to a paradigm shift towards the concept of sustainable cities. As pointed out by McGranahan and Satterthwaite (2014), there are environmental advantages to be gained from urban agglomeration and compact urban forms, but some of the most important urban advantages require urban infrastructure, policies and planning which support the transition to more resilient, healthy and sustainable cities.

The South Africa ecosystem has in the recent times experienced shifts in vegetation and biodiversity loss and the transformation according to Scheiter *et al*., (2018) is linked to land use change out of other factors. These are significantly influenced and driven by increased human population, which resultantly elevates the consumption of land resources. Human activities in Limpopo oprovince, such as grazing, firewood collection, road infrastructure, wide spread of mechanized farming (Lehohla, 2012), have resulted in an increasing demand for these resources, leading to conversion of natural ecosystems into crop land and impervious land uses particularly in towns.

Population increase in this region suggest vegetation structure and functions transformation and biodiversity loss, enhancing soil erosion (floods) and heat episode (Twine and Holdo, 2016), because of land surface exposure to climatic factors. These developments have influenced the urban climate system in Mopani District to experience a warmer and more polluted urban climate than the rural counterpart. This is because urbanization is characterized by removal and invasion of natural vegetation with non-permeable and non- transpiring surfaces such as concretes, asphalt and metal, complemented by high level of anthropogenic heating that drives isolated heat episodes within the boundaries of the towns. This has the potentials of changing the local climate forcing field to redistribute wind, cloud and rainfall (Zhan *et al,.* 2013). The study will further investigate the trend of urban land use change in the study areas based on land cover data available during 1987-2017 using GIS application while establishing its link with urbanisation and changing climate.

2.2.9.2 Sustainable cities

Although researchers have often used the term sustainable city generously with various interpretations, there is no universally acceptable definition of the term. Generally, many go by the Brundlandt (1987) definition of sustainable development this means that a sustainable city should also meet the needs of the present city inhabitants without sacrificing the ability of future generations to meet their own needs. Hence, a sustainable city has the minimum environmental impact and is managed by people dedicated to the minimization of required inputs of energy, water and food, and waste output of heat as well as minimal pollution (Chan, 2017). This has led to several approaches in urban planning which promote innovative concepts of future development of world cities. Such new urban concepts include new urbanism, green urbanism, bio-urbanism or organic urbanism, biophilic cities, smart cities, eco-cities and green cities (Manea *et al.,* 2015). These approaches are not mutually exclusive and are basically aimed at achieving sustainable cities.

Essentially, the sustainable city would generate the smallest possible ecological footprint and produce the lowest amount of environmental pollution, to efficiently use land; compost used materials, recycle or convert waste to energy (Chan, 2017). It would also effectively reduce its overall contribution to climate change in terms of greenhouse gases. Many cities are setting the pace in actualizing the idea of sustainability, while others especially those in developing countries continue to show poor sustainable activities. Examples of some of the most sustainable cities are Vancouver (Canada), San Francisco (USA), Oslo (Norway), Curitiba (Brazil), Eko Atlantic in Lagos, Nigeria, Hope and King City in Ghana, Vision City in Kigali, Rwanda and Waterfall City in South Africa. These cities achieve sustainability from using renewable energy to committed cut-backs on greenhouse gases emissions, and implementing sustainable initiatives (d'Estries, 2011). Summarily, by getting city improvement right, towns can create jobs and provide higher livelihoods, boom financial growth and enhance social inclusion. The decoupling of residing requirements and financial boom from environmentally useful resource use may be promoted, even as neighborhood and nearby ecosystems may be protected, and each city and rural poverty and pollutants may be mitigated (UN-Habitat, 2015). This is the essence of sustainable improvement because it affects city model and town resilience.

2.3 Theoretical Framework

Here, several theories that will aid the discussion and understanding of climate change are examined. These include climate change theories, the Malthusian theory of population growth, and disaster vulnerability theories like the risk-hazard model and the pressure-and-release model.

2.3.1Climate Change Theories

Ever since climate change came to global attention, it has always been a subject of debate. Various scholars over the years have differing stands for and against climate change, its causes and extent (Heyward, M., 2007; Parmesan, C. and Yohe, G., 2003; Perkins, 2018). There have been various theories provided to explain the phenomenon. Bast (2010) highlighted seven of these climate change theories. However, four prominent ones which enjoy considerable support in the scientific community will be examined here to provide further insight into the intricacies of climate change.

2.3.1.1Anthropogenic global warming

The first and most prominent principle of climate change contends that human emissions of greenhouse gases, mainly carbon dioxide (CO2), methane, and nitrous oxide, are inflicting a catastrophic upward push in worldwide temperatures. The mechanism wherein this occurs is referred to as the enhanced greenhouse effect. This principle is referred to as Anthropogenic Global Warming (AGW) and is the principle of changing climate which maximum human beings are acquainted with. It holds that man-made greenhouse gases, in general carbon dioxide (CO2), are the important reason of the worldwide warming which has took place at some point of the beyond 50 years. Backers of the AGW principle contend that the 0.7°C warming of the beyond century-and-a-1/2 of and 0.5°C of the beyond 30 years is often or absolutely as a result of man-made greenhouse gases (Bast, 2010). with use of computer system models primarily based totally on physical principles, theories, and assumptions to expect that a doubling of CO2 in the environment could cause Earth's temperature to upward thrust a further 3.0°C (5.4°F) by 2100. Proponents of the AGW concept consider that man-made CO2 is liable for floods, droughts, extreme weather, crop failures, species extinctions, unfold of diseases, ocean coral bleaching, famines, and literally loads of different catastrophes. All those failures becomes greater common and greater extreme as temperatures hold to upward thrust. According to this concept, not anything much less than massive and fast reductions in human emissions will keep the planet from those catastrophic events.

2.3.1.2 Bio-thermostat

The second principle of changing climate holds that bad feedbacks from organic and chemical procedures totally or nearly totally offset anything positive feedbacks is probably resulting from growing CO2. These procedures act as an "international bio-thermostat", preserving temperatures in equilibrium. The scientific literature consists of proof of at least eight such feedbacks, now no longer counting cloud formation that is dealt with as a separate principle. A prominent one is carbon sequestration (Bast, 2010). This proposes that productiveness of maximum vegetation is stronger due to the fact that CO2 is the number one raw fabric used by vegetation to construct their tissue. The greater the CO2 that may be in the air, the better flowers grow, and the greater CO2 they do away with from the air and store of their leaves, branches, trunks, and roots, a set of approaches called "sequestration." Higher temperatures have a tendency to growth carbon sequestration rates. Carbonyl sulfide (COS), a biologically produced sulfur gas emitted from soils is every other. This makes its way into the stratosphere in which it is converted into sulfate aerosol particles, which mirror sun radiation returned into space, generating a cooling impact at the Earth's climate. COS will increase as flora responds to the continued upward thrust in the CO2 content material of the air, which means it is another bad feedback. Other materials consist of Iodocompounds along with Dimethyl Sulfide (DMS) and Biosols all which can be clearly produced and which offset the feedbacks of CO_2.

2.3.1.3 Cloud formation and albedo

The third principle of climate change submits that modifications in the formation and albedo of clouds create poor feedback which cancels out all or almost all the warming impact of better degrees of CO2. This principle is primarily based totally in large part on observational facts stated through a sequence of researchers, in preference to computer models as in the case of the AGW principle. Richard Lindzen, a professor of meteorology at Massachusetts Institute of Technology (MIT) is a main proponent of this principle. Lindzen et al., (2001) tested higher degree cloudiness facts and sea surface air temperature (SST) data and determined a robust inverse relationship among higher-degree cloud place and the imply SST of cloudy areas of the eastern part of the western Pacific. The place of cirrus cloud coverage reduced through approximately 22% for every 1°C boom in SST. The study concluded that “the cloudy-moist region appears to act as an infrared adaptive iris that opens up and closes down the regions free of upper-level clouds, which more effectively permit infrared cooling, in such a manner as to resist changes in tropical surface air temperature.” The sensitivity of this negative feedback was calculated by Lindzen *et al., 2001* to be so substantial that it would “more than cancel all the positive feedbacks in the more sensitive current climate models.”

2.3.1.4 Human forcing besides greenhouse gases

According to this theory, human greatest influence on climate might not necessarily be the emission of greenhouse gas emissions, but the actual transformation of the surface of the Earth through its activities such as clearing of forests, regenerating deserts through irrigation and the building of cities. In his words, Pielke (2009) describes the theory as follows “Although the natural causes of changing climate and its variations are certainly important, human has significant influences with a diverse range of first-order climate forcing, including, but not limited to, their input of carbon dioxide (CO_2).” These man-made forces that are not greenhouse gases include urban heat islands (UHI). Because of cities’ greater concentrations of energy-generating equipments, gardgets, vehicles and large amounts of concrete, asphalt, and other building and road materials which absorb solar energy and then re-emit thermal energy, a situation called urban heat islands (UHI) results which put cities warmer than their surrounding hinterland. Evidences have shown that the climate system in cities is warming faster than the rural areas counterpart, which has vegetation as buffer, water bodies and less built-up areas. It is submitted that the larger the city, the greater is its warming potential. The centres of megacities may be typically 7-10^{o}C warmer than rural areas, while that of medium-sized cities are typically 4-6^{o}C warmer than rural areas and the centres of small cities typically 1-3^{o}C warmer than rural areas (Chan, 2017). Other significant forcing that is identified includes deforestation, aerosols and ozone, coastal development and jet contrails. These forces are wit attendant local and regional consequences on climate that are equal to or even more than that of anthropogenic greenhouse gas emissions. This leaves little or no warming left to be explained by the AGW theory.

As can be observed, these theories reveal the conflicting notions about climate change. But whatever position is held, the fact remains that the earth temperatures are rising, and two of them provide reasonable explanations for the phenomenon. The science of climate change is still an ambiguous one to a large extent. As observed by Bast (2010), It possibly will now no longer be illuminated a good deal with the aid of using mathematical models which can't generate dependable forecasts of a framework that even proponents of the anthropogenic global warming principle admit is evidently chaotic. It is not possible to competently measure the extent or amount of data essential to feed the models, and there are even uncertainties about which variables have to be included. But over time, the technological know-how have a look at climate change becomes somewhat more exact, primarily based totally on examination of the historical facts and newly assessed empirical evidence.

.2.3.1.5 Disaster vulnerability theory

Vulnerability is an important concept for understanding the human-nature relationship, and owing to its elusive nature different frameworks have been generated with which to analyze and assess the vulnerability of systems. Two archetypal reduced-form models have informed vulnerability analysis: the risk-hazard (RH) and pressure-and-release (PAR) models.

2.3.1.5.1 The Risk-Hazard- Model (RH)

According to Bernardo (2010), the Risk-Hazard-Model was conceptualized by Burton *et al*., (1978) with respect to vulnerability, following White (1942) as one of the first to address disasters from a social science lens. Challenging the technological approach to flood hazards and control, White (1942), emphasized the identification of the responsible factors for people occupying dangerous site in the first instance. The collaboration between White (1942), and Burton *et al.,* (1978) occasioned the birth of the risk-hazard approach to understanding vulnerability. Figure 2.4 illustrates the Risk Hazard Model (Turner *et al.,* 2003).

In addition to this the Intergovernmental Panel on Climate Change (IPCC), attributed vulnerability as a characteristic of three dimensions: exposure, sensitivity, and adaptive capacity. Early scholars of disaster and threat research targeted at the exposure element of vulnerability (Reyes, 2010). They had been especially interested by figuring out who's exposed and to what?, and exposure is usually measured through calculating the magnitude, frequency, and spatial extent of a threat (Ciurean *et al*., 2013). From Figure 2.6, it's far proven that the RH is a characteristic of exposure to the hazard event and the dose-response (sensitivity) of the entity exposed.

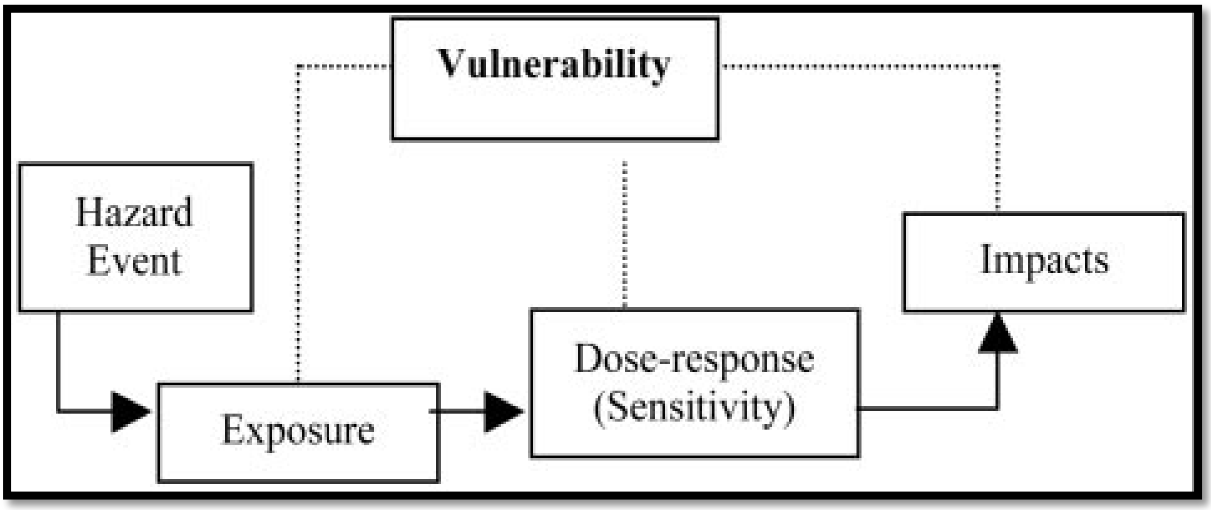


Figure. 2.6: Risk Hazard Model (Source: Turner *et al.,* (2003)).

Past quantitative applications of this model in environmental and climate impact assessment generally emphasized exposure and sensitivity to perturbations and stressors (Warrick, 1980), and worked from the hazard to the impacts. Vulnerability, in terms of the risk-hazard approach, is described as the result of the mixture of hazard risk and the possible for loss to the people that are exposed to the risk. Though the approach has been subject of crititism for several reasons, such as:

i. The ways the systems in question magnify or satisfy the influence of the hazard
ii. The distinctions between the exposed subsystems and mechanism that brought about the major differences in the resultant effects of the hazards
iii. Lack of attention on the role of political economy, especially social structures and institutions, in shaping differential exposure and consequences (Turner *et al.,* 2003).

An attempt to address these fallibilities led to the innovation of the pressure and release model that is subsequently addressed.

2.3.1.5.2 The Pressure and Release Models

This model is an improved version of RH model proposed by Blaikie *et al.,* (1994). Its idea was to understand the interlinkages (nexus) between advancement and the incidence of susceptibility. It is equally an effort attempted to figure out the shortcomings of the risk-hazard approach. Here risk is explicitly defined as a function of the perturbation, stressor, or stress and the vulnerability of the exposed unit (Turner *et al.,* 2003). The model directs attention to the conditions that make exposure unsafe, leading to vulnerability and to the causes creating these conditions. In the Pressure and Release (PAR) framework, risk is defined as a function of a natural hazard and social vulnerability. The natural hazard acting on a vulnerable population is just the trigger event which causes a disaster. Thus, the PAR framework does not emphasize the hazard itself, but the social, political, historical, and cultural processes that create unsafe conditions for people. While the risk-hazard approach views vulnerability as an outcome, the PAR framework views vulnerability as a dynamic process controlled by socio-economic forces (See Figure 2.7).

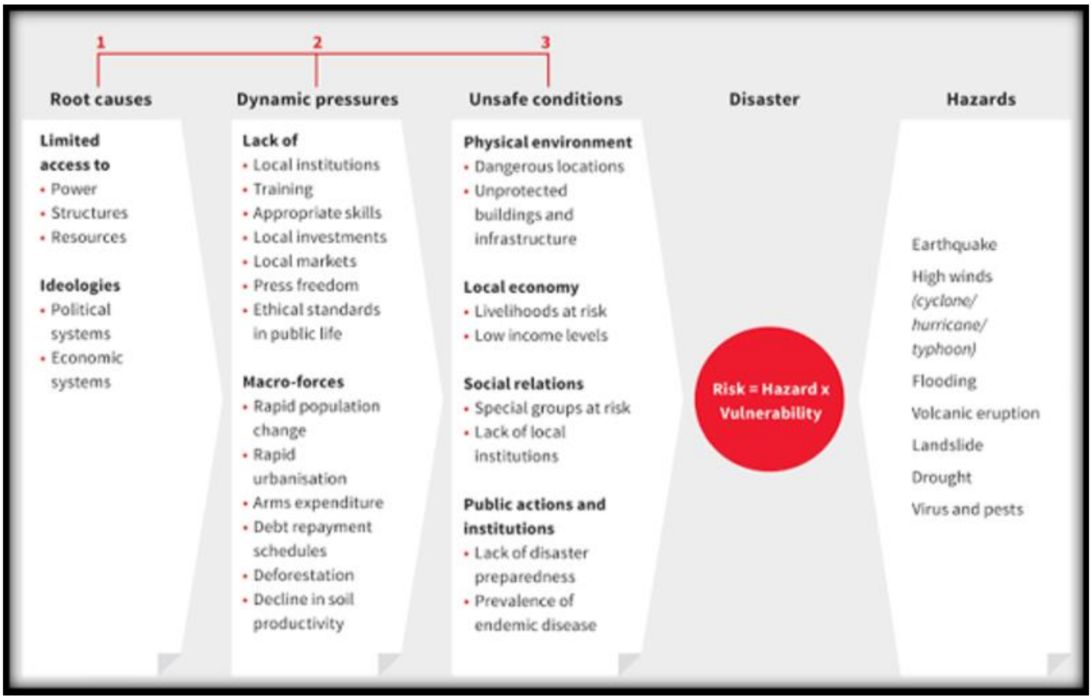


Figure 2.7: Pressure and Release Framework Source: Wisner *et al.,* (2004)

The PAR model operates at different spatial (place, region, world), functional and temporal scales and considers the interaction of the multiple perturbations and stressor/stresses (Wisner *et al.,* 2004). Hazards are regarded as being influenced from inside and outside of the analyzed system; however, due to their character they are commonly considered site-specific. Thus, given their complexity, hazards are located within and beyond the place of assessment. The model emphasizes the underlying driving forces of vulnerability and the conditions existent in a system which contributes to disaster situations when a hazard occurs. Vulnerability is associated with these conditions at three progressive levels:

a) Root causes, which can be, for example, limited access to power, structures or resources; or related to political ideologies or economic systems;
b) Dynamic pressures represented, for example, by demographic or social changes in time and space (e.g. rapid population decrease, rapid urbanization, lack of local institutions, appropriate skills or training) and
c) Unsafe conditions posed by the physical environment (e.g. unprotected buildings and infrastructure, dangerous slopes) or socio-economic context (e.g. lack of local institutions, prevalence of endemic diseases).

The PAR framework has been criticized as being insufficient to address the concerns of sustainability science which consider not just the vulnerability of people, but the vulnerability of the environment as well (Turner *et al.,* 2003). PAR has also been criticized for ignoring the hazards themselves (Cutter *et al.,* 2009), and for being a descriptive approach which in some cases provides a too generic description of vulnerability (Eakin and Luers, 2006). Nevertheless, the framework is an important approach which goes beyond identification of vulnerability towards addressing its root causes and the driving forces embedded in the human-environment system (Birkmann, 2006). This undeniably is also applicable to the problem of global warming.

In conclusion, the knowledge about the different processes of climate alteration and the predictive tendencies in the historical trend has facilitated the gaining of valuable insight that enabled the study in the design and framing of the appropriate research questions as well as the interpretation of the results. The theoretical framework has equally provided the structure within which the relationship between the identified hypothesized variables are explained by providing the assumptions that guided the research. Furthermore, the combination of the theories helped to identify areas that needed to be probed with emphasis.

2.4. The Paris Agreement and South African Adaptation Strategies

At the 21st Conference of the Parties (COP 21) in Paris in 2015, 195 nations historically agreed under the UNFCCC to commit them to ambitious global GHG emission reduction, finance and adaptation (UN, 2015). Apart from all countries having to strive through transformative measures to keep global warming to less than 2^0, the agreement unprecedentedly in the history of UNFCCC history, emphasized nations' obligations on adaptation actions.

The South African Nationally Determined Contribution (NDC) as submitted in September 2015 (RSA, 2015) covers significantly adaptation as a major strategic tool. This is contained in six well-articulated adaptation NDC (A-ADC) goals. These entail planning and objectives, adaptation needs and costs, as well as investments RSA, 2015; Article 4.4). The goals are in line with the provisions of Article 12 of the Paris Agreement which elaborates on how nations can meet their NDC 2020-2030 (UN, 2015). South Africa, like other parties emphasizes the essentials of monitoring, evaluation and processes of learning from adaptation practices (UN, 2015; Article 7, Para 9d).Aside from the requirement for all parties to reveal the climate change impacts and adaptation information, there is equally a specification of global stocktaking of both the progress and the effectiveness of parties' activities towards the goal achievement. Consequent upon this, South Africa developed a set of National Desired Adaptation Outcomes (DAOs) in the fulfillment of transparency obligation. These DAOs were introduced in the first Climate Change Annual Report (CCAR) (DEA, 2016). Figure 2.8 shows the overview of South Africa's adaptation Nationally Determined Contribution goals.

Figure. 2.8: Overview of South Africa's Adaptation NDC

Source: South Africa Second National Climate Change Report, 2017

The background of the encouragement from the UNFCCC for countries to embrace adaptation and comply with Article 7 of the Agreement occasioned the six goals highlighted in Figure 2.8 to enhance the capacity to live and cope with climate change. This constituted the South African (National) Strategy for adaptation. In order to strengthen resilience and reducing households' vulnerabilities to climate change the other five subsequent adaptation goals were formulated. These include: the integration of climate change into national and subnational policy framework; capacity building to facilitate climate change response, planning and implementation. Early warning and development of a vulnerability assessment and adaptation needs framework and communication form the remaining goals.

2.5 Climate trends in South Africa

This section narrates literature on issues that relate to legislations, policies and other documents reviewed to provide not only the basis for the adopted methodologies but also to unpack climate change trends in South Africa with respect to Africa continent.

The Intergovernmental Panel on Climate Change's fifth assessment report notes that it is highly likely that elevated levels of human activity greenhouse gas emissions are the leading cause of the warming of the earth's climate, observed since the mid-20th century. Such changes are seen through average rises in global temperature (with the hottest recorded in the past decade). In recent times, global sea level increases and shifts in natural patterns of rainfall have occurred.

The continent of Africa has recorded a yearly continental average temperature of 1.19°C (2.14°F) above average, with its fourth warmest year indentified to be 2015 in the 111-year record (Global Climate Report, 2020). According to this report, the year 2010 as well as 2016 were recorded the as Africa's warmest on record being 1.44°C (2.59°F) more than average. With an average rate of 0.13°C (023°F) increase per decade, Africa annual temperature has increased.

Meanwhile, from 26 climate stations spatially distributed across the country, mean annual temperature anomalies were estimated and illustrated inFig. 2.9. As calculated from 1981, the South Africa annual average temperature for 2020 was about 0,5°C higher than the 1981—2010 average. Around 1,6°C per decade higher than the average global trend was estimated to be the long-term trend(SAWs, 2021). Term temperature / rainfall forecasts the future impacts of climate change on South Africa's health, water supplies, agriculture, forestry the biodiversity mean that medium-sized cities will be significantly impacted by the phenomenon because they

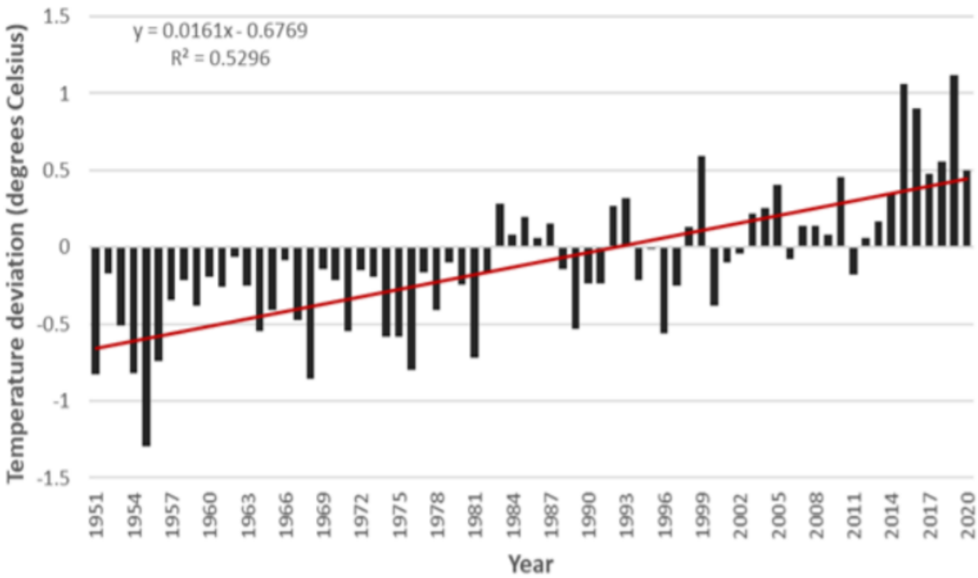


Figure 2.9: Annual average surface temperature derivation for South Africa (Base period: 1981 – 2020). Source: South African Weather Service. 2021

Around 1,6°C per decade higher than the average global trend was estimated to be the long-term trend(SAWs, 2021). Term temperature / rainfall forecasts the future impacts of climate change on South Africa's health, water supplies, agriculture, forestry the biodiversity mean that medium-sized cities will be significantly impacted by the phenomenon because they have less supplies than mega-cities or metropolitan areas in terms of mitigation and adaptation needs.

2.5.1 Recent Climate Trend in Limpopo and Implications for Living

Limpopo is South Africa's northernmost region named after the river Limpopo. It is one of the developing provinces in South Africa, and due to its vulnerability to extreme weather events, it is especially at risk from climate change impacts (Tennant and Hewitson, 2002; Tshiala *et al.,* 2011). The area is affected by the predominant dry, continental, tropical, equatorial convergence zone, and the moist, coastal, subtropical east and marine western Mediterranean air masses, thereby establishing an arid climate condition in the basin (FAO, 2004). On most days, the province faces long sunshine and dry conditions. During the summer months, warm days are often interrupted by a short-lived thunderstorm (Ramaru *et al.,* 2008). It can get very hot in summer (October and March), with average summer temperatures rising to 27ºC and winter temperatures of 20ºc. Most precipitation falls in the summer, and total annual rainfall ranges from about 400-600mm over the province. Although communities in the Limpopo region may have some ability to adapt to the long-term changes in climate, such as increased seasonal temperature and changed patterns of precipitation, they are nevertheless heavily stressed by the frequency of extreme weather events (Tshiala *et al.,* 2011).

Several studies have investigated temperature trends South Africa in recent times. Hugues and Balling (1995) reported an increase of 0.12ºC in average temperatures per decade from 1960 to 1990, and these trends were significant for both non-urban and urban stations. Limpopo has been experiencing increasingly warmer temperatures. Tshiala *et al.,* (2011) analyse trends over Limpopo by using obtained daily maximum and minimum temperatures from hydro-climatic data collected from more than 970 qualifying stations over the 50 years (1950 to 1999). Detailed analysis of the mean annual average temperatures has shown that the highest positive mean annual trend recorded among the 30 catchments over Limpopo was 0.1°C per decade.

In contrast, the largest negative trend is -0.03°C per decade. However, not all the areas in Limpopo exhibited the same trends, with the northwestern portions warming up the fastest. There has been a general increase of 0.12°C per decade in the mean annual temperature for the 30 catchments over the 50 years. A non-uniform pattern of temperature changes was evident across the different catchments; 13% showed negative trends, while 87% showed positive trends in their annual mean temperature. A total of 20% of catchments showed negative trends, while 80% showed positive trends in their diurnal temperature range. The seasonal trends showed variability in mean temperature increases of about 0.18°C per decade in winter and 0.09ºC per decade in summer (Tshiala *et al.,* 2011).

The rainfall statistics of the Provinces are based on "the average rainfall of the homogeneous rainfall districts", as developed by South African Weather Service, which is mostly found within a particular province. There is the assurance of a better weighting of rainfall stations using the approach in the spatial rainfall estimations. From the analyses, near-normal rainfall was received in South Africa across all the provinces. Improvement was observed significantly in the Northern Cape, with recent years records of rainfall being below-normal.

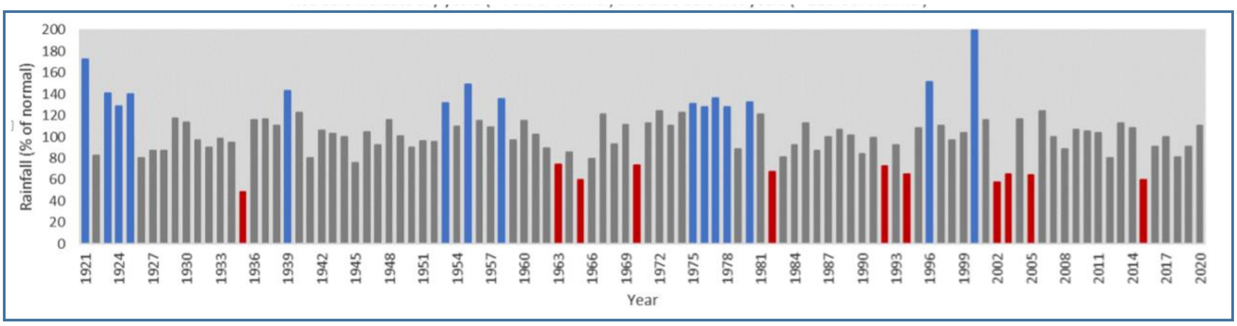


Figure 2.10: Limpopo - Annual Rainfall (% Normal) – 1921- 2020
Red bar indicate dry years (<75% of Normal) and blue bar wet years >125% of Normal)
South African Weather Service, 2021

Like other parts of South Africa, Limpopo is a water-stressed and climate sensitive region (Fig 2.10). Most of it is semi-arid, and the province undergoes droughts and floods. A change in the precipitation or temperature will therefore worsen the already stressed climate. As a result of the rise in evaporation as well as precipitation, an increase in temperature usually triggers the intensification of the hydrological cycle. In other words, temperature increases can lead to changes in precipitation patterns, spatial and temporal distribution of runoff, soil moisture and groundwater supplies, as well as an increase in drought incidence and floods (Arora *et al.,* 2005). Already, the dry season in Limpopo is becoming longer, the wet season is starting later, and droughts are becoming more frequent (Oxfam International, 2009).

The Department of Environmental Affairs highlights the projected impact of climate change in Limpopo;

i. The one-in-ten-year low river flows and one-in-ten-year high river flows are anticipated to decrease, leading to significant impacts related to ensuing water shortages.
ii. Decrease in summer rainfall
iii. Reduced recharge of groundwater
iv. Flooding, contamination of available water, and drought
v. High vulnerability of certain agricultural crops due to decreased water availability and increased temperatures.

2.5.2 South Africa's Climate Change Projections

Models have been used to predict the effect of climate change in regions. Future climatic states are commonly described using computer simulations of the state of the atmosphere, ocean and land-surface, based on different greenhouse gas emission scenarios (DEA, 2011). The climate simulations are known as General Circulation Models (GCMs) and are based on the laws of momentum and mass and energy conservation. They provide three-dimensional simulations of the state of the atmosphere, ocean and land-surface (MacKellar, 2014). The 4th Assessment Report (AR4) of the IPCC used scenarios outlined in their Special Report on Emissions Scenarios (SRES) to provide projections of future greenhouse gas emissions. Insight into the plausible range of changes in temperature patterns in southern Africa, are being obtained from the projections of GCMs, particularly those described in IPCC's fourth assessment report.

These models predict that at the continental level, strong warming is anticipated to occur across the African continent in all seasons at a rate of about 1.5 times the global rate. In South Africa, the increase in air temperatures is likely to be higher over the interior and lower over the coast. Coastal areas are expected to warm by around 1°C and the interior by around 3°C by mid-century. By the end of the century, warming is likely to be around 3°C at the coast and 5°C over the northern interior (DEA, 2011). There is evidence from observations that a strong warming trend has already manifested itself over southern Africa. Kruger and Shongwe (2004) have shown that the average temperatures in South Africa for the 1990s were significantly warmer than preceding decades, for example, 18.48ºC for 1991 to 2003 compared to 18.18ºC for 1960 to 1990. Moreover, changes seem plausible with regards to rainfall. South Africa is projected to become generally drier. Most of the summer rainfall region of South Africa is projected to become drier in spring and autumn.

Climate change modeling also suggests that South Africa's plant biomes will experience a reduction of the area covered by up to 55% in the next 50 years due to warming and acidification trends. The succulent Karoo biome for example could be completely lost by 2050 (Oxfam International, 2009). Significant decreases in rainfall are also projected over the south-western Cape in winter. Furthermore, research in Southern Africa has shown that increases in temperature and changes in precipitation patterns result in increased occurrence of malaria, cholera and other diseases such as strokes, dehydration and skin cancers. The impact of climate change on the Southern Africa health sector is manifested through three major pathways, namely; food and water borne diseases, vector borne diseases and HIV/AIDS. Numerous climate change projections have been carried out for the Southern African region, which rely on downscaled GCMs and regional climate models (RCMs). Most of the models' project drier conditions because of increased warming for most parts of the region (Boko *et al.,* 2007).

In summary, the Government of South Africa using internationally agreed scientific computer models to explore the potential impacts of climate change on South Africa over the next 50 years predicted:

a) Broad reductions of approximately 5 – 10 % of current rainfall, but with higher rainfall in the east and drier conditions in the west of South Africa.
b) Increased summer rainfall in the northeast and the southwest, but a reduction of the duration of the summer rains in the northeast, and an overall reduction of rainfall in the southwest of South Africa.
c) Increased rainfall in the northeast of the country during the winter season.
d) Increased daily maximum temperatures in summer and autumn in the western half of the country.
e) Wetter conditions with a reduction in frost, which could see malaria mosquitoes expand their range onto the Highveld. (Oxfam International, 2009).

2.5.3 Climate change predictions in Limpopo Province

The use of Global and regional circulation models is common in projecting climate to the future at different scales. The South Africa Department of Environmental Affairs (DEA), in its Long Term Adaptation Scenario Flagship Research Project (LTAS), has regionally predicted the future South Africa climate change based on the dynamic downscaling of global climate models with the use of a regional climate model, the Conformal-Cubic Atmospheric Model (CCAM) (Engelbrecht *et al*., 2011), and the use of a Statistical Downscaling methodology (Hewitson and Crane, 2006).

At the University of Cape Town (UCT), the Climate Systems Analysis Group (CSAG) performed the statistical downscaling with scenarios generated for a high mitigation scenario. The year 2000 witnessed the construction of the "business as usual" scenario (A2 scenario), which formed part of AR4 of the Intergovernmental Panel on Climate Change). This scenario is low mitigation with high emissions. However, from the year 2000, the GHGs concentrations were increasing annually at a higher rate than projected by the A2 scenario (Khwashaba 2018). The negative rate in AR2 was surpassed in AR5 scenario of the IPCC, (RCP8.5), which has been accorded a great attention that created the current global pathway. Figure 2.11 indicates the global concentration pathway adopted from Jubet *et. al,* 2016.

In line with the LTAS (2013) the national scale climate future projection of South Africa indicated varying degrees of climate change situation. Different conditions of climate change were identified, these are warmer and wetter climate situations accompanied by a high frequency of extreme rainfall. The temperature at <3°C above the year 1961 to 2000 was projected; warmer/wetter and warmer/drier conditions were escalating the occurrence of drought conditions and, to some extent, higher incidence of extreme rainfall.

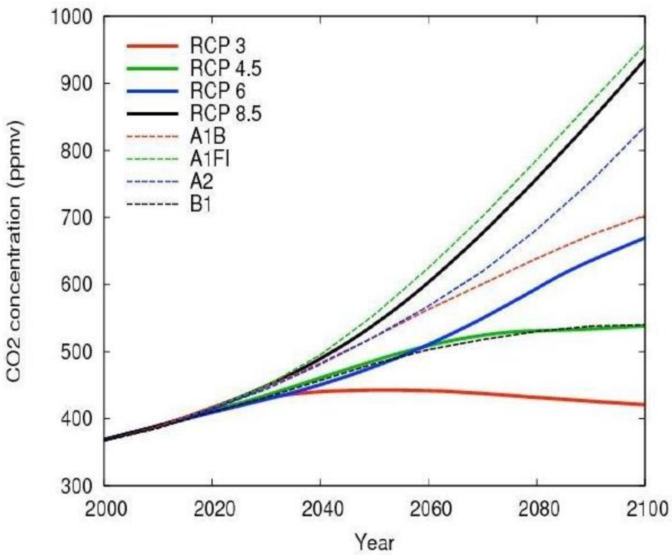


Figure 2.11: The Global concentration pathway (*Source: (*Jubet *et.al, 2016))*

Future projections of different climatic zones have been identified from the use of statistical and dynamic downscaling in the projections of climate (rainfall and temperatures) in South Africa, varying climatic zones are identified, these are from CCAM projection model and this is indicated in Table 2.2.

Tab.2.2: The Future Projections of climate of Limpopo, South Africa

Zone 1 (Limpopo)	Near term (2015 – 2035)	Mid-term (2040 – 2060)	Long term (2080 – 2100)
Temperature	Mostly within the range of current variability, but showing an annual anomaly (increase) of about 2 °C towards the end of the period under RCP8.5	Average annual increases of between 2 and 4 °C	4 – 7°C average annual increase in temperature under RCP8.5, substantially exceeding historical variability. 2 to 3 °C under RCP4.5
	Increased drying under both the RCP 4.5 and RCP8.5 scenarios but still within the range of current climate variability.	Increased drying under the RCP 4.5 and RCP8.5 scenarios strengthening over time, but within the range of current climate variability.	Increased drying under RCP 4.5 and RCP8.5 scenarios strengthening over time, outside of the range of historical climate variability.

(Source:Khwashaba 2018)

Figure 2.12, shows the variability and change in climate in the province of Limpopo. It shows that during the year 1961 to 1970, high rainfall of about 300mm above the average and 1.8°C cooler temperatures. While some wet and warm years were observed, some wet and cool years were equally experienced. The projection towards the year 2040 to 2080 indicates a dryer and warmer climate towards the end of the century, the Limpopo province is projected to be significantly dryer.

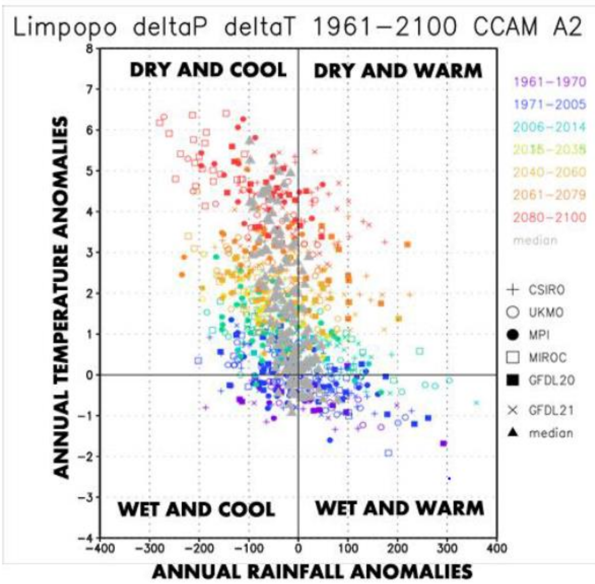


Figure 2.12: Projected changes in temperature and rainfall over Limpopo province
Source: (LTAS Phase 1, Technical Report (no. 1 of 6),(2013))

The fluctuations in the plausibility of future climate variability and change projections may be determined by the diversity, constant and rapid transformations taking place in the urban centres and their dwellers susceptibility resulting from the frequent occurrence of extreme events. Nevertheless, the available past information will continue to facilitate the identification of extreme events with their associated impacts in the years past and equally provide the platform to allow for future climate change projections and future planning

2.5.4 Policies, Strategies and Plans on Climate Change in South Africa

The effect of climate change, exemplified by increased incidence of extreme events such as flooding and prolonged drought is felt across South Africa, thereby galvanizing the government into efforts tailored to address the problem. The economy of South Africa is heavily dependent upon fossil fuel, and due to the relatively high values that can be extracted for pollution intensity and per capita emissions, the nation is a major emitter, making it one of the top 15 most energy-intensive economies in the world, with a large contribution to continental greenhouse emissions (DEAT, 2004). As a non-Annex I country, however, South Africa is not required to reduce its GHG-emissions. Today, it continues to play a significant role in engaging in global climate change programmes, being a signatory to the UNFCCC and having ratified the Kyoto Protocol, in the global climate system. As a UNFCCC signatory certain obligations must be fulfilled including those of:

a) Prepare and update the national GHG emissions and sinks inventory on a regular basis;
b) Develop and implement national and, if necessary, regional climate change mitigation plans and promote effective climate change adaptation.
c) Promote and cooperate in developing, applying and disseminating technologies, practices and processes which regulate, reduce or prevent anthropogenic agents
d) Promoting sustainable management and promote and cooperate in the conservation and improvement of all greenhouse gas sinks and reservoirs.
e) Work together to plan for adaptation to climate change impacts.
f) Consideration of climate change in related social, economic and environmental policies and activities with a view to mitigating adverse economic effects;
g) Promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system aimed at promoting understanding and reducing or eliminating uncertainties.

h) Encourage and participate in the full, transparent, and timely sharing of relevant scientific, political, financial, socio-economic and legal knowledge related to climate change.
i) Promote and cooperate in education, training and public awareness related to climate change.

South Africa has numerous laws relating to environmental conservation and management. The overarching legislation is enshrined in the 1998 National Environmental Management Act provisions. Climate change is specifically cited in the 2000 White Paper on Integrated Pollution and Waste Management and is cited in the South African White Paper on a National Water Policy. It is also specifically addressed in the upcoming National Water Resource Strategy for the Government. However, climate change is not addressed in the current legislation on air quality. During the preparations for UNFCCC ratification in 1997, the need for a national climate change policy for South Africa was identified as a pressing requirement. A Climate Change Response Strategy for the State was therefore implemented. The White Paper represents the culmination of an interative and participatory policy development process that was started in October 2005 (Beaumont, 2011).

This White Paper presents the South African Government's vision for an effective climate change response and a long-term, just transition to a climate-resilient and lower-carbon economy and society. South Africa's response to climate change has two objectives:

a) Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity.
b) Make a fair contribution to the global effort to stabilize Greenhouse Gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a time frame that enables economic, social and environmental development to proceed in a sustainable manner.

The former is often dubbed the adaptation response, and the latter, which will be emphasized here, is called the mitigation response (Beaumont, 2011).

2.5.5 South African Climate Change Adaptation Response

There is wide recognition that the impact of climate change is already being felt in South Africa, as a result of an increased incidence of disease outbreaks, flooding and prolonged periods of drought resulting in rising food prices (Richards 2008). Apart from mitigating its impact through reduction in greenhouse gas emissions, climate change adaptation is receiving attention, as the impact of climate change is increasingly being felt. Adaptation refers to the ability to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2014). Climate change adaptation is a challenging issue, though considerable efforts are already underway at the provincial and local level in South Africa.

The NCCRWP identifies a number of flagships programmes which are to be implemented. Adaptation related programmes include the Climate Change Response Public Works Flagship Programme, the Water Conservation and Demand Management Flagship Programme and the Adaptation Research Programme. The White Paper further recognizes the need for coordinated approaches to adaptation, and detailed adaptation plans are to be developed for a number of key sectors of the economy. These include biodiversity, forestry, water, coastal management, agriculture, health, tourism, land and rural development, local government, fisheries, human settlements, business/insurance, all rolled out to provincial and municipal levels of government.

It is noteworthy that, of all the sectors, the health sector is paramount, yet it has generally been acknowledged that the health sector is lagging behind on climate change strategies (Amis *et al.,* 2014). Most countries in the Southern Africa Development Community (SADC) have not yet developed a specific strategy for health and climate change. South Africa, which is regarded as a leader in the climate change sector, only finalized its National Climate Change and Health Adaptation Policy (NCCHA) in 2012 (Myers and Rother, 2012). Apart from South Africa no other country in the region has a specific climate change adaptation strategy for their health sector.

Even though the National Climate Change Response Strategy for South Africa clearly stated that adaptation measures would be mainstreamed into the health sector, specifically through the Department of Health Strategic Plan, there was no mention of climate change in the National Department of Health Strategic Plan for 2010-2013. The strategy, however, clearly outlined how South Africa plans to combat diseases such as malaria, whose transmission patterns are projected to change along with climate change. According to Myers and Rother (2012), following the COP17 meeting in Durban in 2011 there was an increase in climate change policy development in South Africa at all tiers of government. Till date, Mopani district is yet to come up with an articulated climate change response plan. The district largely relies on the national framework. Although the strategic initiative to establish the District Disaster management centre is a pointer to a better deal with respect to institutionalizing climate change response strategy for the District and the local municipalities.

2.5.6 South African National Disaster Management Framework

At national level, the policy aimed at ensuring an integrated and uniform approach to disaster management in the Republic by all national, provincial, and municipal entities in reducing the risk as well as addressing the associated consequences. The policy gave the responsibility of its administration to the Minister, in consultation with the Cabinet member that is the presidential designate. The policy empowers the provincial government to develop location-specific legislation to regulate the management of disaster, but where such legislation is found inconsistent with this national Act, the national government takes prevalence subject to section 146 of Constitution of the Republic.

The Act promotes the establishment of Intergovernmental Committees on Disaster Management, consisting of Cabinet members in charge and provincial Members of the Executive Council in charge of disaster management. These are selected by the Premier of the concerned province and South African Local Government- selected municipal council members. It further empowers the Minister to establish a National Disaster Management Advisory Forum with several governmental and non-governmental organisational representatives, traditional institutions, and various professionals, except the urban planners. Sec 5. (1).

Under the contents of the framework for national disaster management, the Minister equally has the power to define a national disaster management framework inline with the recommendations of the intergovernmental committee and public submissions. The framework must reflect coherence, transparency, and inclusive disaster management policy. It emphasises private and public sector partnerships. It promotes capacity building, training and research, information gathering and management. Most importantly, it provides a framework for funding disaster management (grants and payments to victims) as well as addressing the co-operation and co-ordination requirements between the stakeholders. It identifies the performance indicators.

Section 8. (1) Establishes a National Disaster Management Centre,which functions within the control of the Minister under a state department of the public service. While under Section 9, its objective centres on the promotion of a disaster management system that is not only integrated, but a co-ordinated, with distinct prominence on prevention as well as mitigation. The Centre derives its powers from Sec. 15(1-4) of the Act, to prepare and regularly review Disaster Management plans and strategies. It supports and assists the organs of state in preparation, review and align the plans and prevent and mitigates the risk of disasters amongst others (Sec 20 (1)).

So as to complement the prevention as well as mitigating disaster risk, the Provincial disaster management framework in Section 28. (1) of National Disaster Management Act was instituted (see Figure 2.13). Through it, provinces are mandated not only to establish but also to implement a disaster management framework aligned to the NDMF objectives which is consistent with the provisions of this Act (No. 57,2002) and the national disaster management framework, 33 (I).

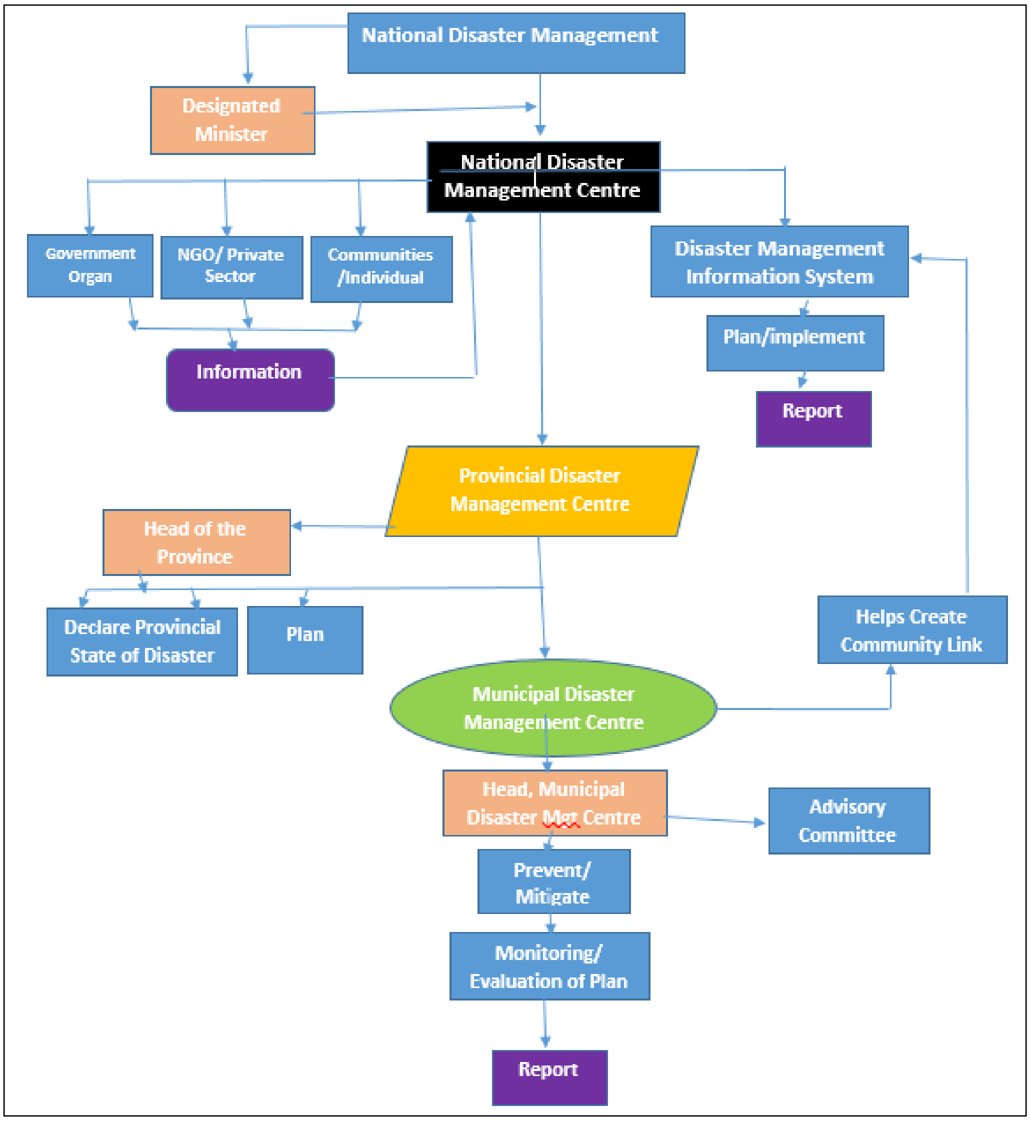


Fig. 2.13: South African National Disaster Management Framework
(Source: Adopted from Act 57, 2002)

In Limpopo, the Provincial Disaster Management Framework and plans, which was instituted within the Provincial Disaster Management Advisory Forum, gave birth to the Mopani district and the Local Municipalities arrangements to establish a Disaster Management Centre, a Plans/Framework, an integrated development Plan, capacity, and their budgets.

2.5.7 South African Urban Planning Policies and Climate Change Adaptation

Urban policy and planning are “state activities that seek to influence the distributions and operations of investment and consumption processes in cities for the common good” (Pillay, 2008). These are however, not activities that are narrowed down to that of an urban scale, but are defined and emphasised by their effects on both national and international economic and social systems. It is a dynamic activity that is a process of design and explanation and its execution is continuous in nature. It is rare to have a once-off, simple and best answer to an urban problem, but rather this is typically arrived at from a range of existing policies and planning options that inform choice making from an informed position.Urban policy is generally occasioned by the power interplay between the diverse societal constituents (interest groups). These groups include government (local, district, provincial and national) and investment in its several segments in pursuit of defined goals which could be contradictory but, in most cases, are complementary. Politics and economy directly influence the nature of urban policy as well as external forces operating locally or globally.

The South African National Urban Development Framework (NUDF) was drafted to offer a nation-wide view on the strategies and to strengthen the capacity of cities and city-regions in the Republic of South Africa for the purpose of shared national growth, social equity and environmental sustainability. This policy was a product of the recognition of the need for an inclusive urban development framework attempts by various Government Departments have in different ways addressed the challenges of urban areas since 1994 with significant achievements in areas such as service extension, municipal reform, urban renewal and economic infrastructure development. However, fewer achievements have been recorded in the mainstreaming of climate change to urban sector planning. This is despite the National Urban Development Framework seeking to align creative initiatives to strengthen mutual results.With this policy, the national government has all kinds of consummate powers to support the development of towns and cities that are more productive, cohesive, and durable.Yet, its intention is to compliment rather than contradict the decentralisation of powers and functions (principle) to the lowest effective level. It is equally not a delegation of full responsibility to local agencies, particularly for complex challenges. By implication, other lower levels of governance (Provincial, District, and Local Municipalities) are at liberty to initiate, develop and implement location specific policies in line with the fundamental principles of the national policy.

The importance of urban areas in the efforts to mitigating various forms of environmental degradation, and to promote climate mitigation and adaptation cannot be over emphasised. However, for most small and medium South African towns, they are poorly designed from an ecological perspective and other environmental impacts with serious potential for enhancing carbon footprint. There is no conscious impact towards climate mitigation and adaptation and most are poorly serviced with paucity of infrastructure and basic services. This has made them vulnerable to various environmental hazards including climate change. Unfortunately, the municipalities within Mopani district are still relying on the National Urban Policy without plans to have a localised policy for the urban sector that embraces their economic, political, and social peculiarities.

The adoption of the Paris Agreement as well as the New Urban Agenda signalled a renewed motivation for action, particularly towards mainstreaming climate change in Urban Policy. National Urban Policy, according to the New Urban Agenda, is an essential instrument to adequately respond to the adversities of urbanization and to harness the associated opportunities. If well harnessed, and effectively implemented, the New Urban Agenda implies not only inclusive, but implementable, and participatory urban policies. This to a large extent will promote Low-Carbon Urban Development (‘Mitigation’) Building Climate Resilience (‘Adaptation’) and address Urban Climate Governance.

However, the broad portfolio of policy initiatives in the Republic is currently in process, and which will have a direct impact on the management of towns, cities, and city-regions. These include the National government new powers to intervene in facilitating service delivery at municipal level and to achieve regional efficiencies; the establishment of a national Housing Development Agency (HDA). This aims at changing the management of human settlement and housing delivery processes.The national climate change mitigation strategy was adopted by Cabinet in 2008 together with the draft Climate Response Policy amongst others. Although, the policy emphasises mitigation measures such as the promotion of green buildings and public transport and coastal cities adaptations to sea level rise, there is less emphasis on adaptation of small and medium sized inner cities of the Republic. The policy is yet to be replicated at both District and Municipality levels.

2.5.8 Mopani Climate Change Vulnerability Assessment and Response Plan

Mopani District Municipality, in line with the National Disaster Management Act, has acknowledged that climate change poses serious threats to both humans and the environment now and in the future development equally. It has recognised the need for actions to mitigate, as well as prepare for the projected changes (adaptation) in the district. Consequently, Mopani District Municipality in 2016 developed a Vulnerability Assessment and Climate Change Response Plan to prioritise the Climate Change Response.

The Plan recognised several ways that climate change will impact human settlements across the district. These include amongst others, increases in the severity of storm events and increases in flooding that will damage strategic infrastructure. Excessive storm events will particularly adversely affect informal dwellings and households located on flood plains with poor or no drainage infrastructure, as well as impacts on human health. The plan thus identifies related indicators, sub-projects, and actions for inclusion in the Service Delivery and the plans for budget implementation (MDM, 2016). The identified project is reportedly held back because of paucity of budgetary allocation among its competing priorities.

2.6 Vulnerability Assessment Models

Vulnerability is an important concept in addressing the problem of climate change because determining its impacts depends not only on the nature of climate changes but on the vulnerability of the places and people who experience those changes (Council of Scientific and Industrial Research, 2017). According to the IPCC, vulnerability to climate change is the degree to which a system is susceptible and unable to cope with, its adverse effects, including climate variability and extremes. Vulnerability as earlier explained has three factors; Exposure, Sensitivity and Adaptive Capacity and can be presented in two forms; Figure 2.14 provides insight into this.

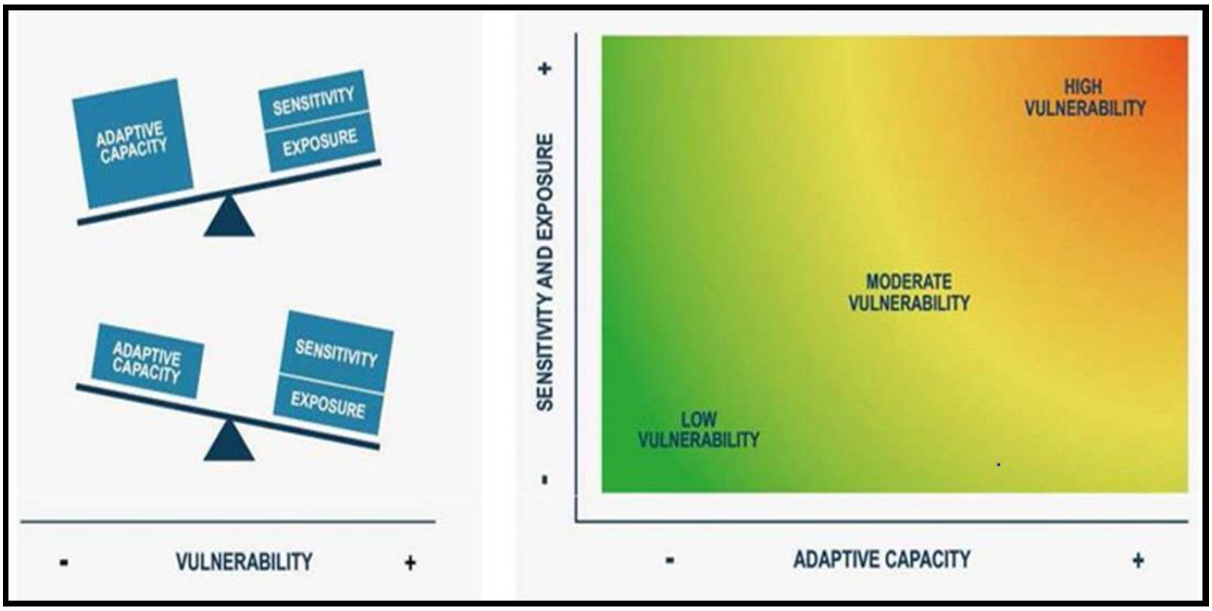


Figure. 2.14.: Adaptive Capacity and Vulnerability Assessment
Source: Adapted from Alberta Sustainable Resource Development (2010); Gionardo (2014).

a) Vulnerability = [(Exposure + Sensitivity) – Adaptive Capacity]
b) Vulnerability = (Potential Impact) – Adaptive Capacity

Potential Impact as observed by Srivastava (2015) consists of exposure and sensitivity. However, assessing vulnerability to climate change is more complicated than simply assessing the potential impacts of climate change, due to the "adaptive capacity" component, even though estimating adaptive capacity is a key element of vulnerability assessment (Gionardo, 2014).

As seen in figure 2.11:

a) Assets with high adaptive capacity and low sensitivity/exposure can tolerate impacts to a greater degree and therefore have an overall low vulnerability.
b) Assets with high sensitivity/exposure and low adaptive capacity are more susceptible to impacts, and therefore have an overall high vulnerability.

Adaptive capacity it should be noted is the ability 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, 2014). Less tangible and harder to document or measure than aspects of exposure and sensitivity, it reflects the status of poverty, health, knowledge/education, and governance.

The process of identifying, quantifying and prioritizing key risks and vulnerabilities of a system to a particular hazard is called vulnerability assessment. However, assessing vulnerability does not mean necessarily calculating a specific number or measuring it with a specific instrument (the "vulnerometer" does not exist). Rather, it rather means describing a situation or a condition through a certain number of factors or elements related to its characteristics (i.e. indicators). Vulnerability is thus a characteristic, trait, or condition. It is;

a) Not readily measured or observable
b) Needs proxy measures and indicators
c) Relative, not absolute
d) Relates to consequences or outcomes, and not to the agent itself.

There are three major approaches to vulnerability assessment: Proxy or indicator-based approaches, Model and GIS-based methodologies, Participatory and multi-stressor approaches and methods (CSIR, 2017).

2.6.1 Indicator-Based Methods

Indicator-Based Methods are the commonly used methods for vulnerability assessment.

a) They use a specific set or combination of proxy indicators in order to produce measurable outputs across various spatial scales.
b) They are easily understood by decision-makers

c) They can be used to monitor trends and the implementation of adaptation responses

Examples are the Livelihood Vulnerability Index (LVI), Household Adaptive Capacity Index (HACI), Well-being Index (HWI) and the Index of Social Vulnerability to Climate Change for Africa (SVA). The indicator based methods however a few limitations have:

a) Lack of reliable data, particularly socio-economic sources (e.g. health)
b) Some indicators fail to capture the spatial and temporal heterogeneity of vulnerability, and are unable to convey uncertainty
c) Difficulty in testing and validating the different metrics used as indicators e.g. good governance, a key component of adaptive capacity, for instance it is difficult to capture in an indicator.

2.6.2 Model and GIS-based Models

The salient elements of these methods are:

a) Vulnerability is often visualized through mapping and spatial analysis
b) Scale: sub-national, national, regional, global
c) Biophysical and socio-economic models
d) Use statistical measures of exposure, adaptive capacity, and resilience

This approach has been used for calculating risk index for flooding based on a set of input datasets in several places. The limitation of the approach is that spatial representations of vulnerability are typically a snapshot of vulnerability. Also, there are often limited spatial data on coping capacity, adaptive capacity, outcomes of social processes, and measures of well-being. Lastly is the impression that there is sufficient information on which to base decisions, and thus leading to stakeholders' being overconfident.

2.6.3 Participatory Approaches

This focuses on affected communities or sectors closely linked with community-based vulnerability approaches. It uses a wide range of tools: cognitive mapping, interviews, surveys, vulnerability matrices, stakeholder engagement workshops and expert-based inputs. It adopts the bottom-up processes, recognizes multiple stressors beyond those of climate and the interaction of various exposures, sensitivities and adaptive capacities over time. Its fallibilities are in the fact that findings are purely based on the perceptions and understanding of workshop participants. Moreover, there is a large number of perspectives and a lot of information which makes it challenging to nail down key messages or a short list of priorities. It also lacks the biophysical perspective like impact modeling and so on.

It is noteworthy that a combination of the different approaches is also possible for a more detailed analysis of vulnerability. It is the result of the interaction of climate hazard with the physical environment, social circumstances, national governance and international politics (See Figure 2.15) and it changes over time in response to socioeconomic process (CSIR, 2017).

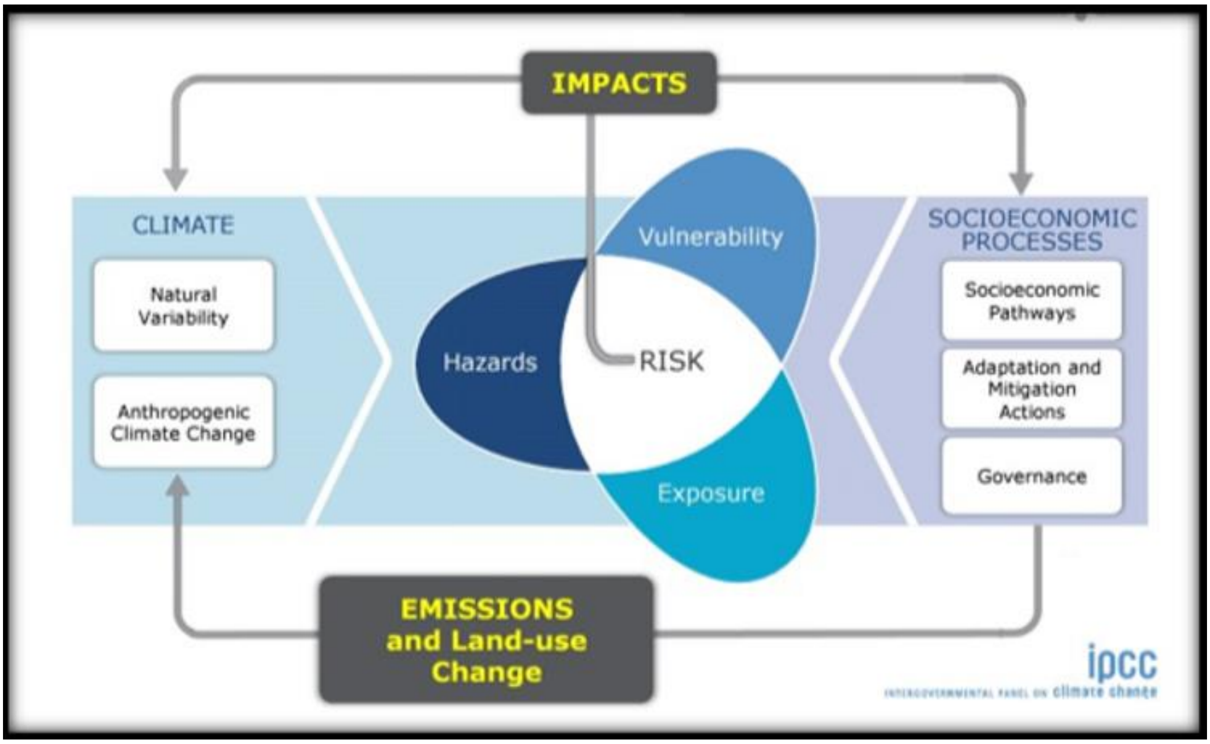


Figure 2.15: Measuring Vulnerability
Source: Council of Scientific and Industrial Research (2017), AR5 (2014)

2.6.4 Levels and scales of vulnerability assessment

Climate change vulnerability research has evolved and currently embraces a holistic location-specific approach (El-Zein and Tonmoy, 2015; Fallmann *et al.,* 2017). On a spatial level, combined attributes are employed to evaluate vulnerability levels at different scales (density, neighbourhood, town & township, subnational, national, regional and global). Results from such findings particularly local enable location-specific programmes, projects and actions (Aubrecht *et al*., 2013; Wan *et al.,* 2018).

Several studies on vulnerability assessment are top-down (large scale) or centred (Lioubimtseva, 2015). They are commonly found in advance countries, such as Europe and America (Kim and Chung, 2013). At this scale, Cheng *et al.,* (2019) conclude that unrehearsed conclusion can only be provided and supported by an overview explanation of the effects. This may make local adaptation policies formulation, programmes' identification and prioritization for sustainable urban planning difficult and unreliable. This is because each city and its dwellers have peculiarities (Schroth *et al.,* 2016). Moreover, Jörn *et al.,* (2010) conclude that the studies of climate change (vulnerability and adaptation) still favour significantly rural areas with only few on small and medium towns, where household vulnerability is more problematic (Thomas *et al*., 2009). On the other hand, according to Bigio (2009); Hallegatte (2011) and Nhuan (2016), the existing vulnerability and adaptation literature on the urban sector are Coastal focused, while those that are not coastal based feature only in titles but not in contents (Watson *et al*., 1996; Wilbanks and Kates, 1999). This is particularly true in developing countries, where attention is more sector-specific with less attention on the spatial character and social fabric assessment of those towns.

Going by the several available methodologies commonly employed to evaluate social vulnerability at different scales and systems, records have shown that the indicator-based method has been the most favoured in its application to address specific hazards (Chang *et al.,* 2015; Siagian *et al.,* 2014; Armaș and Gavriș, 2013). The common social vulnerability indicators include; age, race, health, poverty, income, type of dwelling unit and employment (Adger, 2006; Cutter *et al.,* 2003; Kusenbach *et al.,* 2010; Lee, 2014; McEntire, 2012). Although, disagreements exist in the choice of social vulnerability indicators, most authors subjectively select the indicators based on a review of related literature (Chang *et al.,* 2015). It is noteworthy that very few studies have emphasized the use of empirical approaches in developing grassroots indicators. What is crucial to the choice of indicators is to ensure that they are germane to addressing the research question, test the concepts under operationalization and can easily and effectively communicate the reality of a complex situation.

Adopting a composite indicator which is the 'mathematical aggregate of individual variables or thematic sets of variables' which characterize a diverse concept which can not ordinarily be wholly captured by any single indicator (Cutter *et al.,* 2010) may fail to either be effectively operational or capture the reality of a situation. This approach is not without shortcomings which was the identification of the most appropriate variables that signify susceptibility to hazards at the local level in Mopani. Nevertheless, the idea of 'hazard-and context-specific', as opposed to general elements are suitable for community level vulnerability assessment, for its failure to provide a complete local level description of vulnerability characterized by geographical and social diversity (Brooks *et al.,* 2005).

On the other hand, there are limitations in the quantification of non-direct 'observable phenomena' such as social and mental states, raising the question of validation (Tate, 2012). Notwithstanding this shortcoming, according to Chang *et al.,* (2015), this (indicator approach) is perfect especially for comparative purposes of places as the case of this study. In addition, this approach facilitates a more accurate estimation of a local level baseline of vulnerability which is crucial for policy decision making in disaster risk reduction (Siagian *et al.,* 2014).

This study thus advocates for an expanded and integrated multidisciplinary vulnerability analysis framework capable of promoting unity among various approaches, models and metrics spanning several interests, adequately facilitated by spatial analysis and mapping for ease and clarity of policy making and direction.

2.7 Spatial Approach to Vulnerability Assessment in Urban Areas

The evolution of climate impact assessment was described about four decades ago (in the 90's) using biophysical systems impact estimates from the generated climate scenario for vulnerability assessment and adaptation using a top-down approach (Soares *et. al.,* 2012). Meanwhile more recently, Vulnerability Assessment approaches were location-specific and community-based studies that are linked to vulnerability and closely aligned to social factors. This paradigm shift, according to de Sherbini (2015) was a result of the inclusion and engagement of more stakeholders and most essentially, the application of some tools for decision making such as Geographic Information Systems. Soares and colleagues further argue for vulnerability and adaptation assessments to be more appropriately local, while global and regional scales are appropriate for top-down impact assessments.

A number of recent innovations have been developed using explicitly climate data and climate projections with methods considered sophisticated (Midgley *et al* 2010; USAID 2014; De Sherbinin *et al* 2014a, De Sherbinin (2015). Other good examples are Piontek *et al.,* (2013). Others are climate impact models for the assessment of multi-model scenarios, and the use of geon for modelling spatial units using homogenous conditions as well as spatial homogeneity (Kienberger *et al* 2009; Hagenlocher *et al* 2013). The Hotspot system approach is equally found very useful, exploring geographic teleconnections of climate impact spanning across regions (Krugman 2011).

There is no doubt that the field of vulnerability as well as spatial impact assessment is steadily growing. In most cases the two nomenclatures (vulnerability assessment and spatial vulnerability assessment) are used synonymously, according to Preston *et al* (2011). This is because of the understanding that the constituent components of vulnerability depict to a very great extent "Spatial and Temporal heterogeneity".

Though still in transition, there are several guidelines developed for both measurement and mapping of vulnerability as the most essential step for initiating adaptation decision-making (PROVIA 2013a, PROVIA 2013b). Furthermore, the Nairobi work programmes adaptation assessment planning and practice (UNFCC 2010) and sector specific guidelines, such as health (see Ebi and Burton, 2008) and coastal (see Klien *et al.,* 1999) are emerging. Despite this advancement, the field is still significantly considered as experimental (Sherbinin, 2015). It is against this background that this study employed the use of spatial tools to analyse the households'vulnerability index and other data aspects for visual detailing

2.7.1 Stakeholders Engagement in Spatial Vulnerability Assessment in Urban Area

Consulting with various stakeholders in urban areas is increasingly enjoying patronage among researchers as a critical ingredient of environmental and global change, and is equally gaining momentum in the vulnerability assessment field. Soarese *et. al.* (2012) describes a stakeholder as a person, groups of persons or an entity which would be influenced by a particular outcome, action, policy makers, civil organisation, the media and industry or its sector. The involvement may be either directly with the concerned stakeholder using participatory methods or at a broad consultation level with representatives and domain experts. This is necessary not only to facilitate the determination of goals and of such an exercise from the targeted domains considered germane to the assessment, but it also increases the judicious utilization of the assessment result (Soares *et al.,* 2012).

The shift in approach in favour of stakeholder engagement is informed by failure of the traditional research approach, known by its nature as the "Supply-driven" or top-bottom system of assessment. This has been observed by Pahl-Wostler *et al.,* (2012) to have failed to deliver useful policy or practical remedies to societal challenges, being rather the joint product of academic inquiry on the part of scientists and social realities.

The appropriate applicability of stakeholder engagement approaches to spatial vulnerability assessment is a function of the scope of the assessment and time, as well as available resources. Its nature of being a multidisciplinary research approach has made it expensive both in terms of costs and resources. Although scholars like Kienberger (2012) and Preston *et al.,* (2009) rightly observed that stakeholders' opinion is necessary, but it must be used with caution while assessing vulnerability. In other to prevent the research exercise from becoming just a ritual to fulfil the requirement, the involvement of key stakeholders was considered a priority in this study for a genuine commitment and views.

2.8 Summary of gaps in the literature

Consequent upon this review of the literature, it is considered imperative to recognise the existing gaps which this research aims to fill and for which answers will be provided. The gaps include the following:

The review has shown that man throughout history has witnessed various environmental challenges, so also are the strategies they have employed to adapt and make a livelihood (Huq *et al.,* 2007a). Climate change is a natural phenomenon but has been exacerbated by human (induced) activities. However, studies have equally revealed that climate change currently poses new challenges both for the human and natural environments (Oloke, *et al.,* 2013). The extent and dimension of these challenges remains unclear particularly in poor small and medium urban centres of Africa.

The studies further confirmed that the bulk of climate change vulnerability and adaptation studies still focus on rural climate-fed sector ‘rural water, agriculture’, and ‘sanitation’ (Jörn *et al.,* 2010; Olesen *et al.,* 2011; Leclère *et al.,* 2013; Nhuan *et al.,* 2016). The urban sector has suffered neglect, despite its increasing importance in the world’s social, economic, cultural, and environmental spheres (Sanchez-Rodriquez *et al.,* 2005; Hallegatte, 2011; Nhuan, 2016). Very few studies exist especially on small and medium towns, where households are highly vulnerable (Thomas *et al.,* 2009; Jörn *et al.,* 2010). Existing literature about urban vulnerability and adaptation to climate change tends to have a coastal focus (Hallegatte, 2011; Nhuan, 2016). The literature which is urban and non-coastal based, is featured only in titles, but not in content (Watson *et al.,* 1996; Wilbanks and Kates, 1999) or pays insignificant attention to small and medium sized towns especially in developing countries (Jörn *et al.,* 2010; BNRCC, 2012).

The study unpacked emerging disagreements. Thomas *et al.,(*2009) insisted that resilience and adaptation strategies should target the most vulnerable citizens in small and medium sized towns whose stresses are likely to be exacerbated during climate-change-related disturbances. On the contrary, O’Brien and Leichenko (2000) considered an isolated focus on the urban poor as biased. They noted that no social group or stratum is immune to climate disasters. The argument was promoted on the principles of fairness and justice for all socioeconomic groups (Adger *et al.,* 2006).

Evidences from the reviewed litrerture pointed to the existence of consensus on the concept of adaptation management and strategy as essential to promote urban sustainability and reduction in the level of vulnerability to climate-change-related shocks. Empirical analysis of private adaption behaviour is currently scarce however, and it remains unclear whether people respond to temperature changes or fluctuating rainfall and if they do, what are the driving forces (Berrang-Ford *et al.,* 2011; Ford *et al.,* 2011).

In addition, the studies established the argument for urban planning and management to have the capacity to reduce the negative impact of climate change in towns, considering the complexity, uncertainties, and scale of possible climate change impacts (Nicholls *et al.,* 2007; Stephane, 2009). The review further reveals that most climate change policies in South Africa are formulated at macro level. This is the reason why they have consistently failed because they neither reflect nor connect with location-specific situations (Piya *et al.,* 2012). Several studies have advocated that adaptation to climate change should be the municipal planning's responsibility and be household-based (Adger *et al.,* 2007; Huq *et al.,* 2007a; Milly *et al.,* 2008). Hence, an effective mainstreaming of climate change adaptation to spatial planning requires an assessment of the local situation, to cater for the peculiar needs of the local community. From there, input for formulating macro policies will be generated.

The current knowledge gap in the spatial planning system and practice as regards climate change uncertainties and that of the underlying factors of climate change vulnerability with respect to small and medium towns' socioeconomic components and other relevant influencing indicators was uncovered. There are strong indications that despite South Africa's position as a signatory to numerous international conventions and treaties, several of these conventions have not yet been institutionalised at the lowest (community) level for effective impacts.

On a general note, the studies have argued in favour of an integrated approach to vulnerability assessment and it is submitted that an isolated approach is insufficient to draw any meaningful inference. The study further advocated for a multidisciplinary vulnerability analysis framework spanning several interests and which is adequately facilitated by spatial analysis and mapping for ease of policy making and administration.

It is therefore very expedient to embark this study which focuses on an in-depth investigation of the issues relevant to urban components of human-environmental systems and to recommend policies and strategies for sustainable urban management in the face of climate change. The methodological issues such as data collection procedures, sampling frame and size, data analytical techniques among others are examined in the next chapter.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

While the previous chapter explores the various conceptual and theoretical issues, which provide a consistent notation for the study, the focus of this chapter is the overview of the research methodology adopted to achieve the aim and objectives of the study as stated in sections 1.4.1 and 1.4.2. The research processes employed to study the assessment of the vulnerability and adaptation of households to climate change is in line with the concept of assessing whether the adaptation strategies and capacities of households and planning agencies can address the challenges of vulnerability to climate change in small and medium-sized towns within the Mopani District Municipality Limpopo Province.

The study adopted community-based climate change research using ethnographic approaches that facilitated understanding the causes, consequences, and remedies of climate change from the viewpoint of the most affected (Crate, 2011a). The study involved an intensive analysis in providing some regional perspectives of the incidences of climate change vulnerability and their coping strategies among households.

3.2 Research Design

The research design explored the use of a systematic approach to adequately address the highlighted research questions in chapter one of this report. This study assessed topical issues in climate change, urban growth and climate-related hazards, urban households' exposure, sensitivity and their capacity to cope with associated consequences of climate change in some selected towns in Mopani District, Limpopo province. The Conceptualisation of the thoughts assisted in developing the framework for the methodology adopted in the study. On this basis, required data were analysed upon which the results were presented and the implications discussed. The summary of findings forms the base to draw conclusions and recommendations.

Table 3.1: Methodological Matrix

	Objectives	Types of Data and Sources	Objectively Verifiable Indicators (OVI)	Deliverables	Data Analysis Methods
1	Examine the trend and pattern of temperature and rainfall during 1958-2017, in Mopani District.	Daily Rainfall & Temperature 1958-2017 from South African Weather Service (SAWS) and other relevant sources	• Historical trend • Average annual • Min & Max occurrences • Intra anual average change in precipitation and temperatures (1958 – 2017) • Frequency of climate related disasters (floods, heat wave) over these years	• Average Minimum & temperature • Inter Annual and Intra Annual Average trends in temperature and rainfall • Anomalies in temperature and rainfall	• Time series analysis • Number of occurrences • Pearson's Correlation Coefficient
2	Assess the magnitude of households' vulnerability (with regards to exposure, sensitivity, and adaptive capacity levels) in the selected towns;	**Exposure** • General Locational Character • Location and Topographical maps • Land use map characteristics • Household Socioeconomic Status **Sensitivity** • Fatalities • Damage to properties • Income structure **Adaptive Capacity** *Economics (Barr 2005)* • Wealth (income) • Livelihood Diversity • Durable Asset • Insurance Coverage Source: from field Survey (questionnaire, interview) *Human (Wall and Marzal, 2006)* • Education	• The Location, topography/terrain, Land use/land cover (Built-up, vegetation, bare land water body • Age, Sex, incomes, Educational Qualification, Marital status etc • Death of family members due to climate change related disasters • Total properties/income sources damaged by flood/landslides • Share of natural/remunerative income to total income • Number of occurrence and severity of the five-climate change related diseases • Type/number of livelihood activities • Housing condition, • household assets, communication equipment, first Aid Box, etc • experience of adaptation and disaster management • Participation at training courses, propagation, rehearsal for disaster mitigation & adaptation • Information sharing and exchanging on Climate Change	• Location and Topography • Decadal land use/land cover change • Hazard Score (Exposure) • Hazard Score (Sensitivity) • Personal Possession Index (PPI) Vulnerability=E+S-AC UN Habitat (2011)	• Land use / land cover change • Land use /Land cover Maps • Locational & topographical mapping • Land use & land use change • Density Mapping • Personal Possession index (PPI) • weighting, using Principal Component Analysis (PCA) Filmer and Pritchett (2001) • Percentage Proportion, and • Likert Scale; Mean Scores; • Ordered Logit Regression Model

		• -Skills, training & experience • -Awareness of Disaster & CC Source: from field Survey (questionnaire, interview) Ecological/(Natural (Nhuan et. al. 2015) & Urban Landscape • Water sources and availability • -Soil pollution/ Air pollution • -Open spaces/ neighbourhood spaces • -Urban Landscape • Community Capability	• Number of insurance coverage • Water availability • Water contaminated • Soil contaminated • Air pollution • Availability/Level of Urban Green spaces • Level of Imperviousness • Plot coverage/soft landscape • Availability of Infrastructural facilities, Social Services, Neighbourhood parks and gardens, Site for future development and forested land, agricultural reserved area among several other variables.		• Herfindahl index of diversification ANOVA (Analysis of Variance)
3	Analyse the spatio-temporal variations in households' vulnerability in the selected towns of the District;	• Hazard (Exposure) Index • Hazard (Sensitivity) Index • Household Vulnerability Index Source: Generated from the analyses		• Neighbourhood variation • Towns variation • District	• Geospatial Monitoring and Modelling System • ArcGis23
4	Examine households' and urban planning response to the impacts of climate change in the selected towns; and the district	• Policies, • Strategies, • Legislations • Project initiation/generation and implementation • Staff strength and capacity • Adaptation programmes and projects executed Source: Mopani Disaster Management Centre & Local Municipaliries, Department of Environmental Affairs; - other relevant agencies	• Powers and responsibilities • Urban Development Policy • Climate Change Response strategy • Risk & Disaster response plan • Spatial Planning and Land Use Management		• Narrative • Frequency distribution
5	Propose adaptive measures and decision support tools upon which sustainable planning strategies will be built			-Mopani Hot Spot Reporting System with web -Mopani GIS Centr	

3.3 Types and sources of data

The bulk of the data for this study were obtained from both primary and secondary sources. Monthly and annual data on the climate parameters (rainfall and temperature) were sourced mainly from the global gridded dataset. For land use and land cover change detection, four sets of satellite imageries for 1987, 1997, 2007 and 2017 were used and complemented by observations. The imageries facilitated the comparison of the land use/land cover statistics to identify the trends and rates of change and characterise the land use/ land cover change in the towns between 1987 and 2017.

Secondary data that were considered relevant to the respective objectives of the study were sourced from relevant media and responsible agencies and institutions of government and libraries. For instance, for the general location, character (urban morphology) of the selected towns, the location and topographical maps, land use maps, community infrastructure maps etc. were sourced from the Local and District Municipalities and provincial and national government private organisations (Tab 3.1). Other relevant secondary data included Integrated Development Plans, Spatial Planning and Land Use Management Act, (SPLUMA), the South African National Urban Development Framework (NUDF), the National Climate Change Response Strategy, and other relevant gazettes. Households' socioeconomic characteristics-related information was gathered from Statistics South Africa (StatsSA) and Community Surveys. The review on the theories and concepts, the national, provisional and district climate trends and projections, as well as South Africa's Emissions trends and Vulnerability Assessment Models and other relevant information, were harvested from published journals, conference proceedings, texts, and periodicals such as the International Journal of Urban and Regional Research on relevance of planning to climate change mitigation and adaptation, Journal of Human Ecology where hypothesized ecological indicators were harnessed, Journal of Land Use, where the influence of land consumption and vegetation invation by other land use on human vulnerability to climate change and International Journal of Climatology, for climate related information, to mention but a few.

3.4 Data collection, instrumentation

The study used structured questionnaires to elicit in-depth information on the socio-economic characteristics of the respondents as well as perceived use, benefits and values of urban green space.

Landsat Images (described in Table 3.4), obtained through Earth Explore (USGS), and complemented by Arc GIS and GIS IDRISI were used first to georeference and then map out the towns covered by the study areas. Consequently, the data relating to the quantum of the built-up areas and the green spaces in the study areas all in square metres were computed from the map output.

3.4.1 Questionnaire and its Design

The design of the questionnaire was in four stages.These stages are; scaling approach, the contents layout, the design of the questionnaire as well as the administration of the questionnaire. Thus, for this study, two sets of questionnaires were used; these are the questionnaire for the urban households/residents, and the local Municipalities.

3.4.1.1 Questionnaire Scaling Approach

Ordinal and interval scales measurement were used in the questionnaire; this was applied in order to allow for relevant information for the study. With the ordinal and interval scales, a set of numerical information were arranged in a suitable order and sequence that facilitated ranking in order of importance or suitability. This enable some part of the questionnaires to be structured by respondent's opinion weighing and ranking, that facilitate the test for existing relationships within and between the employed variables. This study employed two relevant statistical techniques; Principal Components Analysis as well as Multiple Regression Analysis, as noted by Pallant (2005). The questionnaire adopted in several instances Likert Scale to provide information on level of importance, intensities or degree of events.

3.4.1.2 Contents, Layout and Design of the Questionnaires

The two types of questionnaires designed with different contents and purpose. The designs of the questionnaires were done to gather information from the respondents residing in the six selected urban areas in the Mopani District. The instrument contains a mixed approach of both open and close-ended questions. The open-ended part allows respondents to freely express their opinions on the questions raised in the questionnaire, while the close-ended ones provide respondents with alternative answers from which choice can be made within the space provided for such (Dawson, 2009).

The content and layout design of the first set of questionnaires that was designed to elicit information on households head in the selected towns is divided into 2 sections (A & B) with each of these parts furter divided to subsectionsparts. For instance, Section A part 1 containing “General Information” and Part 2 which comprises of residents’ socioeconomic characteristics, while in Section B, questions pertaining to the knowledge of climate change among households, this include: Causes and Effects of Climate Change, Vulnerability (Sensitivity), and Adaptive capacity. The second set of questionnaire has two main sections comprise of two subsections, which have several questions on the general information and general administration of climate issues in the municipalities.

3.4.1.3 Administration of the Questionnaires

The questionnaires were administered in batches. The first set of questionnaires for the urban residents were on random basis administered to the target population in the selected towns. This was done with the assistance of field officers engaged to conduct the exercise. The exercise took an average of 20 days each at every location (town) except in Modjadjiskloof and Hoedspruit that took three and two days respectively. The second set of questionnaires was administered on the relevant professionals in the three relevant units and Department (environment, disaster management and administrative) of the municipalities, to harness relevant information for analysis.

3.4.2 Oral Interviews

Oral interview was conducted with some relevant stakeholders to harness information regarding their participation in planning and decision making, perception on causative factors of vulnerability components and suggestion on appropriate adaptation strategies.

3.4.3 Physical Observation

At the inception of the research work, team led by the director of Mopani district disaster management centre conducted a visitation round the district to have first hand information about the physical characteristics and peculiarity of area of study. The six selected towns were visited, and some key stakeholders were met and background information regarding research interest were gathered. The observation facilitated the casual understanding of the study area upon which our further visitations was made.

3.5. Sampling Frame and Sample Unit

Where data were sourced and the estimation of number of samples that were drawn from the population is the focus of this subsection.

3.5.1 Sampling frame

The sampling frame for this study is made up of the six selected small and medium sized towns which were Giyani, Hoedspruit, Nkowankowa, Modjadjiskloof, Phalaborwa and Tzaneen. These were purposively selected to serve as areas of study on which the necessary primary data was collected for analysis.

This study used the "updated gridded climate dataset" (referred to as Climate Research Unit, (CRU TS3.10) as obtained from the monthly observations at global meteorological stations, from the University of East Anglia data, at 0.5° x 0.5° latitude/longitude grid cells. The monthly dataset includes two climate variables (mean rainfall and temperature). The data was based on a grid from latitudes 24.4°S to 23.3°S and 30.0°E and 31.1°E between 1958 and 2017 (temperature) and 1958-2016 (rainfall). Several studies like Mitchel and Jones (2005); Harris *et al*., (2014) justify the use of this data set. Mitchel and Jones (2005) updated the earlier resolution (0.5° x 0.5°) latitude/longitude, which was monthly data constructed by New *et al*., (2000). Harris *et al*., (2014) updated the data set to 2009 and equally provided for a semi-automated regular updating system from 2009 onward called (CRU TS3.10). The monthly climate data was substantially drawn from Climate Research Unit (CRU) monthly archives through the World Meteorological Organisation (WMO) in partnership with the US National Oceanographic and Atmospheric Administration (NOAA). The non-availability (or limited) of town–specific climatic data, and the discontinuity nature of existing station data, necessitated the use of data from this source.

3.5.2 Sampling Unit

For a home-based study of this nature, households in residential houses in the six selected towns formed the sampling units where the samples were drawn, and the questionnaires were administered to the household heads.

3.5.3 Population of Study

Table 3.2 highlights the population Figures and household sizes, as well as the annual growth rates of the selected towns. It equally depicts the population Figures of these towns as projected from 2011 Figures to 2017 census Figures. An asterisk (*) indicates a Local Municipal Population Growth Rate where the town's rate could not be established.

This projection was considered necessary to inform and facilitate determination of sample size across the sampled towns.

Table 3.2: Population Figures and households' number in the selected towns

Selected Towns	2011 population Figure	Average Household Size	Annual Growth Rate %	2017 Population (projected)	Household Number
Phalaborwa	13 108	3.1	2.61	15 298	4 934
Modjadjis Kloof	1 815	2.7	*-0.29	1 785	661
Hoedspruit	3 157	2.8	* 1.08	3 368	1 202
Giyani	25 954	3.1	1.08	27 660	8 922
Tzaneen	14 571	2.9	1.5	15, 933	5 494
Nkowankowa	48 255	4.0	2.4	50 599	12 650
Total	106 860	3.1		114 643	34 790

*Local Municipal population growth rate (2001 - 2011)
Source: StatsSA (2011) and Community Survey 2016;

3.5.4. Sample Size and Sampling Procedure

The best sampled population can be considered as a function of sample size and sampling method. The determination of sample size during the survey was a big task, considering time and fund limitations and population size involved and required laid down procedures and adopting of appropriate formulas. On the prescription of Lwanga and Lemeshow (1991), for populations above 10,000, the formula below is appropriate. In the formula, the total sample size is denoted as "n". Considering the computed total number of households which is (34,790), given the desired degree of accuracy at 0.05, the sample size was determined as follows:

$$n = \frac{z^2 pq}{d^2} \quad \text{...} \quad (3.1)$$

Where:

Z= the standard normal deviation at 2.0 which corresponds to the 95% confidence level

P= the proportion in the target population estimate to have a characteristic to be 50% i.e. 0.50

q= 1.0 P

d= the degree of accuracy is set at 0.05

This gives a total sample size of 400 respondents.

Furthermore, in order to compensate for non-responses, an adjustment was made to the calculated sample size with an anticipated response rate of 80%, and then the actual sample size arrived at:

$$n_s = \frac{n}{0.8} \quad \text{……………..………………………} \qquad (3.2)$$

Where n= 400

This gives a total sample size of 500

This implies that 500 households were interviewed through their respective heads (regardless of sex), proportionally distributed among the six selected towns across the local municipalities in Mopani District (Table 3.3). Respondents were selected based on their willingness to participate in the interview exercise. Enumerators were adequately trained to appropriately handle the administration of the questionnaires and conduct the interviews after obtaining the verbal consent of participants. Repeated calls were necessitated for households where a qualified member was not available at the time of the initial visitation.

3.5.5 Sampling Technique

Having established the household numbers in each of the selected towns as indicated in Table 3.3, the number of sampled households was estimated for each of the six towns. The procedure for estimation was adequately guided and statistically determined as described under sample size. Table 3.3 indicates the various sample sizes for respective towns estimated from the average household size and, the number of households. The perc-

Table 3.3: Sampled households from the selected towns in Mopani District

Municipality	Towns	Average HHSize	No of HH	HH %	Required sample size	Sampled HH
BA-Phalaborwa	Phalaborwa	3,1	5 861	16,85	67	84
Greater Letaba	Modjadjis Kloof	2,7	661	1,90	8	10
Maruleng	Hoedspruit	2,8	1 202	3,46	14	17
Greater Giyani	Giyani	3,1	8 922	25,65	104	128
Greater Tzaneen	Tzaneen	2,9	5 494	15,79	63	79
“	Nkowankowa	4.0	12,650	36.36	145	182
	Total		34 790	100	400	500

Source: Census StatsSA (2011) as projected to 2017 entage covered by each town over the total (six) selected communities gives the estimates for the proportion share and the number of sampled households per town, over the entire sampled households

The household distribution of the questionnaire was informed by the respective proportional share between the selected towns' populations. Household heads being the primary focus were selected using a systematic random sampling technique. Samples were drawn based on individuals, and each element (household head) in the population had an equal probability of being selected for sampling. The household from which the first respondent was interviewed was picked using balloting from the population to ensure an unbiased start, while subsequent samples were selected with the use of statistical random Tables (Morenikeji 2006).

3.5.6 Sampling Procedure

This study adopted multistage sampling techniques with the following sampling procedures centred on small and medium-sized communities carefully selected considering the varying minimum population defined as 'urban' (500 in South Africa) (Hartshorn 1991). One town each was purposively selected from the five Local Municipalities which constitute the Mopani District, except Tzaneen municipality, where two towns were selected. These towns were Giyani, Hoedspruit, ModjadjisKloof, Phalaborwa, Nkowankowa and Tzaneen.

3.6 Techniques of Data Analysis

The techniques that were used in analyzing data for this study are described in the following subsections.

3.6.1 Definition of Targeted Respondents

Guided by the peculiarity of this study, household heads formed the targeted population focus, regardless of sex, age and social status. However, where heads of households were not available, any designated or eldest adult member of the household who stayed in the house on a permanent basis was interviewed.

This project adopted various analysis technique which are highlighted and discussed in the following sub sections.

3.7 Measurement of Variables

This study identified some variables which were considered and hypothesized to have either direct or whatever influences on either the vulnerability levels of the households or its components. These variables are referred to as Objectively Verifiable Indicators (OVI) and were objectively measured with various statistical methods and tools, and these included the following:

3.7.1 The Trend in Temperature and Rainfall

To detect the trends (past and potential) of climate parameters, Time Series Analysis was adopted using the available annual and monthly parameters (temperature and rainfall) from high-resolution data from the global data. Time series analysis techniques were used to detect climatic trends and cycles in annual and monthly temperatures and rainfall during 1958-2017 in the study area. To comply with the definition by the WMO (1989), two (2) climate cycles' data records across Mopani District (1958 and 2017) were analyzed.

3.7.2 Topographical Analysis

As required to generate point data with x (Longitude), y (Latitude) and z (Altitude) attributes, Google earth pro was used to capture x,y, and z data in multiple points and different areas using Google pro to generate the data. The study further used 'gps visualizer' to add the elevation data at www.psvisualiser.cpm.elevaion. The UTM was projected under zones with z,y and z coordinates and "Datum" to WGs 84 and finally determined the contour interval.

3.7.3 Households' Socio-economic Attributes

This set of variables were individual respondent-related and were measured as interval and nominal variables (e.g. sex, income, marital status, age, occupation status, etc.) forming the background upon which individual susceptibility could be influenced.

3.7.4 Land Cover Changes

This study involved the use of geospatial analysis of available LandSat imageries for 1987, 1997, 2007 and 2017 to analyze the changes in land cover in the selected towns. Using data (LandSat imageries) from various public sources in bands, Color infrared composition was used to carry out the land use analysis and classification, Band 2, Band 3 and Band 4 were used for the years 1987, 1997 and 2007, and Band 3, Band 4, and Band 5 for the year 2017. This was because Bands 2, 3, and 4 on Landsat 8 use natural color, thus, to achieve a color infrared composition in Landsat 8, Bands 5, 4 ad 3 were used. The geospatial analysis was carried out with the use of ArcGIS 10.3 software. Images generated for different years from this analysis, were overlaid to obtain a visual representation of the extent of changes that occurred during the period for each of the land cover strata.

The land cover projection of the towns of study to year 2047 (informed by 30 year climate cycle) was carried out using the CA Marcov cellular automata in the TerrSet Geospatial Monitoring and Modelling System. Land cover change probabilities were created from the comparison of image classification of Landsat ETM 2007 and Landsat 8 OLI 2017 in Marcov. The Landsats' attributes are described in Table 3.4. The resulting probabilities were used to predict land cover for the year 2047 in CA Marcov. The prediction was validated by predicting 2017 land cover from probabilities obtained from earlier years (1997-2007), using the confusion matrix accuracy assessment technique.

3.7.4.1 Satellite Imagery Processing and Image Classification

The study acquired satellite imageries for 1987, 1997, 2007 and 2017. Table 3.4described the features of the acquired imageries

Table 3.4 Characteristics of the Satellite imagery used in the study

Selected Town	Image Year	Platform	Date Complied	Spatial Resolution	Source
Giyan	1999	Landsat	16/8/2019	30meters	United State Geological Survey
Hoedspruit	1999	Landsat	13/8/2019	30meters	United State Geological Survey
Nkowankowa	1999	Landsat	8/8/2019	30meters	United State Geological Survey
Phalarborwa	1999	Landsat	22/8/2019	30meters	United State Geological Survey
Tzaneen	1999	Landsat	28/8/2019	30meters	United State Geological Survey
Modjadjiskloof	1999	Landsat	6/8/2019	30meters	United State Geological Survey
Giyan	2009	UMD	22/7/2019	25meters	Google maps
Hoedspruit	2009	UMD	31/7/2019	25meters	Google maps
Nkowankowa	2009	UMD	20/7/2019	25meters	Google maps
Phalarborwa	2009	UMD	15/7/2019	25meters	Google maps
Tzaneen	2009	UMD	12/7/2019	25meters	Google maps
Modjadjiskloof	2009	UMD	8/7/2019	25meters	Google maps
Giyani	2019	Quantum GIS	20/6/2019	20Meters	Bing Microsoft
Hoedspruit	2019	Quantum GIS	24/6/2019	20Meters	Bing Microsoft
Nkowankowa	2019	Quantum GIS	27/6/2019	20Meters	Bing Microsoft
Phalarborwa	2019	Quantum GIS	29/6/2019	20Meters	Bing Microsoft
Tzaneen	2019	Quantum GIS	30/6/2019	20Meters	Bing Microsoft
Modjadjiskloof	2019	Quantum GIS	5/7/2019	20Meters	Bing Microsoft

UMD: Universal Maps Downloader (Source: Author, 2017)

The land use /land cover stratification adopted four categories of features as the training set, these include: the built-up area; vegetation; bare land, and water body (Table

3.4). These training sets were subjected to the conventional Supervised Raster Classification (Maximum Likelihood Classification) Algorithm (using ERDAS IMAGINE 9.2 software). The software was equally used to compose, convert the satellite imageries interface, and subsequently transposed to ArcGIS 10.3 software for the graticules, legend, scale bar and the true north composure. Table 3.5: shows the classification and description of land uses.

Table 3.5: Classification and Description of Feature

Classification	Feature Description
Built-up area	This includes residential, industrial and commercial structures, in towns and village settlements, transportation infrastructure that are revealed evidence of development
Water body	This includes those portions of land that are unaltrred or affected by human activities, of which the forest canopy still maintained
Bare land	This includes those portions of land that are altered or affected by human activities, with no forest nor vegetation cover

Source: Campbell, (2002) cit. in Owoeye 2016.

3.7.6.2 Accuracy Assessment

In order to perform accuracy assessment correctly, two types of information were compared. These are the Landuse/Landcover (LULC) of the towns of study in 2017 and the predicted LULC of the towns for 2017 based on probabilities generated from LULC changes of previous years. The LULC classification of 2017 (being the current year) was used as the reference map and the predicted LULC of 2017 was used as the interpreted map.

The relationship between these two sets of information was expressed in two forms namely: the error matrix (which describes the comparison of these two sources of information) and the Kappa coefficient (which consists of a multivariate measure of agreement between rows and columns of the error matrix). With the error matrix, the user’s accuracy and the producer’s accuracy was determined before obtaining the Kappa coefficient which showes the accuracy of the comparison. The User’s Accuracy (UA) which also measures the error of commission was computed using the number of correctly classified pixels compared to the total number of pixels assigned to a particular category.

$$UA = \frac{\text{Total number of correct pixels in a category}}{\text{Total number of pixels of that category derived from reference data(row data)}} \ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3)}$$

The Producer's Accuracy (PA) which also measures the error of omission showed the actual number of pixels correctly classified in a particular category as a percentage of the total number of pixels actually belonging to that category in the image.

$$PA = \frac{\text{Total number of correct pixels in a category}}{\text{Total number of pixels of that category derived from reference data(column data)}} \ldots\ldots\ldots\ldots\ldots \text{(3.4)}$$

The overall measure of accuracy was calculated for the entire image across all classes present in the classified image.

$$PA = \frac{\text{Sum of the diagonal elements}}{\text{Total number of accuracy sites (pixels)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

The Kappa coefficient (K) was used to measure the agreement between two maps, taking into account all elements of the error matrix.

$$K = \frac{\text{Observed Accuracy} - \text{Chance Agreement}}{1 - \text{Chance Agreement}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.6)}$$

Where:

Observed Accuracy = Observed correct data, representing accuracy reported in the error matrix (overall accuracy)

Chance Agreement = Expected correct data, which represents correct classification

3.8 Households' and Communities Vulnerability to Climate Change

This study adopted the UN Habitat (2011) measure which expresses Vulnerability in terms of its three components: the subtraction of 'Capacity to Adapt' from the summation of 'Exposure to and Sensitivity (incidence) towards climate-prone hazards'. This is symbolised as:

Vulnerability = Exposure + Sensitivity – Adaptive Capacity

V = E + S – AC ……………………………………… (3.7)

Where: V is Vulnerability; E is Exposure; S is Sensitivity; AC is Adaptive Capacity.

We further expressed this as:

PVI= HEI + HSI - ACI .... (3.8)

Where: PVI = Perceived Vulnerability Index; HEI =Hazards Exposure Index;

HSI = Hazards Sensitivity Index; and ACI = Adaptive Capacity Index

3.8.1 Exposure:

This was evaluated through the established trend of climate parameters, prevalence of climate related diseases, frequency of flood occurrence and respondents' duration of stay in years (reflecting how long they have persistently been exposed to these parameters and their associated health challenges). This was rated through a Likert Scale of Exposure, to arrive at the household exposure level and classification.

3.8.2 Sensitivity:

The strong assumption was adopted that the degree to which a system is affected or modified is via either internally or externally-induced disturbances (Gallopin, 2003). We therefore adopted the impact of climate disaster on livelihood as the indicators of sensitivity (Daze, *et al*., 2009). Loss of properties, fatalities i.e. death of family member to, and frequency of occurrence of climate related disturbances over the period were used. Natural resource-based income was assessed against remunerative income

3.8.3 Adaptive Capacity:

With the integrated approach the study adopted the prescribed screened indicators. This denotes the following components: social (Sietchiping, 2006), governance (Nhuan *et al.,* 2015), economic (Barr, 2005), Human (Wall and Marzal, 2006) as well as Ecological and Infrastructure (Nhuan *et al.,* 2016). In agreement with their capability to minimize risks from climate shocks through risk pooling, risk distribution or as a buffer during extreme climatic events are (Nhuan *et al*., 2015; Sen, 1987 and Borooah, 2011). About 52 Personal and 49 Communities Possession variables were used to arrive at a Personal Possession Index and Community Assets Index to determine the respective adaptive capacities (Appendix 1).

Aside from the consideration of the total monthly income of households as an indicator of coping capacity, the study also considered the households' Livelihood Diversification Index (number of incomes on which households depend). This was based on the assumption that households with income from diversified sources will have the opportunity to distribute impacts among them in the event of climate change-prone hazards, implying a higher capacity to adapt to such shocks (Nhuan *et al.,* 2015).

3.8.4 Aggregate Vulnerability Index:

The indicators that influence vulnerability were hypothesized and were analysed using the Ordered Logit Regression Model. The choice of this Model was informed by its ability to order and calculate the individual Household Vulnerability Index, the total Households' as well as the contributions of each hypothesized indicator. Descriptive statistics were used to complement the analyses..

3.8.5 Measurement of Community Adaptive (Resilient) Capability:

This study measured from households' and communities' screened lists of those assets, facilities and infrastructures that were hypothesized in literature to be very essential to the people and their communities' well-being. It also measured those that could rob them of the coping response to environmental hazards. Assets possession/deprivation were measured to determine the coping capacities of households and communities, considering about 52 assets (items) for households (Personal Possession (PP)) and 49 assets (items) for communities (Community Asset (CA)) (see Appendix 1). Dummy variable measurement was employed to derive Minimum Utility Values (MUV) from possessing an asset, where possession was scored: 1, and no possession was scored: 0 and as a missing value (adding to 0), where the person did not desire to have that asset. The summation of possessed asset scores presented the aggregate score of a household/community. The percentage proportions of both households and community were thus adopted as a Personal Possession Index (PPI) and Community Asset Index (CAI) from the prescribed screened lists of assets.

3.9 Data Analysis

The statistical methods that were used in the study are highlighted under this section while the Statistical Package for the Social Sciences (SPSS) version 20 was employed to analyse the data.

3.9.1 Socio-economic Attributes of Households

To assess the variation in attributes of the households across the selected towns, their neighbourhoods, as well as the district, the study employed descriptive statistics where cross tabulations and frequency distributions were used. To further test the significance level of the variations across communities, the Chi Square test was specified in the cross-tabulation procedure in SPSS.

3.9.2 Past Trends of Temperature and Precipitation

Considering data for the two climatic cycles the trend was examined using Time Series Analysis, adopting the Parametric T-test to determine the fitness of the slope Coefficient on a simple linear equation:

$$Y = a + bx \quad (3.9)$$

It will be significantly different from zero, if there is an indication of the presence of a linear trend the slope coefficient sign in the equation indicates whether a positive or negative trend exists. The year of recording forms the independent variable in the formula (x). The climate parameters form the dependent variables used to establish the Standardized Regression Coefficient (SRC) which represents the strength and signs of any trend for each of the variables (equally referred to as beta weight) which is equivalent to the Unstandardized Regression Coefficient multiplied by (Sx /Sy).
Where: Sx is the standard deviation of the independent variable; and

Sy is the standard deviation of the dependent variable.

The calculated value (SRC) is equal to the Pearson's Product-Moment Coefficient between the dependent and independent variables (Roy and Balling, 2004). While the absolute value of the Coefficient above 0.20 implies a statistically significant trend at the 0.05 confidence level. The trend for the current data was determined, whether positive or negative, and a score of +1 was awarded to the value in a time series that was larger while a score of -1 was otherwise awarded to values that were smaller. The overall score used for the time series data was Mann-Kendall statistic (non-parametric test). The choice of Mann-Kendall (non-parametric) statistics was informed by its strength in its application without necessarily making any assumption about the form of the underlying distribution. Though mindful of the shortcoming of its effectiveness capable of being hindered in the case of approximately or normal distribution, this loss in effectiveness is surprisingly relatively small leading to an impressive result (Sheldon 2017). Essentially, unlike t test, rank–sum test (non-parametric) is designed for the detection of any difference in population distribution (Kandethody and Chis 2021).

The data of the parameters were further analysed by estimating the monthly average of minimum, maximum temperature and the variations in both trends, while the monthly averages from the daily mean of rainfall was as well analysed, from which seasonal and yearly interpretations were done and presented in Figures (graphs)..

3.9.3 Assessing Households' Vulnerability to Impacts of Climate Change

The vulnerability assessment was conducted following the UNHABITAT (2011). This was measured by netting out the coping capacity score from the summation of the overall hazard scores (Exposure and Sensitivity), formula 3.7.

3.9.3.1 Measuring Households Exposure

Having established the trend of climate parameters, households' perception of how long they have been exposed to the hazards was rated through the Likert Scale of Exposure. Time Use: Not Exposed (1) for less than a year of exposure; Just Exposed (2) for 1-5years of exposure Exposed (3) for 5-10years of exposure; Very Exposed (4) for 11-15years of exposure and Very Much Exposed (5) for > 15years of exposure. This was subjected to Pearson' correlation analysis against the rate of change and trend in climate parameters, to analyse the existence or otherwise of the relationship between household exposure level and the rate of change in climate as hypothesised in this study.

3.9.3.2 Measuring Household Sensitivity

This is the degree to which a system is affected or modified by either internally or externally- induced disturbances (Gallopin, 2003). Impacts of climate disaster on livelihood were adopted as the indicators of sensitivity (Daze, Ambrose and Ehrhart, 2009). It included Loss of properties, occurrence and prevalence of climate related diseases, fatalities i.e. death of a family member, as a result of climate related disturbances over the period of investigation. It also incorporated income that is natural resource-based, for example, agriculture, livestock, forest, honey and handicraft and others that are not; that is, remunerative income such as salary jobs, non-farm skilled jobs, remittance abroad and social grants. (Piya, Maharjan, & Joshi, 2011b). Using Pearson's Correlation Coefficient, the existing relationship between household income structure and their sensitivity as hypothesized was examined. Therefore, the mean summation of the score on exposure (HEI) and sensitivity (HSI) at various levels of measurement was calculated. The calculated values were the mean scores of the overall hazards (HEI+HSI).

3.9.3.3 Measuring Household Adaptive Capacity

From about 52 identified Personal Possession variables and 49 Communities Possession variables, a Personal Possession Index (PPI) and a Community Assets Index

(CAI) were derived. The percentage possession from the hypothesized indicators from its summation was scaled from 0-1, implying a calculated indicator value that is more asymptometic to (closer, but not up to or intersecting with) 1, indicates a higher adaptive capacity, but any calculated indicator asymptometic to zero (0) indicates a weak or low adaptive capacity (Nhuan *et al*., 2015). The result of the calculated indices were further subjected to the Likert Scale of Capability as: Very Much Capable (5) for possession of 81-100% of prescribed assets; Very Capable (4) for possession of 61-80% of prescribed assets; Capable (3) for possession of 41-60% of prescribed assets; Not Capable (2) for possession of 21-40% of prescribed assets; and Not Capable at all (1) for possession of less than 21% of those screened assets.

3.9.3.4 Households' Vulnerability Assessment

On the whole, vulnerability was broken down into m specific dimensions of impact, and given a corresponding weight (wi, I =1,…, m) for each indicator. Following Filmer and Pritchett (2001), a Principal Component Analysis (PCA) was employed in weight assignments. PCA is considered appropriate in a work of this nature (Cutter *et al.,* 2003; Gbetibouo and Ringler, 2009; Nelson *et al*., 2010b) to avoid personal biases and emotions. Hence, PCA was run on Data Analysis and Statistical Software (STATA14) unconnectedly for the chosen indicators of exposure, sensitivity, and adaptive capacity indicators. The loadings from the first component of the PCA were used as the weights for the indicators. The weightings varied, ranging between 0 and 1, signs which denoted the direction of relationship with other indicators used to construct the respective indexes. Dimension ranged from values 0 = no impact to 1 full impact. The magnitude, as determined by the calculated value of the weights described the contribution of each indicator to the value of the index.

The sum of the weighted vulnerabilities across all dimensions gave the particular household's total vulnerability Vhhi, as:

$$\sum_{j=1}^{m} X_{wj} / \sum_{j=1}^{m} w_j = Vhh_i \quad \text{.......................................} (19)$$

The contributions of each of the identified dimensions (indicators) was derived by summing the dimensions and calculating the particular dimension's contribution to vulnerability. For the HVI, the sum of the weights is set to be:

$$\sum_{j=1}^{m} w_j = 100 \qquad \text{……………..………..……… …. …} (20)$$

An Ordered Logit Regression Model, which is an extension of the Binary Logic Model, was applied (STRATA 14) to examine the extent of household vulnerability, This Model is appropriate for scenarios with more than two values for the dependent variable (Dragos and Veres, 2007). In this study, the dependent variable has three categories: low vulnerability, moderate vulnerability and high vulnerability. The low vulnerability category was used as a reference.

According to Dragos and Veres, (2007), this is indicated as, lowly vulnerable = households with HVI ranging from 0 to 47; moderately vulnerable = households with HVI range of 47.1 to 63.7 and highly vulnerable = households HVI range of 63.71 to 100. The outcome was further subjected to Pearson's Correlation Coefficient to measure the strength of association that exists between the Households vulnerability Index and across the selected towns in the district as hypothesised.

Selected socioeconomic factors including but not restricted to age, gender, marital status, length of stay, level of education etc. were diagnosed as influencing factors of vulnerability in the study area. Thus, we further subjected the result to ANOVA (Analysis of Variance), because the independent variable is a categorised variable (not continuous). This enabled determination of the statistical significance of variation in the selected socioeconomic attributes of households, particularly as they influenced vulnerability levels across the selected towns as hypothesised earlier.

To examine the influence of the Livelihood Diversification Index (LDI) on the overall vulnerability level of households in Mopani, the LDI was calculated adopting the Herfindahl index of diversification (Kimenju and Tschirley, 2009), represented as:

$$D_k = 1 - \sum_{i=1}^{N} (S_{i,k})^2 \qquad \text{……………..………………………} (21)$$

Where;

Dk = the diversification index, i = specific livelihood activity,

N = total number of activities being considered;

k = the particular household, and

Si, k is the share of I th activity to the total household income for kth household.

The Diversification Index was further investigated through an Ordered Logit Regression Model (OLRM), to examine the influence which LDI had on the Household Vulnerability Index, if any, across the towns as hypothesised.

3.9.4. Analysing Attributes that influence Households' Vulnerability

To examine some attributes that influence HVI, the study further subjected to correlation analysis some household's socioeconomic characteristics (such as age, gender, income, highest qualification), being independent variables to determine which and to what extent has influenced households' vulnerability index. Pearson's Correlation Coefficient (r) was employed to test the relationships. In addition, the components of vulnerability (exposure, sensitivity and adaptive capacity) and some household characteristics' relationship was analysed using Multivariate Analysis of Variance.

3.9.5 Appraising Household Response Patterns to the Impacts of Climate Change

Patterns of household responses to the impacts of climate change was cross examined and subjected to cross tabulation with the selected towns and some socioeconomic attributes of the households and subsequently subjected to Chi-square to examine any spatial variation and verify the level of significance.

3.10 Spatial Analysis of Vulnerability (Vulnerability Mapping)

The Spatial distribution of households' vulnerability indexes obtained from the statistical analyses was graphically represented in the form of maps. The boundaries of the maps for the selected towns were established using google street Map, because of its ability to show delineated boundaries, based on their spatial coverages. These maps were plotted on google earth pro with paths saved as the Keyhole Mark-up Language (KML) polygon format which are usually in decimal degree. Since we worked with Universal Transverse Macartor (UTM) coordinates, KLM was converted to UTM and finally to a shapefile to make the work on ArcMap possible. This was possible because we made use of Global Mapper (an application used in area and distance calculation, raster blending, feathering, spectral analysis, contrast adjustment and elevation querying etc). Brought to the ArcGis interface was the shapefile to display, edit as well as map-based query and analysis.

The above process was undertaken by delineating towns into official sections (neighbourhoods). We then populated each neighbourhood with results from the Vulnerability Index analysis. Populated town maps were converted from shapefiles to raster files using Map Algebra, where vulnerability indexes were analytically transformed to maps.

3.11 Technology and Tools for Mopani Disaster Reporting System:

This part highlighted the technology and tools employed to desigh and develop the mobile application and web for Disaster Hotspot Reporting and Monitoring System: a mobile application and web-based system.

3.11.1 PreHypertext Preprocessor (PHP)

PHP is a recursive acronym for**PreHypertext Preprocessor (PHP)** the programming language allows web experts to develop dynamic content that can adequately interacts with databases. It is embedded in HTML. Its attraction is that its a server side scripting language can manage contents that are dynamic, tracking of sessions, databases, and can build complete site for e-commerce sites. In addition, It is zippy in execution, especially when compiled as an Apache module on the Unix sside. The MySQL PHP also supports a large number of major protocols such as POP3, IMAP, and LDAP. PHP4 added support for Java, PHP **is** Simple, Efficient, Secure, Flexible and familiar (https://www.tutorialspoint.com/php/index.htm; https://www.guru99.com/php-tutorials.html

3.11.2 Javaming Language

The Administrative web interface is designed and developed using HTML5, JavaScript, jQuery while the client mobile interface is developed using JAVA/XML (Extensible markup Language) through Android Studio and Webstorm (an Integrated development environment). The attractive features of JAVA include the following: it is Object Oriented, Platform Independent, Simple, Secure, Architecture-neutral, Portable and Robusthttps://www.tutorialspoint.com/java/index.htm, https://www.programiz.com/java-programming, https://howtodoinjava.com/java/basics/java-tutorial/

The business intelligence is developed using PHP (Pre hypertext Processor). It serves as the business logic that powers the application. The database system used as the back end is MySQL Database which helps to build a secure and robust data modelling across all entities through MySQL workbench. (Appendix 15)

3.11.3 MYSQL

MySQL is popular database management system software among developers that is used for managing the relational database. It is open-source database software, which is supported by Oracle Company. It is fast, scalable and easy to use database management system in comparison with Microsoft SQL Server and Oracle Database. MySQL is frequently used to compliment PHP scripts for creating good and dynamic server-side or web-based enterprise applications.https://www.javatpoint.com/mysql-tutorial

3.11.4 ANDROID:

Android is an operating system based on Linux with a Java programming interface for mobile devices such as Smartphone (Touch Screen Devices which supports Android OS) as well for Tablets too. This is an open-source operating system that can be customized, supports connectivity for GSM, CDMA, WIFI, NFC, Bluetooth, etc. for telephony or data transfer, etc https://www.tutorialspoint.com/android/index.htm, https://www.javatpoint.com/android-tutorial

3.11.5 SYSTEM DESIGN (Use of Google Map API)

Google APIs application was used for the design. The APIs are programming interfaces developed by Google that allow communication on Google platforms and services. The major attractions of the applicasion are that they, among others, are flexible and interactive as they facilitate integration to other services. Further, the client of Google API makes provisions for a common point of entry to Google Play services as well as provides the management of the network connection between the user's device and each Google service. The Google map API key was used to aid easy caching of residents location in their respective municipalities.(https://developers.google.com/android/guides/google-api-clienthttps://en.wikipedia.org/wiki/Google_APIs)

3.12 Data Presentation

This project adopted the use of plates, figures and tables for the presentation of data for clear understanding and visual appreciation.

3.13: Chapter Summary

This chapter has described the research processes employed to study the assessment of the vulnerability and adaptation of households to climate change in line with the aim and objectives. The chapter presents the climate variables (temperature and rainfall) that are key and related to household vulnerability to climate change. It further described the types and sources of data, the methods of data collection and analysis as well as the media through which the analysed data were presented. It is against these procedures used in this chapter that the subsequent chapters (four, five, six, seven and eight) were based in response to the objectives of the study. In the succeeding chapter four, the spatio-temporal trend of climate parameters in Mopani during 1958-2017 are presented.

CHAPTER FOUR

SPATIO-TEMPORAL ANALYSIS OF CLIMATIC PARAMETERS IN MOPANI

4.1 Introduction

While the preceding chapter dealt with the narration of the methodologies employed in this study, this chapter deals with the first objective, analysing the climate variables (Temperature and rainfall) that are key and related to household vulnerability to climate change. Both Temperature and precipitation are considered critical, as they can influence most socio-economic activities as variables that urban households consistently depend on for their wellbeing in the Mopani District. The annual cycles, interannual variability, and anomalies in Temperature and precipitation in the district were analysed in the district and the selected towns. The associated implications were equally discussed..

4.2 Temperature Trend in Mopani District (1958 - 2017)

This section presents the results of Time Series Analysis on the trends in interannual variability of temperature in the Mopani District from 1958 to 2017 (60 years) for a meaningful analysis of the variables. In developing countries generally, vital statistics such as data on temperature and rainfall dates perhaps to the colonial era and early independence in some cases. Even then, where available, the coverage is severely limited to airport cities, administrative headquarters or major cities. This explains why small and medium-sized cities, in most cases, are not covered by meteorological observations. Thus, this necessitates using “updated gridded climate datasets” such as the CRU TS3.10, which have a long history of observations and wide coverage. In this study, temperature values are extracted and used for subsequent analysis and discussion in what follows.

4.2.1 Interannual Cycle of Mean Minimum and Maximum Temperature 1958-2017

To show the behaviour of temperature from year to year, the interannual variability of temperature in Mopani was analysed during 1958 and 2017. As presented in Figure 4.1 illustrates the mean interannual variability of temperature (minimum and maximum) during 1958 and 2017.

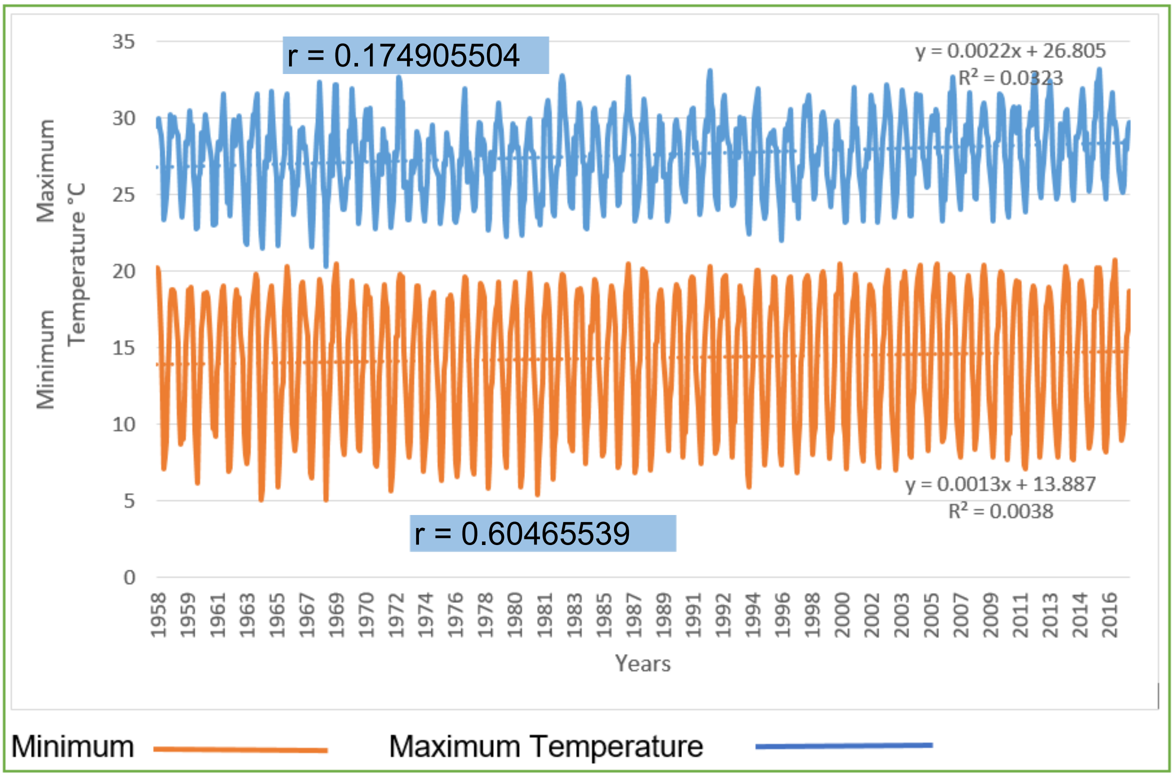


Figure 4.1 Mean inter-annual variability of temperature (Minimum and Maximum) over Mopani District (1958-2017)

From Figure 4.1, the mean minimum as well as mean maximum interannual temperatures both exhibit an upward trend throughout the period of examination (1958-2017) with the trend slope y=0.0013x+13.887 (Minimum) and y=0.0022x+26.805 (Maximum). By implication, Mopani District exhibited an increasing trend in temperature during the period of examination (1958-2017). The figure further illustrates that the mean temperatures (minimum and maximum) have consistently been on the increase at inter-annual time scales throughout the period in the district (see Chikoore, 2016; Sylvester and Phokele, 2013).

The temperature trends implications for rain-fed agricultural production and urban livelihoods in the district through the increased evaporation can reduced soil moisture. This is an indication of a worrisome situation that calls for caution because of the associated human health risks and other serious environmental externalities that are already being felt across the selected towns.

In the analysis of the annual cycle of temperature; it presents the analysis of the long term mean seasonal variation of temperature in the district (1958 to 2017). The result is presented in Figure 4.2 which shows a mean pattern with high values. The values as reflected in the seasonal variation are observed to be at a minimum (coldest) during the austral winter (June-August) between 7.76063296 and 9.69683785,

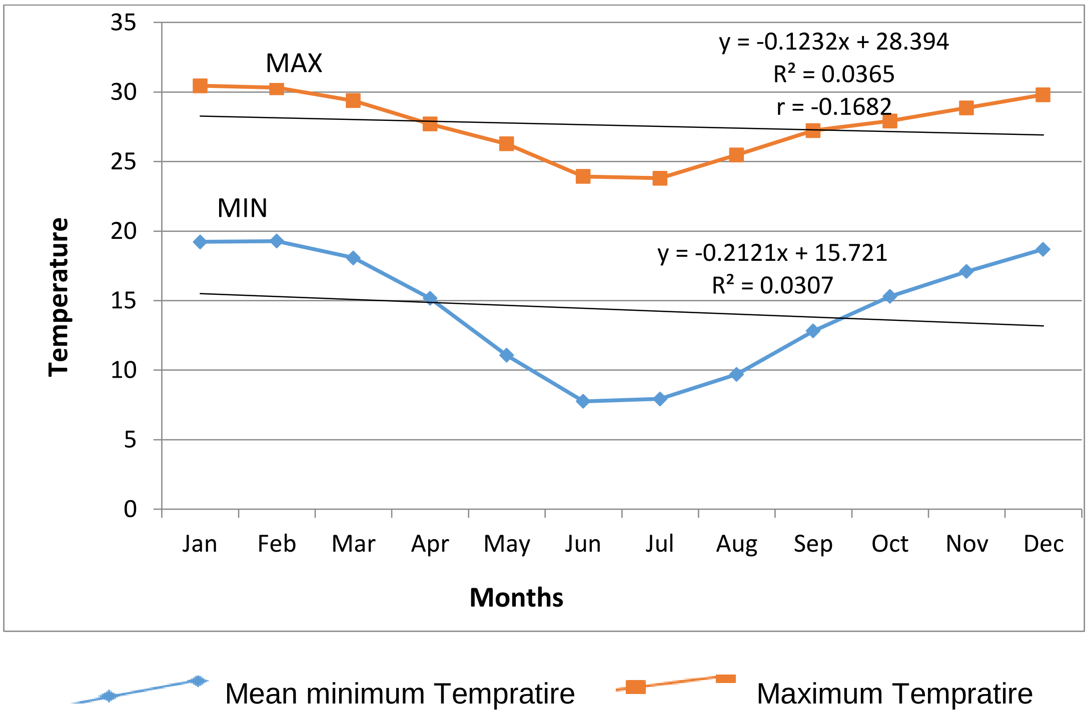


Figure.4.2: Seasonal variation of Mean Minimum and Maximum temperature 1958-2017

Between these months, the district experienced the warmest minimum temperatures with between 18.6948 and 19.2290°C. However, the seasonal variation of mean maximum temperature was consistent with the mean minimum trend with the peak (warmest) being between 23.9314 and 25.4752 (lowest) and 29.7984 and 30.4508°C the hottest being between December and February

Notwithstanding these trends, there are cases of extreme temperature (anomalies) observed during the same period of examination. For example, Figure 4.3 shows the anomalies in mean monthly temperature from 1958 to 2017 in Mopani District.

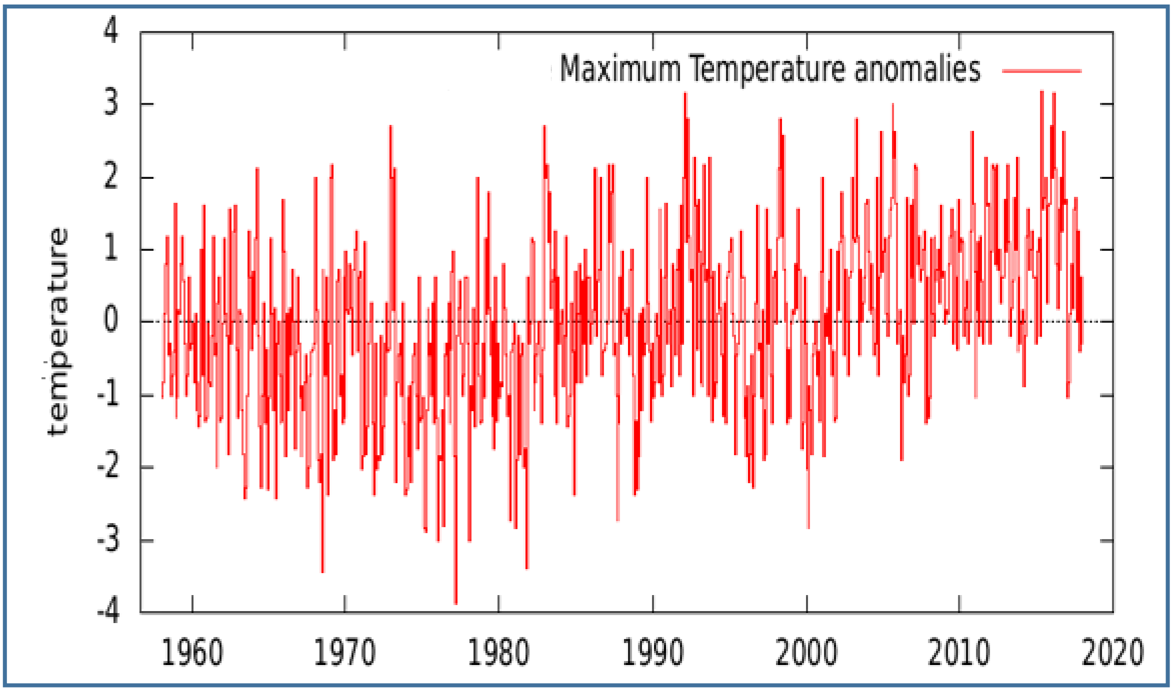


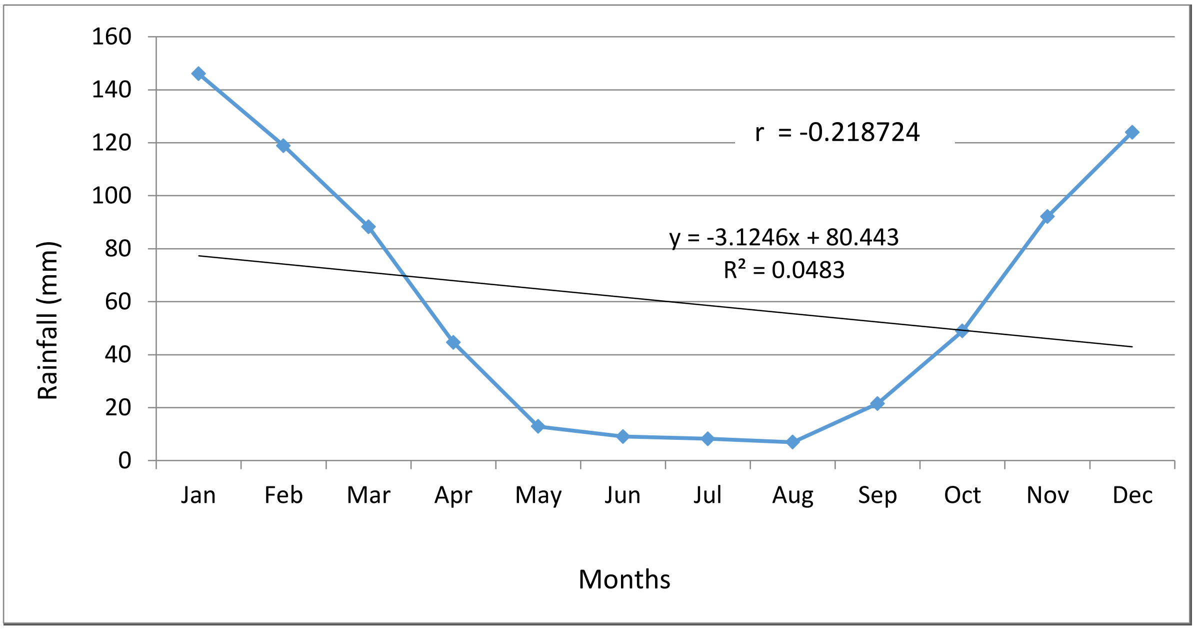
Figure 4.3: Anomalies in the mean monthly temperature (1958-2017) across Mopani District

It is shown that temperatures have become consistently warmer, particularly during the more recent period from the year 2000 (see Kruger and Nxumalo 2016). It equally indicates varying extreme situations at different years, ranging from severe cold weather and heat episodes, resulting in occasional droughts and wildfires. As shown in the figure, the district inhabitants may have at different times suffered heat-related stress in the extreme cases as a result of heatwaves with resultant drought effects over the years, e.g. in 1973, 1992, 2007 and 2016 (see also Maponya *et al.,* 2013; Mpandeli *et al.,* 2015).

4.3 Patterns of Rainfall in Mopani

The trend analysis of interannual variability of rainfall was conducted to assess the mean monthly rainfall values from 1958 through 2016 in the district using Microsoft Excel. The result Is presented in Figure 4.4 – 4.6 and show low and inconsistent rainfall trends in the Mopani region.

The mean annual cycle of rainfall in Mopani District was examined, and the results were presented accordingly. Figure 4.4 illustrates the mean annual cycle of precipitation over the Mopani District 1958-2016



Mean annual trend of precipitation
Figure 4.4 Mean annual cycle of precipitation over Mopani District 1958-2016

According to Figure 4.4, the mean annual cycle of rain across the district of Mopani is significantly seasonal, with an austral summer period (November to March) receiving the bulk of the rainfall. The mean rainfall for December, January, and February are respectively about 125 mm, 148 mm, and 121 mm. The district sometimes experiences the early onset of rain, around September and October, whilst rainfall cessation may also be early during drought. The rainy season may sometimes be prolonged until around April. The year's remaining months (May-August) are mainly dry with little or no rainfall.

The rainy season alternates between wet and dry spells at intra-seasonal periods in southern Africa (Makarau 1995). The length of wet and dry spells may determine the seasonal total even though the intensity of daily rain is also gradually increasing due to climate change. The heightened vulnerability levels of households may compromise their capacity to adapt to the impacts of climate variability and change in the urban area of Mopani District.

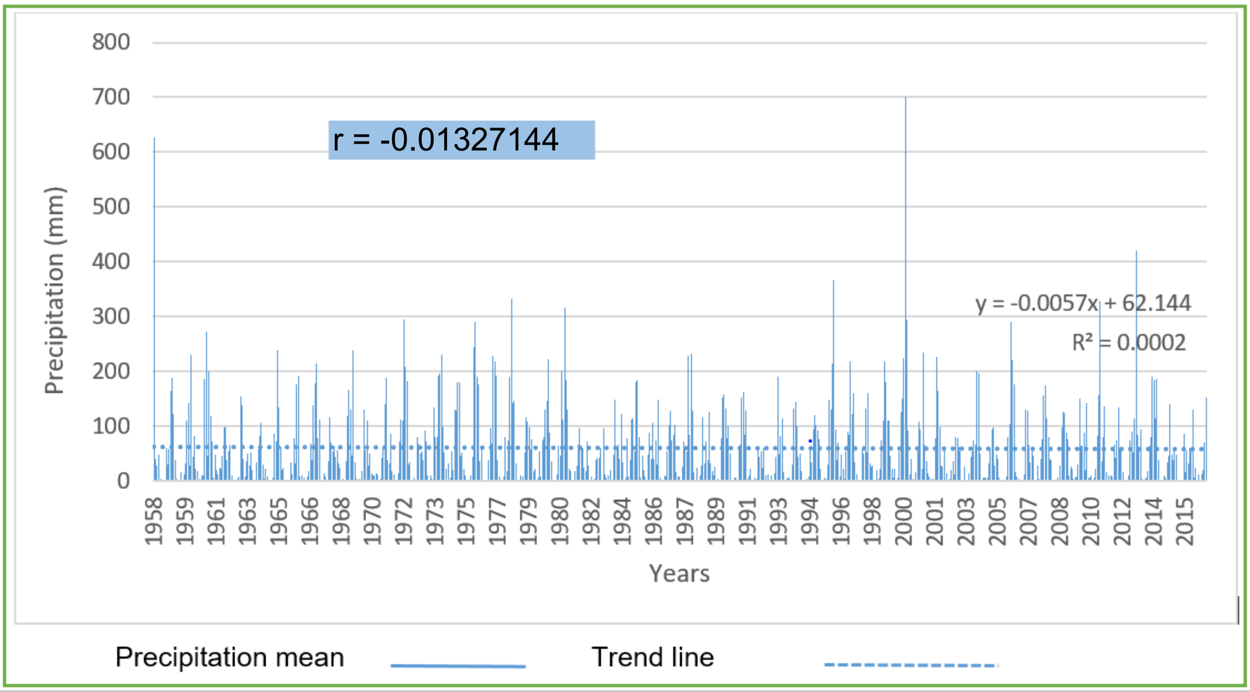


Figure. 4.5: Interannual variability of mean precipitation over Mopani District (1958-2017)

From the analysis of the available data (1958-2016), it was found that the district's record of annual average rainfall varied from year to year, from as low as 34 mm (1965), 33 mm (1970), 28.9 mm (1982) and 32 mm (2002). The highest annual average rainfall recorded in the district during the same period was about 137 mm in 2000 with over 700 mm in February. With R square = 0.0002, time accounts for no significant influence on the variation. The slope line (-0.0057x-62.144) indicates a decreasing (negative) trend with correlation coefficient r = -0.03289. However, a casual overview of the long-term average trends may be deceptive; especially when and where extreme events during the period have no significant influence (Chikoore, 2016).

Figure 4.6 indicates the high variability between extremes of both wet and dry seasons across the district of Mopani. This is a signal to the high household level of exposure invariably resulting in the increased vulnerability of the inhabitants of the selected towns to extreme weather events such as floods and droughts. These findings are consistent with Mulenga *et al*. (2003) and Chikoore (2016). They are also similar to the findings of Usman and Reason (2004) and Kabanda (2005), who found the highest variability of precipitation, occurred across seasons in the Limpopo River valley, the climatic region this study was based on.

The increase and prolonged dry seasons in Limpopo are not unconnected with El Niño, as drought seasons are characterized with frequencies of high dry spells (Chikoore, 2016).

Notwithstanding the trend as depicted in Figure 4.5, there are incidences of extreme cases during the period of investigation.

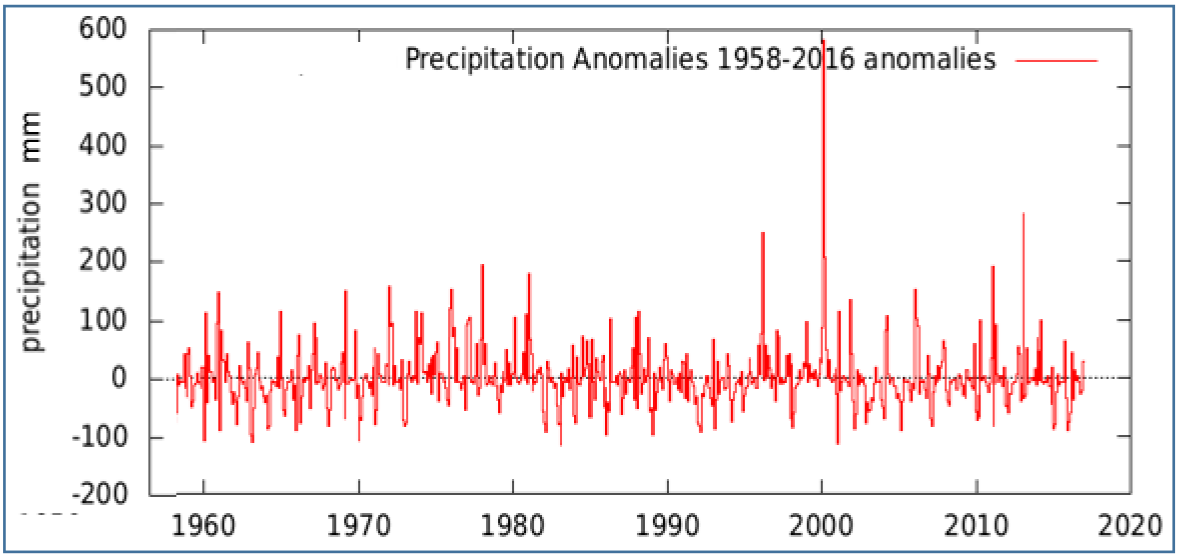


Figure 4.6 Interannual variability of rainfall anomalies over Mopani District: 1958-2016

The figure shows that drought tends to be a regular and recurring phenomenon during the period under consideration. Since every incidence of drought has its peculiarities, these might not necessarily be parallel to others in terms of spatial coverage, intensities and effects. The figure indicates a manifestation of widespread fluctuating low rainfall patterns throughout the two climatic cycles in the district (1958-2016). This signifies a persistent households' exposure to dryness, worsened by reduced water availability occasioned by a dearth of rainfall, resulting in drought situations in some cases. The stronger the intensity of drought, the wider the spatial extent of its negative anomalies. This result agrees with that of Kabanda (2005) in his study of the northern Limpopo drought.

However, there were interruptions of the trend, the most recent being recorded in 1996, 2000 and 2016 (Figure 4.5) when significant positive rainfall anomalies were recorded in the district. In 2000, up to 600mm of rain was dumped in Mopani, the highest in sixty years.

The inter-annual variation between seasons was examined, and rainfall was found to be highly variable, thus making it undependable over the district. The trend in the figure depicts a reducing trend in rainfall since the 1980s through to 1990s (see Kabanda 2005 in his study on the trend of drought in Limpopo Province). However, the findings of Jury (2013); MacKellar *et al.,* (2014) are contrary to this, indicated in the time series analysis (Figure 4.6).

The downward trend in precipitation suggests the potential of water stress in the district, the situation some countries in Africa already faced (Boko *et al.,* 2007). This promises to aggravate the number of people in Africa who are already facing an acute water crisis. The consequences would mostly challenge the elderly, children and women (the most vulnerable class) (Adeboyejo *et al.,* 2012).

4.7 Chapter Summary

This chapter analysed temperature and rainfall trends in the Mopani district from 1958 to 2017. The study analysed the inter-annual variability of temperature and precipitation and examined the anomalies in the temperature and precipitation patterns in Mopani District. The analysis of the trend (temperature and rainfall) is considered pertinent to the understanding of their nature and tendencies in the district, it equally not only critical to determine the exposure level of the residents, particularly those of the towns under study, but to identify extreme climate hotspot for proper adaptation measures.

The chapter demonstrates that the inter-annual trend of both the minimum as well as maximum temperatures was consistent, exhibiting an increasing trend throughout the two climatic cycles expressed by a linear regression of both minimum and maximum temperatures. This implies an increasing (warm) trend with time across the district of Mopani. The observed temperature displayed a changing phenomenon, indicating that the district residents have been exposed to warmer temperatures on average every succeeding year during 1958-2017. This phenomenon has evaporation of soil moisture implications with a significant impact on the rain-fed livelihood that is urban-related in the district. Nevertheless, there existed anomalous situations of extreme temperatures in different years, ranging from extreme cold weather and heat episodes, resulting in occasional droughts and wildfires, impacting significantly on the dwellers of these towns. While the reported trend in mean precipitation across the Mopani District was low with varying inter-annual intensities, there was equally high variability between extremes (anomalies) of both wet and dry seasons across the district.

The trend scenarios of the parameters imply a potential for high exposure and vulnerability among residents of the district. It is equally critical to influence most socioeconomic activities, upon which urban households consistently depend for their wellbeing.

Having analysed the trend and patterns of temperature and precipitation, as stated in objective one, the next section presents the analysis of the locational characteristics (land use and land cover changes, and the socioeconomic factors of the households). Access to community services in the selected towns is examined to understand their particular attributes that may influence vulnerability.

CHAPTER FIVE

LOCATIONAL CHARACTERISTICS AND ACCESS TO COMMUNITY SERVICES IN SELECTED TOWNS

5.1 Introduction

The preceding chapter deals with objective one of the study by examining the trends in the occurrence of climatic parameters, particularly temperature (1958-2017) and rainfall during 1958 and 2016. This chapter seeks to complement and establish the connecting links between objectives one and two by examining the locational characteristics of the towns selected for this study, to comprehend their terrains, land use composition and transformation, with the view to understanding their dynamics and relationships with the occurrence of climate-related hazards (e.g. flooding, heat episodes etc.). According to Saleh (2020) and Dolan and Walker (2006), there is the assumption that "lower elevation implies higher vulnerability", and "higher imperviousness is related to different degrees of exposure to heatwaves". Based on these assumptions, a detailed survey of the location characteristics of the six selected towns was undertaken to unpack their elevations and levels of impervious concrete surfacing. In addition, the features of the terrain (topography) of the towns was analysed using GPS Visualiser via GIS. The study undertook land uses and land cover changes over 30 years to analyse the changes that might have occurred during the period to influence households' exposure to climatic factors, particularly heatwaves and surface runoff.

5.2 The Location and Topographical Characteristics of Selected Towns in Mopani

In order to examine the influence of topographical characteristics on the households' vulnerability to climate change, the analysis of the terrains of the selected towns was conducted.

5.2.1 TzaneenTown

Tzaneen is described as a tropical garden town located in Mopani District of the province of Limpopo (Greater Tzaneen Municipality Integrated Development Plan, 2017). It is the second largest town in the province, situated within the tropical and subtropical, high rain, fertile lush, agricultural land.

Figure 5.1 depicts the topographical nature of Tzaneen. As shown in Figure 5.1, the nature of the topography of Tzaneen is generally low lying but undulating in nature.

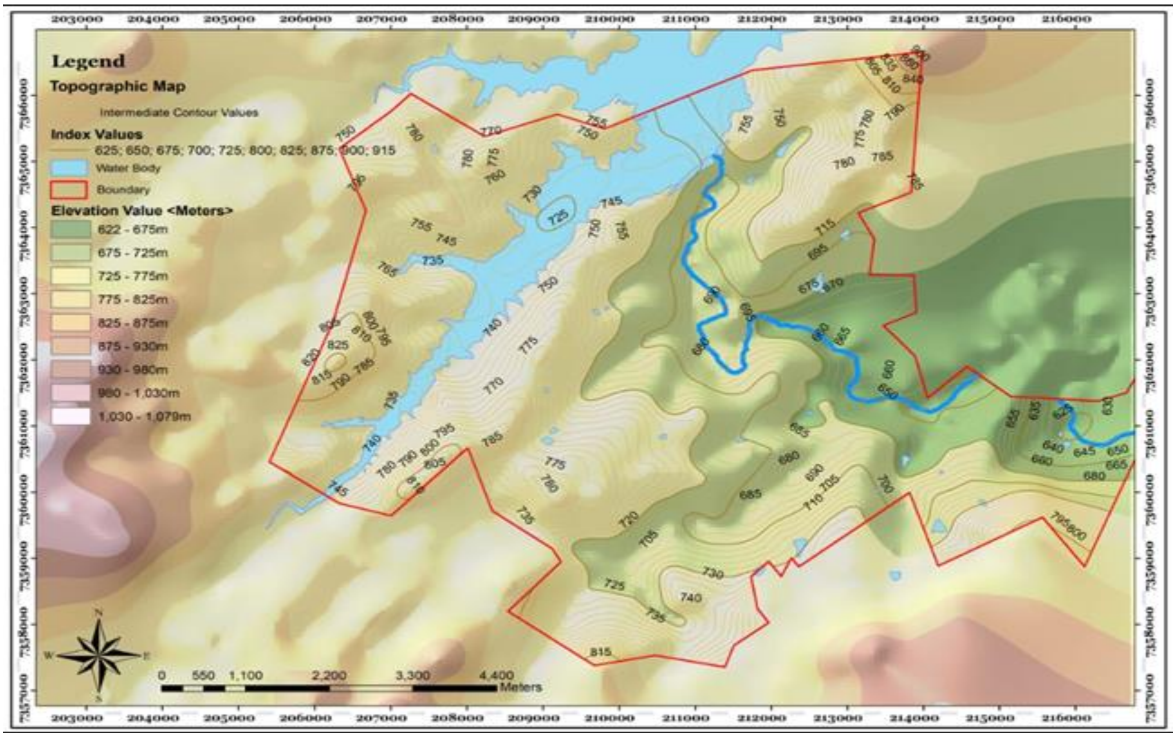


Figure. 5.1: Topographical Map of Tzaneen, Mopani District
(Source: Author's Field Data 2018)

The topography has an elaborate elevation towards the north, ranging from about 725m to 755m above sea level. In the south, it ranges from 680 to 815m above sea level. The land configuration to the east is between 625m and 695m and between 735m and 825m above sea level toward the western part of the town. Plate 5.1 shows the rivers on the eastern part of the town and the lake being recharged by small streams being covered by road construction.

Plate 5.2 also shows the grass land cover of the low lying areas with weeds blocking the drainage. The undulating relief of the town may be a possible factor responsible for the relative slow flow of rivers and which enhances runoff and overflow. This is capable of producing floods, especially when water passages are partially or totally blocked, and tributary flows are interrupted. This was common in Tzaneen during road construction.Plate 5.3 shows bareground suggestive of quarries next to the road along the R71, causing washing away of the soil surface, gullies, and exacerbating surface runoff during downpours.

Plate 5.1: Stream recharging the main river in Tzaneen

Plate 5.2 grass land cover of the low lying areas in Tzaneen

Plate 5.3 Quarried site along R71 Highway in Tzaneen

5.2.2: Nkowankowa town

The study examines the topographic characteristics of Nkowankowa to understand the nature and the likely influence it has on the households' vulnerability. Figure 5.2 describes the nature of the terrain of Nkowankowa town.

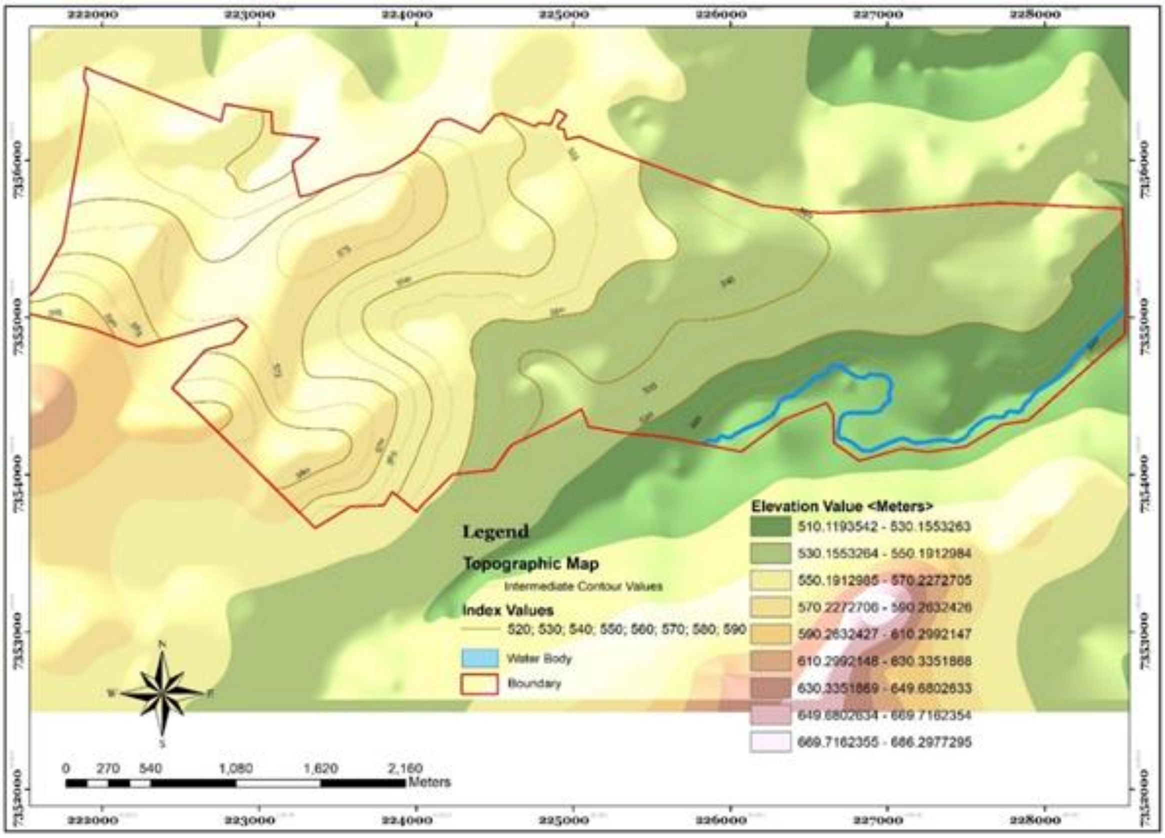


Figure. 5.2: Topographical Map of Nkowankowa, Mopani District
(Source: Author's Field Data, 2018)

Figure 5.2 reveals that Nkowankowa terrain is undulating but relatively flat. Its topography spans between 510m and 600m, extending from the east through the south-eastern axis, Nkowankowa has the lowest land height of about 510m. The terrain increases in height towards the core of the town, with water bodies on the south-eastern and northwestern portions flowing towards the eastern axis of the town. This exposes some parts of the south (Section D) to mild but regular floods, aggravated by the wet nature of the land in the same part of the town, through the inner zone. Higher elevations (about 595m) above sea level can be observed towards the west, through to the southwestern part of

Nkowankowa. Generally, Nkowankowa on average has between 520m (lowest) and 595m (highest) heights above sea level (Figure 5.2). The south east and southern part of Nkowankowa, towards the Letsitele River, marks the lowest part of the town. The low lying nature of the town's terrain, coupled with it's unproclaim status (characterized by unauthorized building) of Section D part of the town, reflects the destabilisation of the ecosystem of the area. Plate 5.4 shows the low lying terrain of the Section, characterized by

Plate 5.4: low lying wetland invaded by building in Section D of Nnkowankowa
(Source: Author's Field Photo, 2018)

Plate 5.5: Lack of Drainage on either side of Road D 5011 at Section B, Nkowankowa
(Source: Author's Field Photo, 2018)

wetland, significantly infringed upon with the invasion of built-up land uses, mostly unauthorized. Several buildings were constructed without recourse to basic planning standards with no basic infrastructure and services. Plate 5.5 shows a typical road (Road D 5011) with no drainage on either side of the road in Section B, Nkowankowa.

Despite the nature of the topography, significant roads in Nkowankowa did not have a drainage channel to complement the topography to ease off the evacuation of runoff water during a downpour. These scenarios had induced frequent incidences of flash floods in the town. These had exposed many households' to vagaries of weather and invariably induced and worsened their vulnerability to climate-induced hazards in the town.

5.2.3: Hoedspruit town

Hoedspruit, the administrative headquarters of Maruleng Municipality, according to Figure 5.3 is situated on a gentle sloping terrain. The elevation of the small town spanned

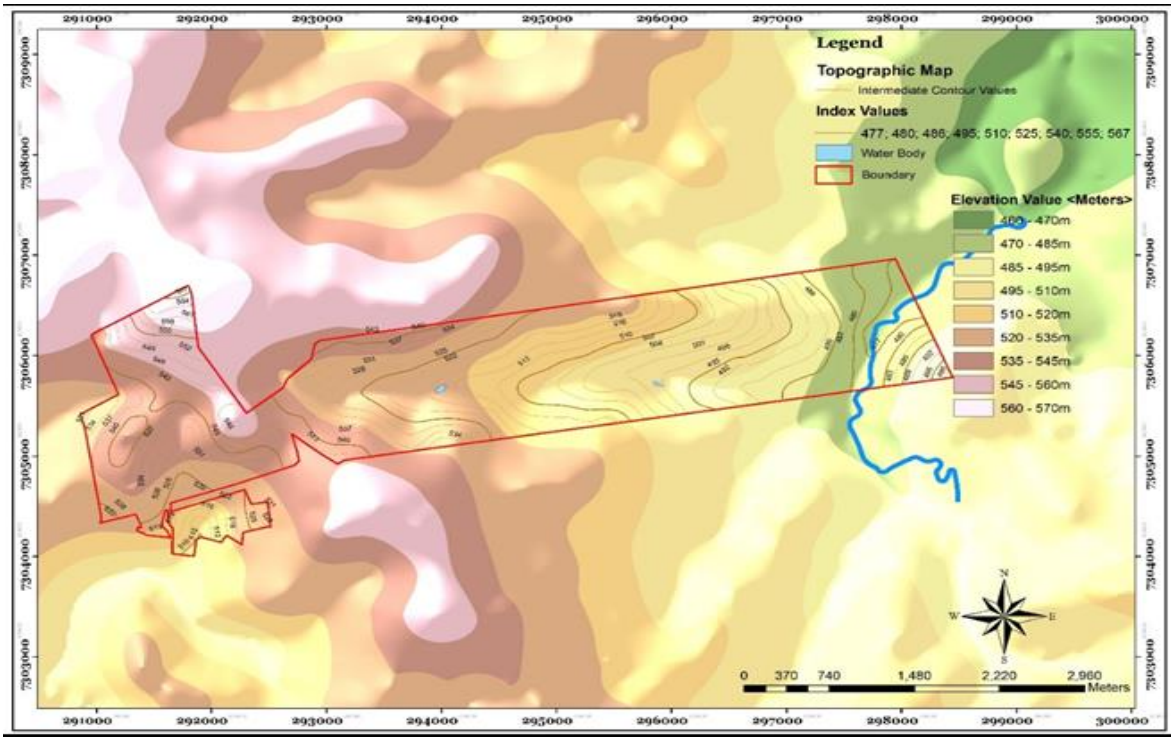


Figure. 5.3: Topographical Map of Hoedspruit, Mopani District
(Source: Author's Field Data, 2019)

between 477m on the eastern zone of the town to about 500m above sea level in the western flank. Figure 5.3 indicates that the terrain of the town is slightly higher in the centre of the locality, as the landscape gradually gains height towards the middleof the town. The topography implies its ability to induce high volumes of runoff water from the heartof the town to the surrounding periphery. This situation can increase exposure of both the town centre and the periphery to flash floods and exacerbates the residents' vulnerability, particularly during heavy rainfalls.

5.2.4 ModjadjiskloofTown

Formerly called Duiwelskloof, Modjadjiskloof is located at the foot of the escarpment. Figure 5.4 graphically depicts that the terrain has an average elevation height of about 875m above sea level with a very thickly forested valley. The town's steep elevation ranges from

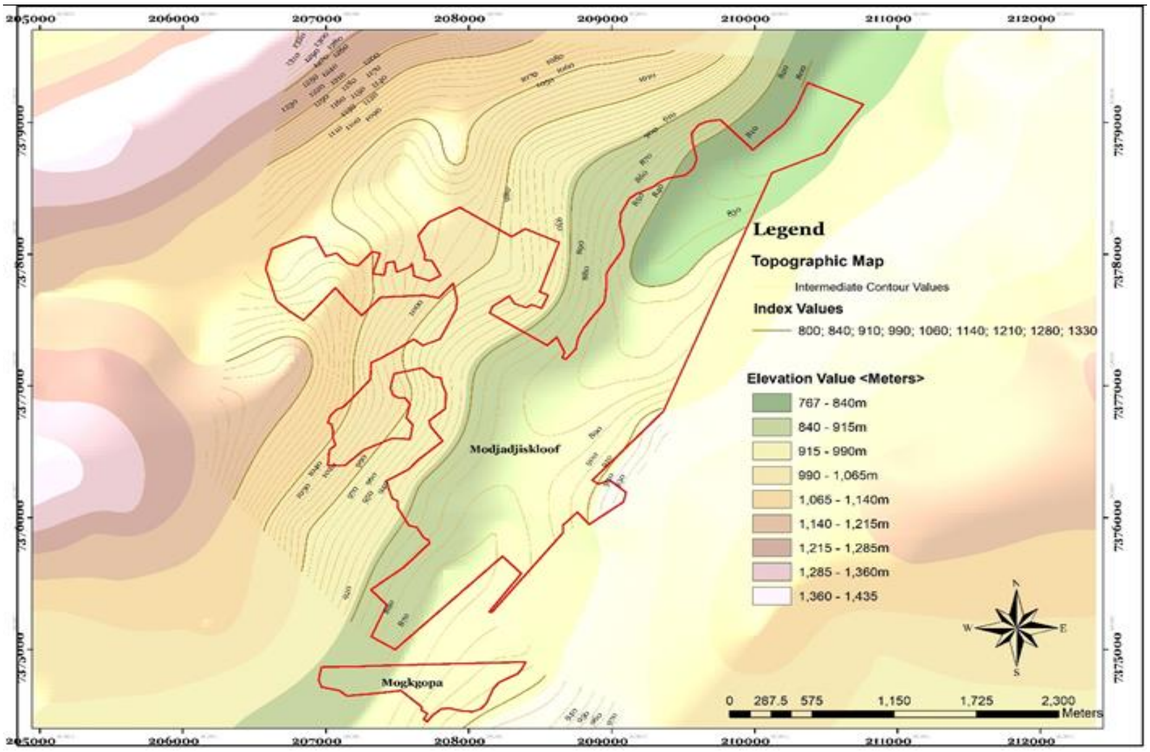


Figure. 5.4: Topographical Map of Modjadjiskloof, Mopani District
(Source: Author's Field Data, 2019)

650m to 1090m above sea level on the northeast to the Western part respectively. The very steep topography of the town enhances the surface runoff. Plate 5.6 shows a road and office under threats by runoff, occasioned by a steep elevation and lack of Drainage. Plate 5.7 shows a residential building under threat by terrain-induced erosion in Modjadjiskloof town, exposing the property and the occupants to climate related hazards. In the near future, the impact of erosion may be devastating for this building and the occupants if it is left unattended to.

Plate 5.6: Road under threats by runoff occasioned by steep terrain and lack of Drainage in Modjadjiskloof **(**Source: Author’s Field Data, 2019)

Plate 5.7: Building Foundation threatened by steep slope-enhanced erosion in ModjadjisKloof(Source: Author’s Field Data, 2019)

Plate 5.8: impervious surfacing as adaptation strategy against threats caused by steep elevation in Modjadjiskloof(Source Author’s Field Data, 2019)

Plate 5.7 shows a residential building under threat by terrain-induced erosion in Modjadjiskloof town, exposing the property and the occupants to climate related hazards. In the near future, the impact of erosion may be devastating for this building and the occupants if it is left unattended to. Plate 5.8 illustrates the impervious surfacing as an adaptation strategy that is equally capable of increasing a heat episode while at the same time escalating surface runoff.

Mogkopa is a small, isolated hostel in the southern axis, serviced by Modjadjiskloof. It is a settlement recognised as being part of the main Modjadjiskloof town. Although it is a small semi informal settlement, its topography is characterized by a gentle slope from the east towards the west (Figure 5.4). On the eastern flank, the terrain varies from 870m from the core area of the settlement to 900m above sea level, and equally ascends from 870m from the middle to 900m height to the east.

5.2.5: Phalaborwa

The result of the topographical analysis of Phalaborwa town is depicted in Figure 5.5. The figure shows that Phalaborwa has a low lying flat terrain ranging from 442m (being the highest point) on the north western area to 433.5m (being the lowest) elevation to the north-eastern edge of the town.

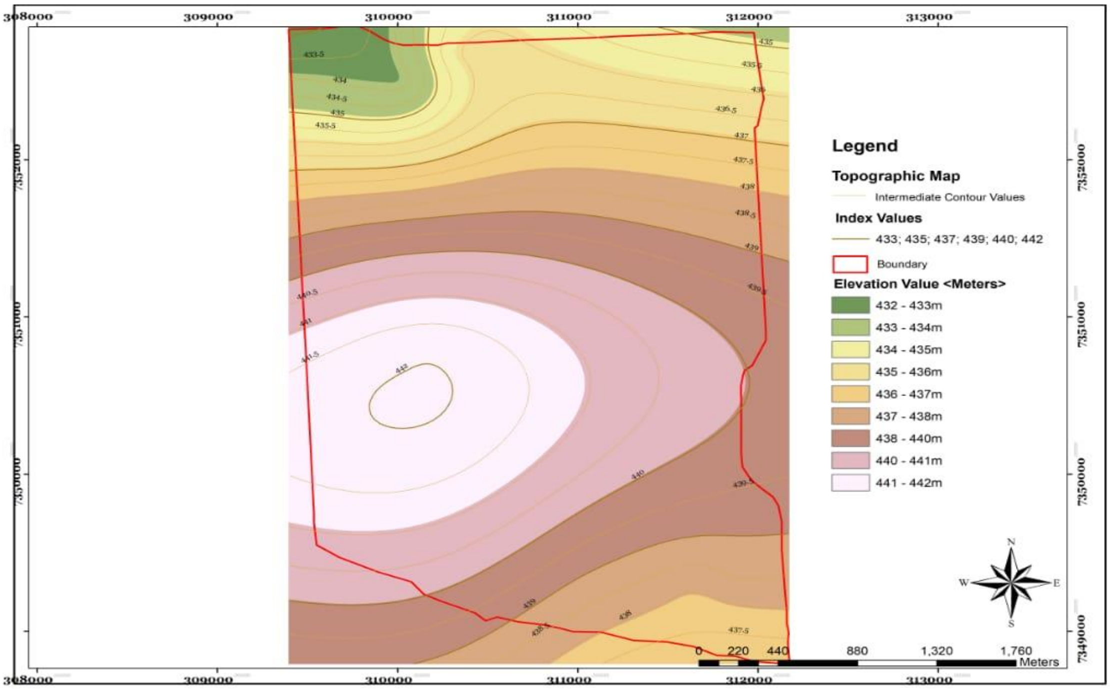


Figure. 5.5: Topographical Map of Phalaborwa, Mopani District
(Source: Author's Field Data, 2019)

The west and the central region of the town was as high as 440m above sea level, as shown in the topographical map of the town (Figure 5.5). The impacts of the topography on surface runoff may be enhanced by certain factors such as absence of drainage channels on roads. Plate 5.9 shows the impact of surface runoff as a result of the absence of drainage.

Plate 5.9: The impact of surface runoff in the absence of drainages on Hans Pirow Lu Street inPhalaborwa **(**Source: Author's Field Photo, 2019)

Plate 5.10: Erosion threatened Sealene road, Phalaborwa for Lack of drainage (Source: Author's Field Photo, 2019)

Figure 5.10 shows erosion- which is gradually destroying Sealene road in Phalaborwa. Meanwhile, debris eroded from high lying areas are equally seen to influence the blockage of drainages and tarred road surface. The resultant effects of this is the increased tendencies of water (runoff) to overflow to houses, shops and farms compounding human lives and livelihoods exposure and vulnerability.

5.2.6: Giyani town

Giyani topography is depicted in Figure 5.6 and it's characterized by a low elevation, situated on the northern bank of the Ritavi River with about 473m and 846m as minimum and

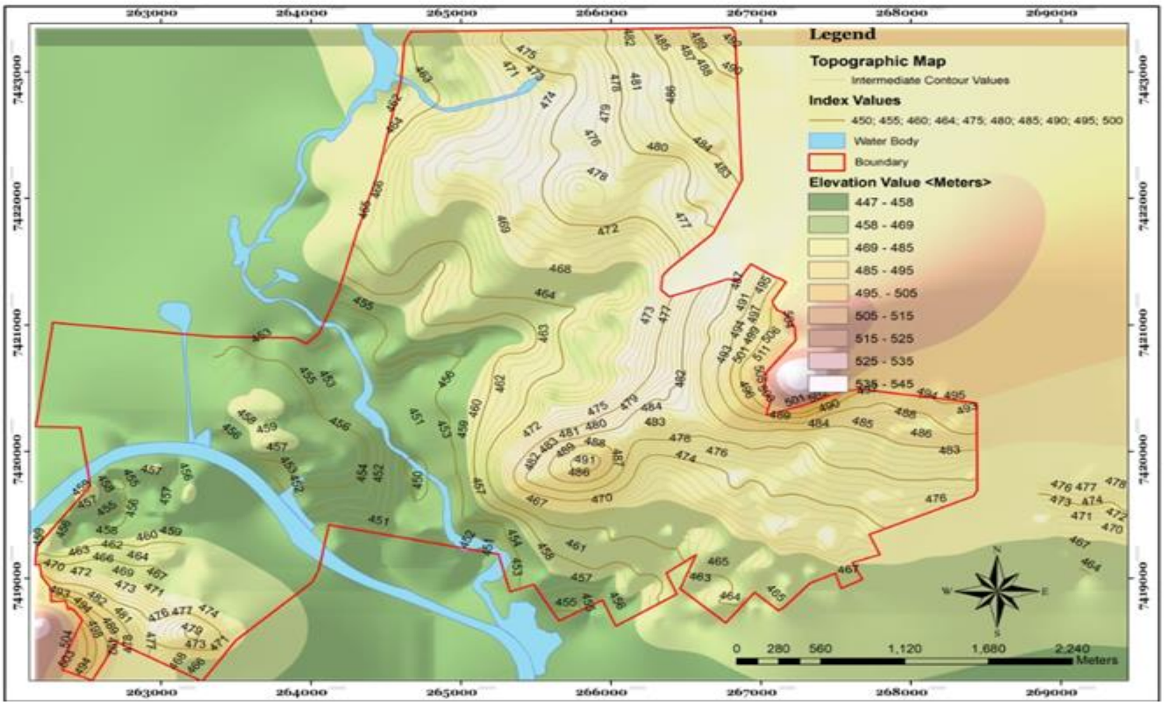


Figure 5.6: Topographical Map of Giyani, Mopani District
(Source: Author's Field Data, 2018)

maximum altitudes above sea level respectively. To the north, the terrain ranges from 462m (minimum height) to 492m (maximum height), with a water body on the eastern flank of the town. To the south, the elevation presents about 451m and 491m respectively as minimum and maximum heights. The landscape of Giyani town significantly slopes from north to west and from east to west, and equally from southwest to north- east. The valley has created a path for the flow of rivers with a topographical height not exceeding between 450m and 459m on the sides of the two rivers. These zones are situationally prone to flooding during heavy downpours.

5.3 Land use and Land cover Change in the selected towns in Mopani

This section further describes the locational characteristics of the study areas, with this stage analysing the nature of land use and land cover transformation as well-as their magnitude and trends.

5.3.1 Introduction

The extent of spatial transformation in land use and land cover in the study area is considered essential to determine its most likely relationship with vulnerability components, in particular exposure and capacity to cope. The submissions in this section were premised on the assumption that land use transformation and alteration (such as deforestation, impervious coverage, etc.) influences exposure and can compromise the households' coping ability in case of hazards. An analysis was undertaken to explain the changes which have taken place in land usage and coverage at different but regular time intervals (decadal) from 1987 to 2017 in the selected towns. This geospatial analysis was possible using the available Landsat images for 1987, 1997, 2007 and 2017 to analyse the transformation in land cover in these towns. Data (Landsat images) were sourced from various public sources with the use of ArcGIS 10.3 software.

5.3.2 Magnitude of Land Use and Land Cover change in the Selected Towns

Outlined below is the analysis of the land use and land cover changes of the selected towns in the Mopani District Municipality.

5.3.2.1 Tzaneen Town

The analysis of land cover changes obtained from the Landsat satellite images are summarised in Table 5.1. This shows the magnitude of land use and land cover changes in the selected towns from 1987-2017 and is graphically represented in Figures 5.7-5.10.

Tab. 5.1: Extent of Land use and land cover change in Tzaneen town in 1987-2017

Classes	1987		1997		2007		2017	
	Area(Ha)	%	Area(Ha)	%	Area(H)	%	Area(Ha)	%
Built up	448.11	7.37	501.12	8.24	653.58	10.74	1050.21	17.27
Vegetation	4924.26	80.95	4825.2	79.3	4386.2	72.11	4056.75	66.69
Bare land	253.35	4.16	464.49	7.64	728.28	11.97	625.95	10.29
Water body	457.29	7.52	292.23	4.80	315	5.178	350.1	5.75
TOTAL	6083.01	100	6083.01	100	6083	100	6083.01	100

(Source: Author's Computation, 2019)

The table shows that Tzaneen in 1987 had 448.11ha of land designated for built-up areas, an equivalent of 7.37% of the town's total area. Vegetation cover accounted for 4924.26ha (80.95%), while about 4.16% coverage was left for bare land. Water bodies covered457.29ha (7.52%) of the totalTzaneen land area in 1987.

A gradual increase in the built-up areas was observed in Tzaneen, for example between 1987 and 1997, there was a 0.87% increase, adding up to the total land designated for building to 8.24% and in 2007 this increased to10.74%. The town's built up land area unexpectedly jumped to 17.27% in 2017. This implies that the town is rapidly urbanizing and that concrete surfaces are on the increase. These are depicted respectively in Figures 5.7 a& b. Green belt (vegetation cover) dominated the Tzaneen landscape in 1987 followed by water body (blue color) and the built-up (brown color).

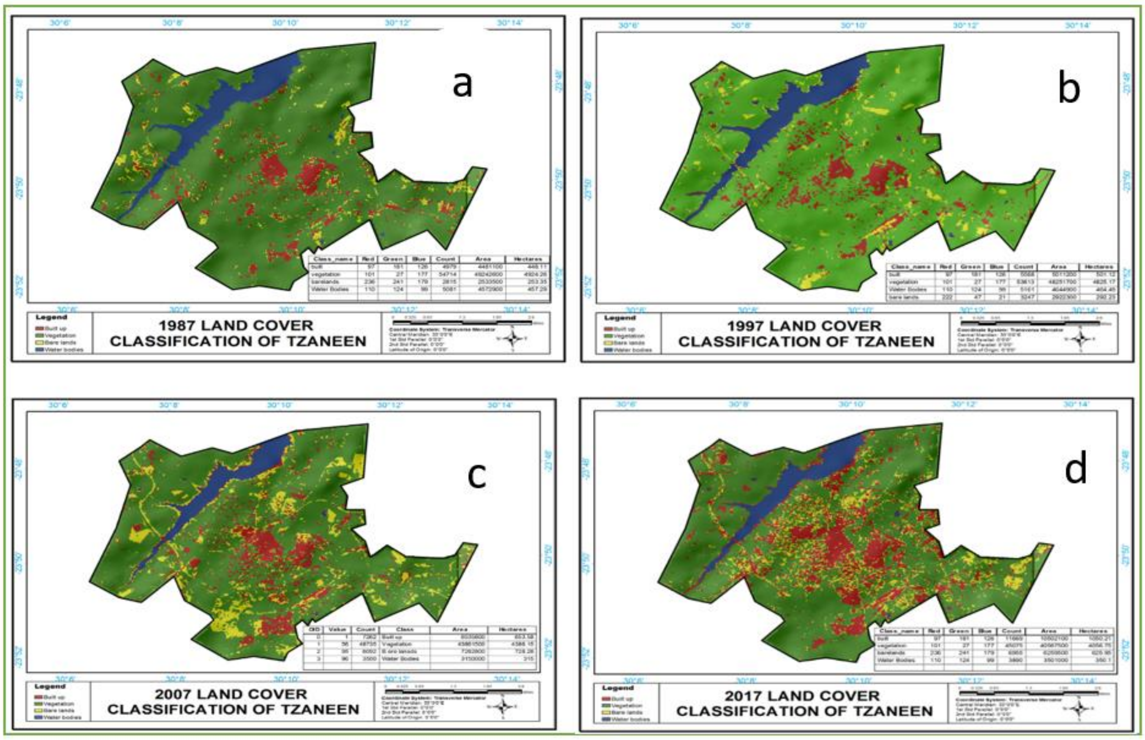


Figure. 5.7(a-d): Land use and land cover change in Tzaneen town from 1987to 2017
(Source: Author's Field Data, 2019)

Further analysis revealed that compared with vegetation cover, it is evident that Tzaneen vegetation cover was being lost to other land uses. For example (Figure 5.7a), the vegetation cover depleted from 80.95% in 1987 to 79.32% in 1997, while bare land increased from 4.16% to 7.64% during the same periods. Similarly, table 5.1 (as depicted in Figure 5.7c) shows that in 2007, the vegetation cover further decreased to 72.11%, while the bare land further jumped to 11.97%. In 2017, the vegetation cover had depleted to as low as 66.69% and the bare land decreased to over 10%.

From 1997 through to 2007, the impervious land cover (built-up) had invaded about 653.58ha, depicting 10.74% of the total Tzaneen town. To confirm the trend of consumption in the vegetation land cover, a look at the results shows that in Tzaneen town, vegetation cover

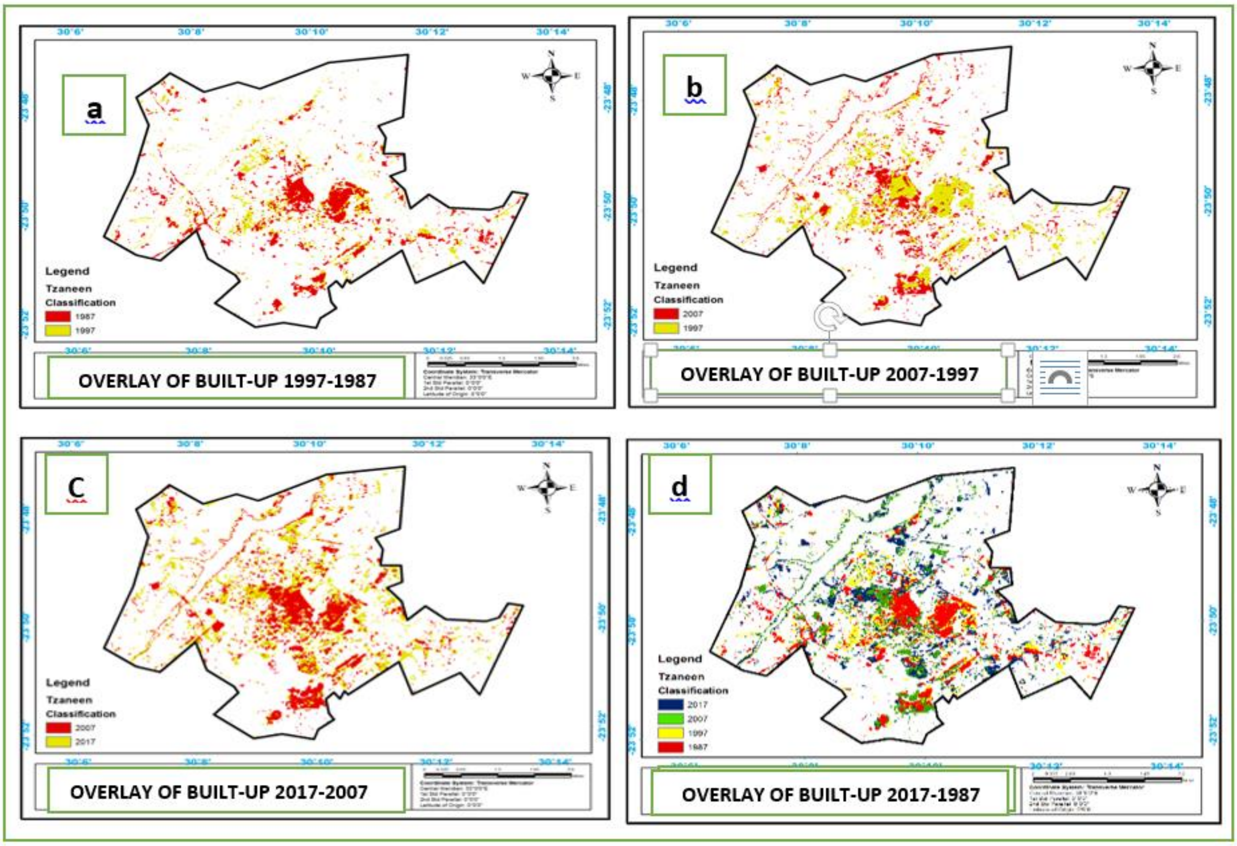


Figure. 5.8(a-d): Land use and land cover change in Tzaneen town from 1987to 2017
(Source: Author's Field Data, 2019)

was consistently in its depletion. In 2007, for example, the land use had reduced to just 4386.15ha (72.11%) and to 4056.75ha (66.69%), ten years after. Bare land was equally not spared by this development during these same periods. Thus, sizeable land that was vegetated was further compromised to increase bare land to about 728.28ha (11.97%). Except in 2017 (Figure 5.7d), the bare land cover was slightly consumed to retain 625.95ha (10.29), within the same period. Water body coverage was limited to 315ha (5.178%) of the total land cover. Figure 5.8 (a-c) shows the transformation in decades, while Figure 5.8d shows the transformation in totality experienced in Tzaneen in three decades, see appendix 3 also..

Addressing the changes experienced over the decades, Appendix 3 shows that not less than 88.18% of land area covering approximately 5363.82ha maintained their original uses throughout the period between 1987 and 1997 (Figure 5.7a). This trend was consistent between 1997 and 2007 (Figure 5.7b) as well as 2007 and 2017 (Figure 5.7c), where 81.69% and 80.32.82% of land cover retained their previous states respectively. No part of the town, as revealed in Appendix 3 was conceded to be built-up between 1997 and 2007. Although about 10% of the land was revegetated between1997 and 2017, 996ha of vegetation cover was compromised and rendered bare within the same period. This has rendered the landscape exposed and prone to soil erosion. Plate 5.11 indicates a typical infrastructural development threat, which rendered vegetated land bare and finally led to an impervious surface.

Plate: 5.11: imperveous land use invading greenbelt in Tzaneen (along R71)
(Source: Author's Field Data, 2019)

Figures 5.9 to 5.11 present the graphical representation of the results of the Pearson's correlation and Regression analysis conducted to examine the relationship between the transformations in land use and land cover against the time period from 1987 to 2017. The Figures respectively present the result for the built up, vegetation cover and bare land.

Figure 5.9 shows that the relationship between the trend in the built-up area of Tzaneen and time between the period 1987- 2017, with the correlation coefficient r =

0.92903 implying a positive (increasing) relationship between the variation in the built up area and time.

This result implies that as the time passed, the built-up area cover equally increased. While the regression analysis shows with y = 195.9x + 173.5, R^2 = 0.8631, implying that time can explain 86.31% of the variance in the built-up area of Tzaneen. Figure 5.10 presents the contrary picture during the years 1987 to 2017.

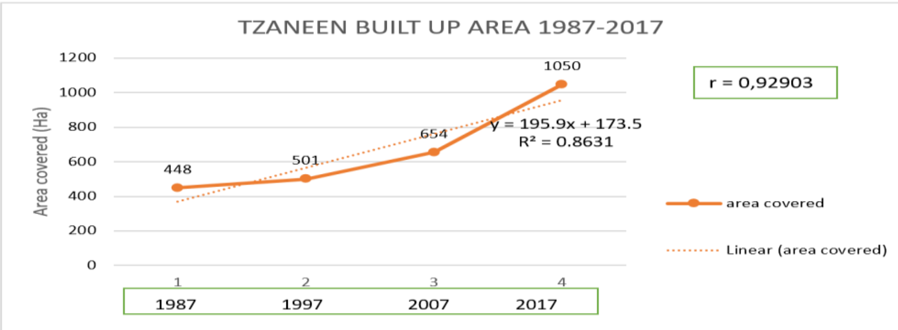


Figure 5.9: Trend of Percentage Change of Built-up in Tzaneen
(Source: Author's Field Data, 2019)

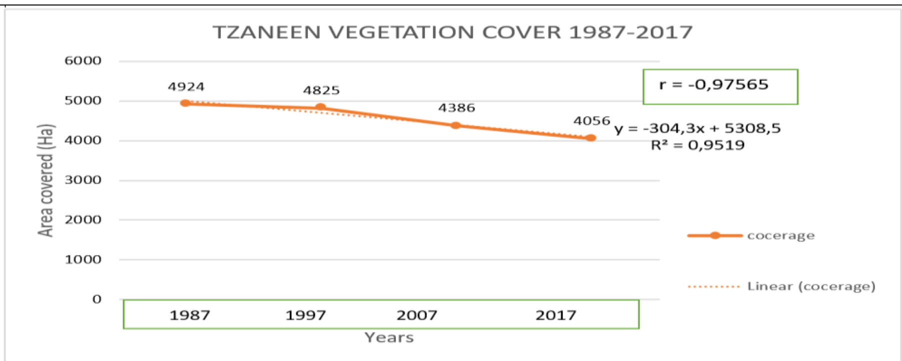


Figure 5.10: Trend of Percentage Change Vegetation in Tzaneen
(Source: Author's Field Data, 2019)

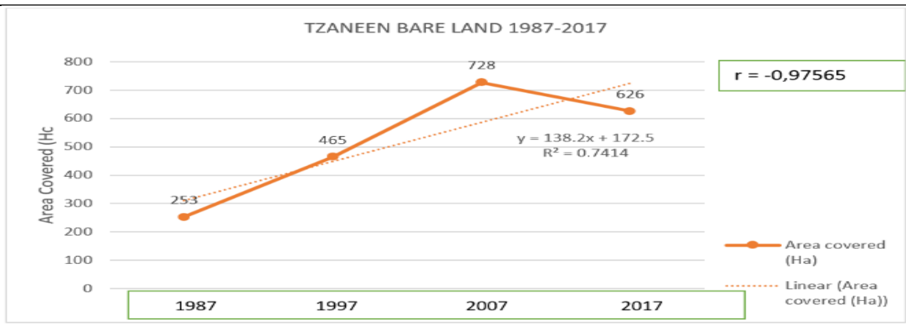


Figure 5.11: Trend of Percentage Change of Bare land in Tzaneen
(Source: Author's Field Data, 2019)

Thus, vegetation in Tzaneen witnessed a decreasing trend, moving in an opposite direction with time, with r = -0.97565, implying a negative relationship between vegetation cover and time (the result suggests that as year increases the vegetation cover reduces). With $R^2 = 0.9519$ implying 95.19% variance in vegetation cover can be explained by time. However, with respect to bare land, Figure 5.11 denotes an increasing trend from 1987 through to 2007 before it declined between 2007 and 2017. But on the average, throughout the three decades, the bare land increased with $r = 0.97565$.

The steady increase in the built-up areas in Tzaneen from 1987, through to 2017 may not be an unexpected development in a city of its type. This enjoyed the attention of the White apartheid planning policies and strategies for many years. These favoured the location of infrastructure and job creating land uses which attracted the patronage of some industries, major Malls and commercial hubs, and various multinational entities. Being the administrative headquarters of the Greater Tzaneen Municipality for some decades was equally connected to the expansion of the town, coupled with consistent population growth. However, the invasion into the vegetation area and the increase in bare land coverage can best be explained by the quest to provide for the increasing population, the basic infrastructure and service as well-as mechanised farming system in and around the town (see plate 5.1). These are exposing the land to climatic agents, which invariably enhances susceptibility through an exacerbated exposure. These findings confirmed that urbanization compromises vegetation and significantly alters land use cover and invariably enhances vulnerability through an enhanced exposure/ (Olayiwola and Igbavboa, 2014; Odjugo, *et al.,* 2015).

5.3.2.2 Nkowankowa Town

Table 5.2 summarises the results of the assessment of the transformation of land use and land cover in Nkowankowa in three decades (1987-2017). The table reveals a built-up area coverage of about 195.93ha (13.74%) in 1987. It exponentially increased by about

Table 5.2: Land use and Land cover Change in Nkowankowa town (1987-2017)

Classes	**1987**		**1997**		**2007**		**2017**	
	Area(Ha)	**%**	**Area(Ha)**	**%**	**Area(Ha)**	**%**	**Area(Ha)**	**%**
Built up	195.93	15.74	641.88	51.55	983.97	79.03	1018.35	81.79
Vegetation	989.82	79.50	586.80	47.13	119.16	9.57	197.10	15.83
Bare lands	59.31	4.76	16.38	1.32	141.93	11.40	29.61	2.37
Total	1245.06	100	1245.06	100	1245.06	100	1245.06	100

Source: Author’s Field Data, 2019

300% coverage in 10 years, to about 641.88ha (51.55%) of the total Nkowankowa land area. The trend was consistent through 2007 to 2017, when the built-up cover accounted for 983.97ha (79.03%) and 1018.35ha (81.79%) respectively as indicated in the same table.

Table 5.2 is supported by Figure 5.12a-d showing the land cover of 989.82ha (79.50%) being vegetation cover in 1987, this was invaded and reduced by about 32.37% in 1997. In 2007, vegetative cover in the town had substantially reduced from 79.5% in 1987 to less than 10% in 2007. However, between 2007 and 2017 the land use (vegetation) recovered from invasion to account for about 15.83%. As it can be observed, the rapid increase in the built-up areas in Nkowankowa during these periods suggests a significant loss in other land uses (e.g. vegetation cover and bare land).

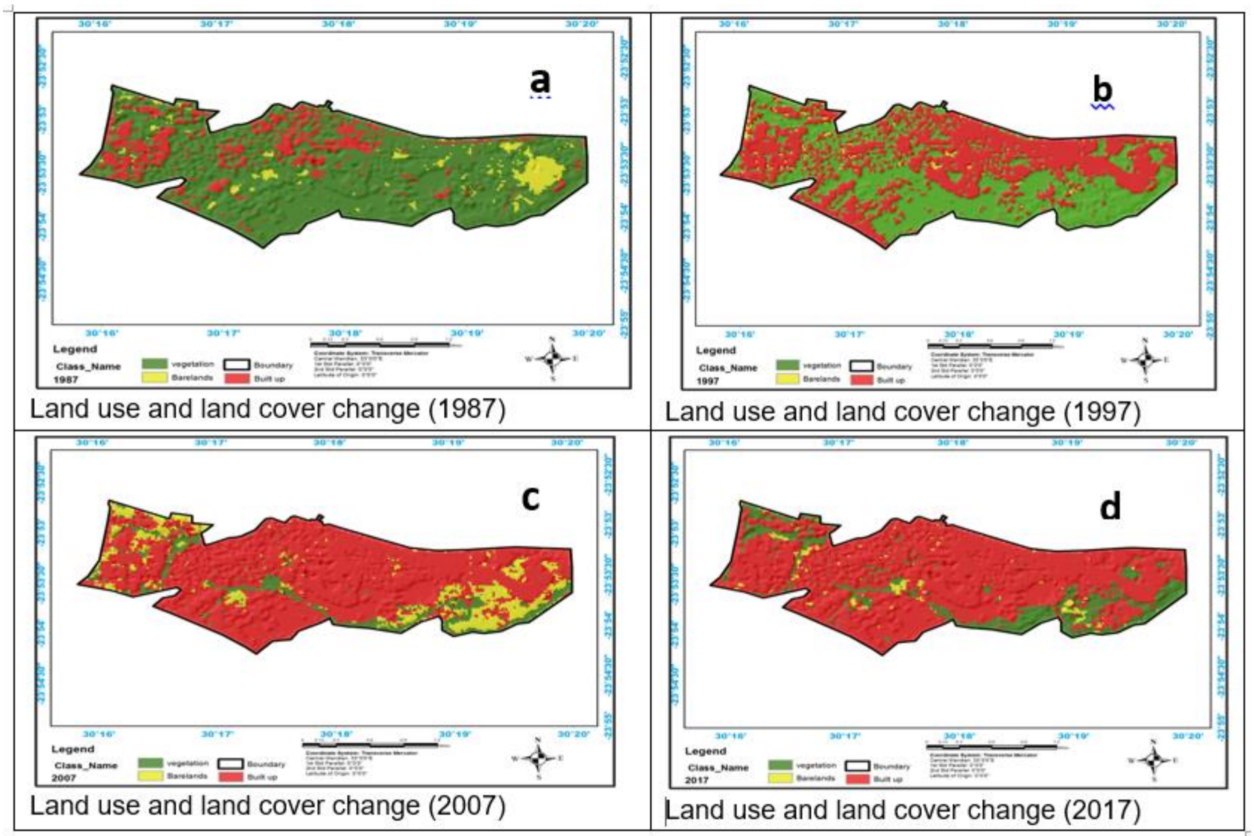


Figure. 5.12(a-d): Land use and Land cover Change in Tzaneen town from 1987to 2017
(Source: Author's Field Data, 2019)

There existed a relationship between vegetation cover and bare land in 2007. As the green belt reduced in coverage, the bare land increased in size. This suggests that more land areas are exposed to climatic factors than are covered. The extent to which each of the land uses affected each other will further be presented in the subsequent section of this report.

Figure 5.12a illustrates the spatial transformation in land uses from 1987 to 1997. The green color signifies vegetation cover, the red color depicts the built-up areas, while yellow shows bare land in Nkowankowa.

The succeeding decade's land transformations are captured in Figure 5.12b, with the graphical representations of the decade from 1997 to 2007 which show the transformations and coverages of the various land uses (built-up, vegetation, bare land) in Nkowankowa. The figure also shows the magnitude of changes recorded at various decades (1987 through to 2017).Figures 5.13 (a-d) and Appendix 4 reveal that about 35.75% of land area covering approximately 445.14ha experienced transformation throughout the period of 1987 and 1997 from green belt to buildings.

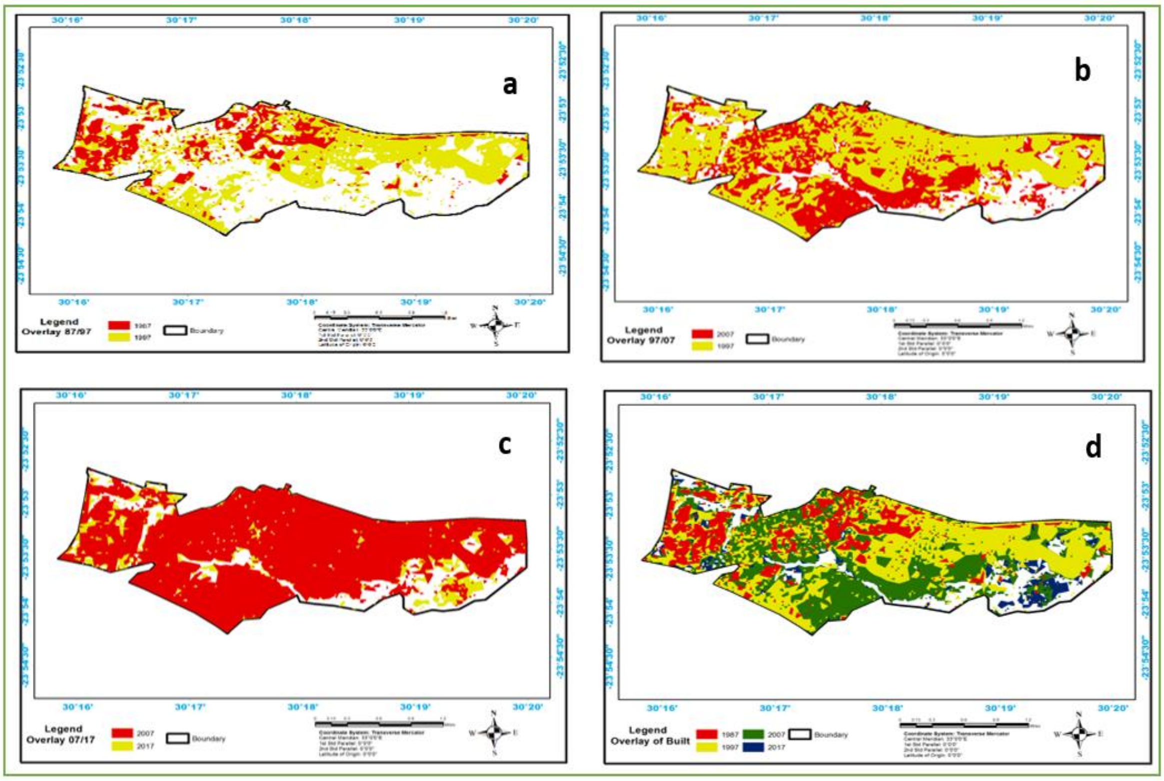


Figure. 5.13 (a-d): Overlay of Land use and Land cover Change in Nkowankowa town (at10 years interval) from 1987to 2017(Source: Author's Field Data, 2019)

About 33.93ha of bare land within the same period was invaded by the built-up area. However, the succeeding decades (1997-2007) witnessed 14.13ha and 35ha of bared land and vegetative cover respectively annexed by the built-up component of Nkowankowa town (Figure 5.13b). However, the built-up area still occupied an additional 5.58% (69.48ha) as well as 24.39ha respectively of bare land and vegetation between 2007 and 2017 (Figure 5.13c). Appendices 5-7 capture the land use and land cover transformations that the landscape of Nkowankowa experienced in their varying magnitudes from decade to decade from 1987-2017.

The loss of vegetative cover increased between 1997 and 2007 by over 1000% from less than one percent between 1987 and 1997. Some land uses retained their previous purposes for which they were used during this period, Figure 5.13d shows the general transformation in the land use and land cover during the three decades (1987-2017). Figure 5.14 shows the trend in the transformation of land use in Nkowankowa, depicting the result obtained from the Pearson's correlation analysis of built-up area.

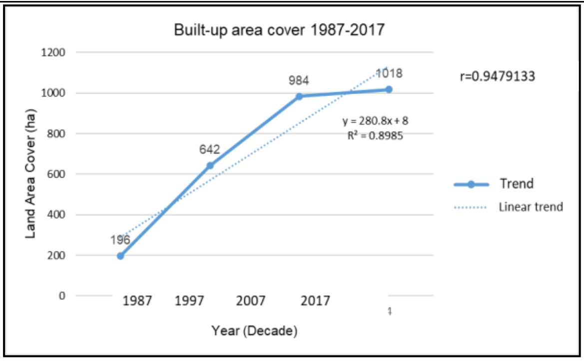


Figure. 5.14: Trend of Percentage Change of Built-up Area in Nkowankowa 1987-2017s

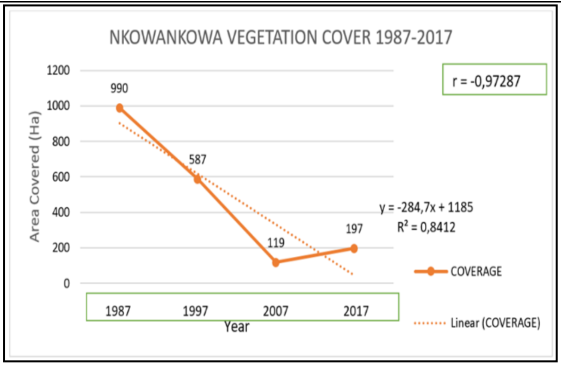


Figure. 5.15: Trend of Percentage Change of Vegetation Area in Nkowankowa

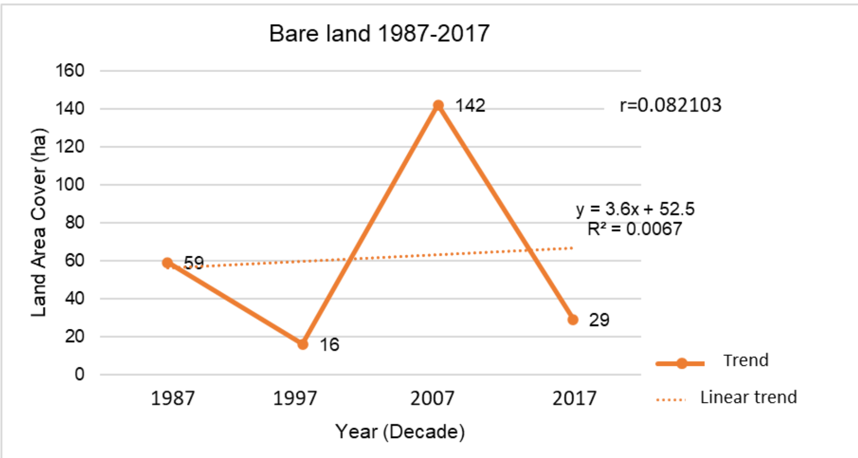


Figure. 5.16: Trend of Percentage Change of Bare land Area in Nkowankowa
Source: Author's Field Data, 2019

Figure 5.14 reveals an increasing trend in the built-up area when correlated against time, with r = 0.947913 and R^2 = 89.9%, implying a very strong upward relationship between time and built-up area change, i.e. the built-up area increased with time.

Figure 5.15 indicates the transformations that took place in the three decades. The result observed a negative relationships between vegetation with time, with r = -097287 during the period 1987 – 2007. On the contrary, Figure 5.16 presents the three decades (1987-2017) of bare land transformation in Nkowankowa town. The figure shows an increasing trend in bare land transformation, with r = 0.088243.

In summary, the built-up area consumed 32.9ha bare land and vegetation on an annual basis, while about 4ha of vegetation was equally transformed on a yearly basis to bare land from 1987 to 2017. The trend, if left unchecked could endanger the environment, as well as aggravate the warming tendencies of the town. The factors that may be responsible for the transition recorded in the built-up sector of Nkowankowa are not improbable. These were partly and significantly influenced by the influx of people to the township on an annual basis, on one hand. This is because Nkowankowa is not only seen as a child-friendly township, but largely as a low crime rate town, and thus a liveable city. On the other hand, the town enjoys the attention of the Municipality in services delivery and extension. Despite the fact that the Township is not fully under the management of the municipality, yet Section D for instance, under the control of the Traditional Authority, continues to enjoy provision of basic services from the municipality despite their unproclaim status. This implies cheap land, free water rates, free waste evacuation and free tenement rates. These have together contributed to cheap building construction compared to other proclaimed portions of the township with almost equal advantages.These have however facilitated, sprawling, as development invades wetland and flood-prone sites, with significant impervious development. Plate 5.12 illustrates a typical.

	
Plate 5.12: Wetland/ vegetation invaded by built-up land cover in Nkowankowa	**Plate 5.13:** Impervious Land cover inNkowankowa, Section A

development in Nkowankowa invading wetland/vegetation, resulting in to situation that aggravates surface runoff and flash floods during a downpour.

Similar development can be seen as captured in Plate 5.13 showing a typical example of landscape that was dominated by concrete and asphalt surface which prevents the penetration of water and hence, escalates surface runoff on one hand, while on the other hand it traps head during the day and releases it at night creating an urban heat island in the town.

5.3.2.3 Hoedspruit Town

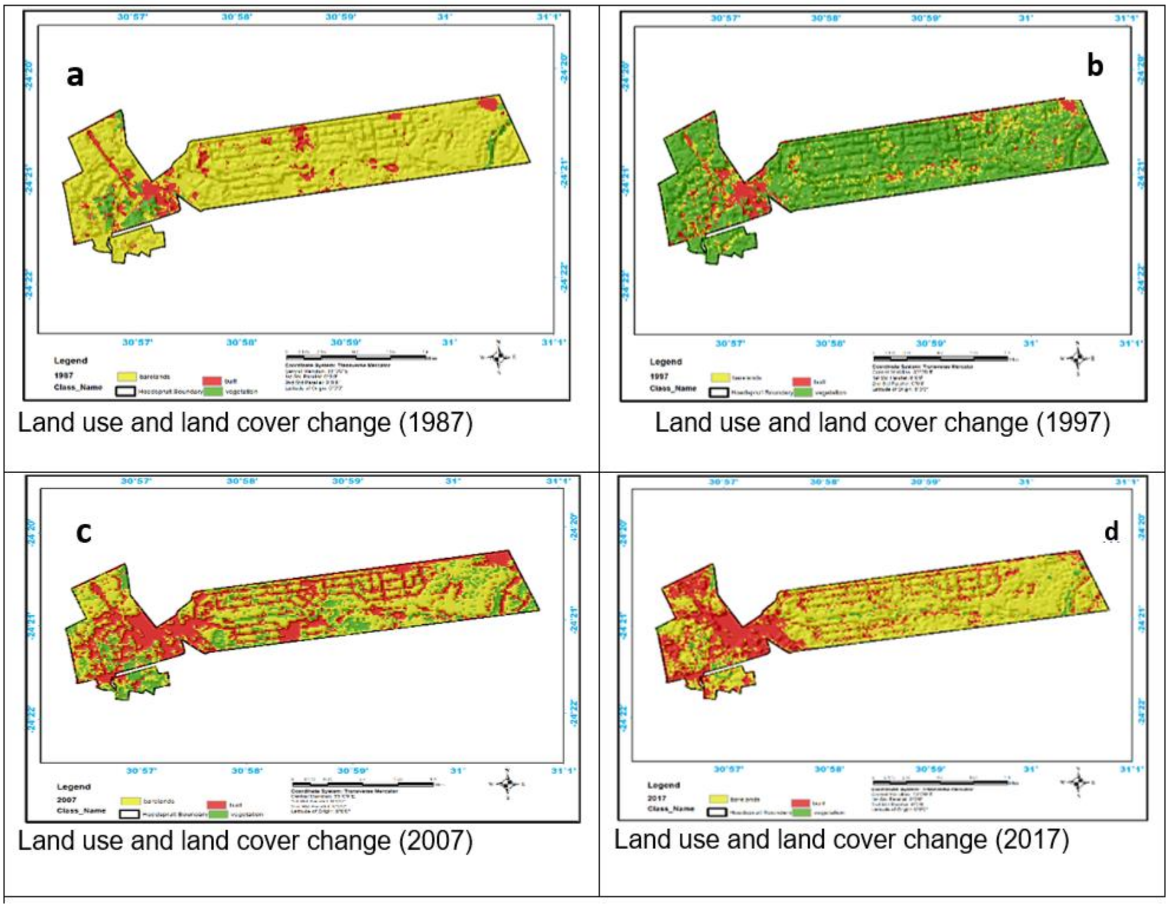
Results of Analysis, as summrised in table 5.3 reveals that in 1987, built-up areas claimed 98.37ha i.e. (10.18%) of Hoedspruit's total land area, while about 824.58ha (85.34%) and 43.29a (48.8%) respectively were covered by bare land and vegetation. Similarly, in 1997, 15.32% and 15.38% of land were respectively accounted for by built-up area and bare land. Significantly, Hoedspruit town landscape was dominated by vegetation in 1997 covering about 69.3%, a clear departure from what was obtainable in 1987. Table 5.3 shows the classification of land use and land cover changes in Hoedspruit between 1987 and 2017.

Table 5.3:*Extent of Land use and Land cover Changes in* Hoedspruit *town (1987-2017*)

Classification	1987		1997		2007		2017	
	Area(Ha)	**%**	**Area(Ha)**	**%**	**Area(Ha)**	**%**	**Area(Ha)**	**%**
Built up	98.37	10.18	148.05	15.32	285.03	29.50	345.24	35.73
Vegetation	43.29	4.48	669.6	69.30	31.23	3.23	161.01	16.66
Bare lands	824.58	85.34	148.59	15.38	649.98	67.27	459.99	47.61
Total	966.24	100	966.24	100	966.24	100	966.24	100

Source: author's Field Data, 2019

Figures 5.17 (a-d) show the spatial representations of the observed trends in land use transformation at different decades, between 1987 and 2017 in Hoedspruit. The built-up areas are shown in red color, vegetation cover in green and bare land depicted in yellow.Figure 5.17a illustrate the graphical representation of land uses as at 1987 and shows that out of the total 966.24ha of land only 105ha was designated for built–up, 4.48% for green belt. The largest proportion (85.34%) was accounted for, by bare land. On a similar note, through 1997, 2007 and 2017, up to 15.3%, 29.5% and 35.73%alterations were recorded for the same use accordingly. The vegetation component of the town respectively fluctuated to cover from 69.3% to 3.23% and 16.66% during the same period. Hoedspruit bare lands that was about 824.58ha (85.34%) in 1987, lost its status of dominating land use in the town to vegetation cover by declining to 148.59ha (15.38%) in 1997. Bare land regained some significant proportion ten years after to retain 67.2%, but lost some again to maintain 459.99ha (47.1%) in 2017 (Figure 5.17c). Figures 5.17b and d complement the summary presented in Table 5.3 by presenting the graphical representations of the land use transformations in 1997 and 2007 respectively.



Land use and land cover change (1987)

Land use and land cover change (1997)

Land use and land cover change (2007)

Land use and land cover change (2017)

Figure 5.17(a-d): Land use and Land cover Change in Hoedspruit town from 1987to2017

Source: Author’s Field Data, 2019)

Figure 5.18a reflects the magnitude of the changes which took place in various land uses from 1987 to 1997. The Figures show that tremendous transformations took place. In particular the vegetation cover increased from about 43.29 ha (4.48%) to about 669.6 ha (69.3%), all at the expense of the built-up areas.

As summarized in Table 5.3, Figure 5.18 (a-d) graphically presents the magnitude of land use and land cover changes from 1997 to 2007 in Hoedspruit. The Table illustrates that the built-up areas increased from 285.0 ha (15.32%) in 1997 to 148.05 ha (29.5%). The vegetation cover was depleted in 2007 to 31.223 ha (3.23%), that is, losing about 65% from the previous decade. Bare land however, increased from 15.38% to 67.27% over the same period.

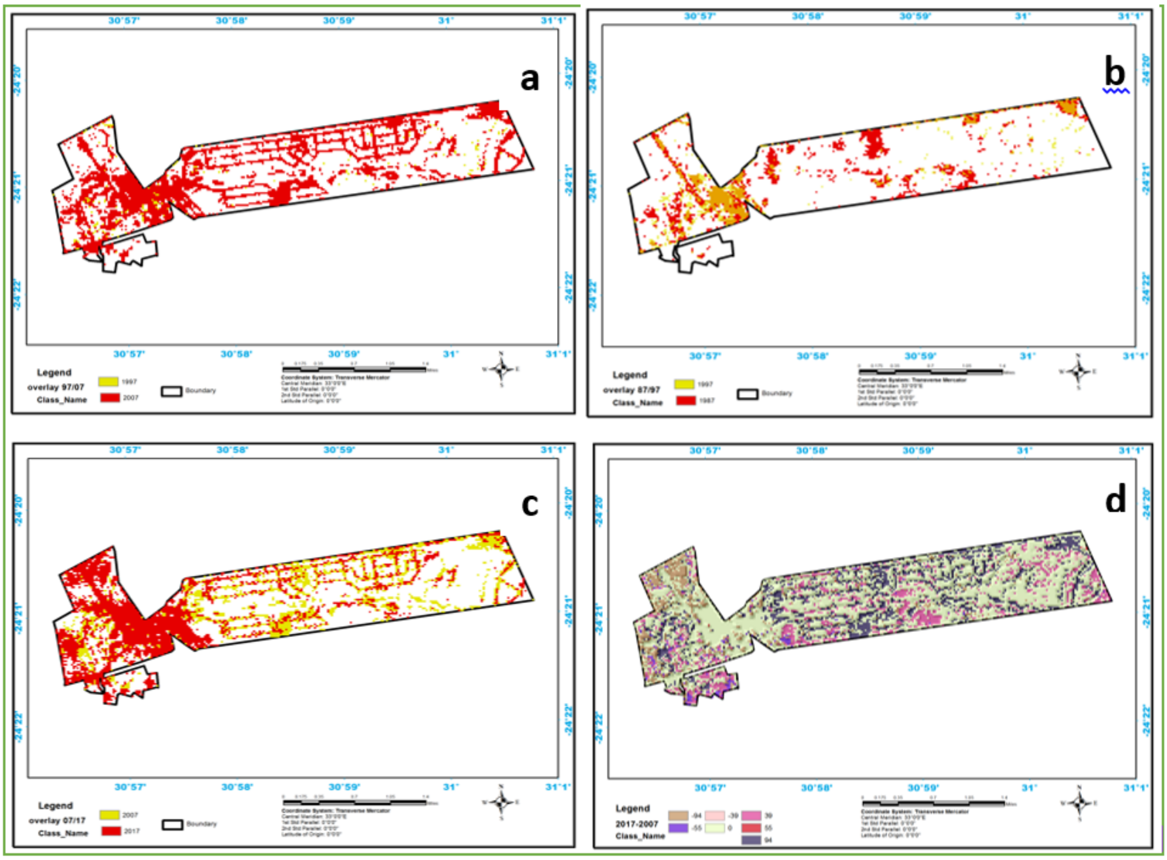


Figure 5.18 (a-d): Land use and Land cover Change (overlay) in Hoedspruit town from 1987to 2017 (Source: Author's Field Data, 2019)

Figure 5.18c shows the graphical representation of the changes that occurred in Hoedspruit from 2007 to 2017. It shows that vegetation cover increased alongside the built-up areas, while bare land on the contrary reduced.

On account of the differentials in the forms which the changes in land use have taken, Hoedspruit in the last three decades has witnessed land transformations from one category of use to another. The general analysis of the forms of transformation by categories of land uses are presented in Figure 5.18 a-c. These land use and land cover changes in Hoedspruit town between the decades (1987-1997), and (1997-2007) indicated vegetation cover as the most consumed (See Appendix 8). Figure 5.18d presents the holistic transformation that took place in the town during the year2007-2017, with residential dominating.

The built-up land use continued to invade other categories of land use in Hoedspruit, and the trend in the variation of land uses coverage was examined, using Pearson's correlation. The result, as shown in the Figure 5.19, reflects a positive relationship between the built-up sector of the town and time, with r = 0.982691. This indicates that the built-up area increased over time, Figure 5.20, on the contrary presents a reducing relationship between vegetation and time with coefficient r = -0.122. This implies an inverse relationship. As years increase, the vegetation cover reduces. Figure 5.21 shows that bare land was depleted over time, with r = -0.265029. Both vegetation and bare land were invariably lost to built-up areas.

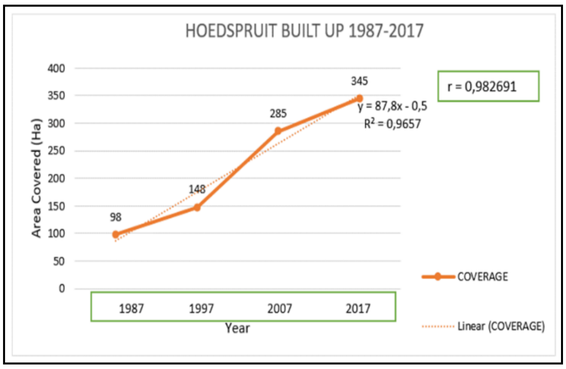


Figure.5.19: Trend of Percentage Change of Built-up Area in Hoedspruit

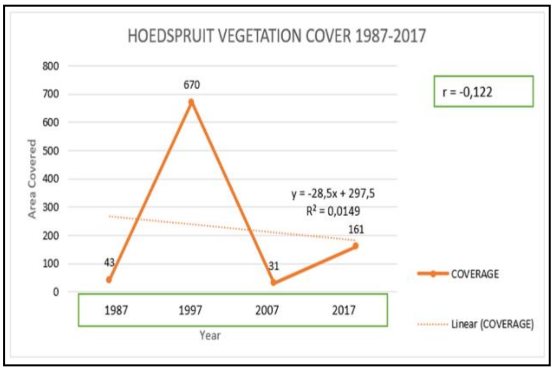


Figure.5.20: Trend of Percentage Change of Vegetation cover in Hoedspruit

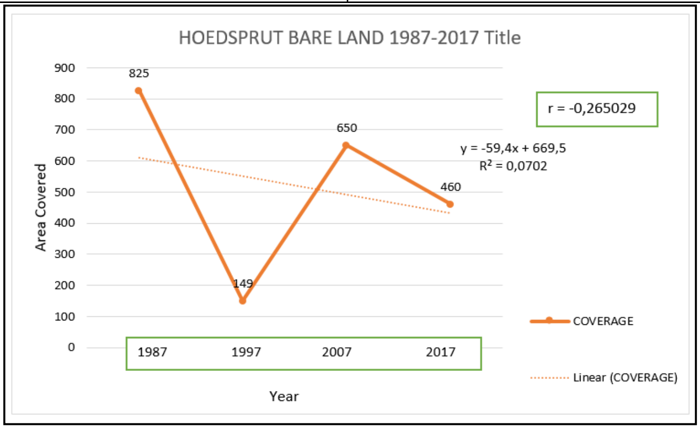


Figure. 5.21: Trend of Percentage Change of Bare land Area in Nkowankowa
Source: Author's Field Data, 2019

Figures 5.19-5.21 show the graphical representations of the increasing rate of expansion of built-up areas at the expense of bare land use transformation in Hoedspruit during 1987-2017, the rate of consumption of both bare land and vegetation by built-up areas may partly be explained by the increasing population (table3.2). It must equally be noted that Hoedspruit has taken advantage of the Kruger National Park, to attract and provide land for tourists and hospitality business needs and activities. These included hotels and guest houses, restaurants, and large grocery stores. The establishment of a civil airport terminal (the Eastgate airport) in 1990 was a major single land and vegetation consumer.

These among other factors have led to the consumption of vegetated land and its conversion to other uses. However, if this is left unaddressed, it could lead to a gradual devastating environmental situation, such as the continual exposure of land and humans to harsh climatic conditions and eventual threats to lives and the ecosystem. These can overstretch the coping capacity of people and exacerbate the vulnerability level of the residents of the town.

5.3.2.4 Modjadjiskloof Town

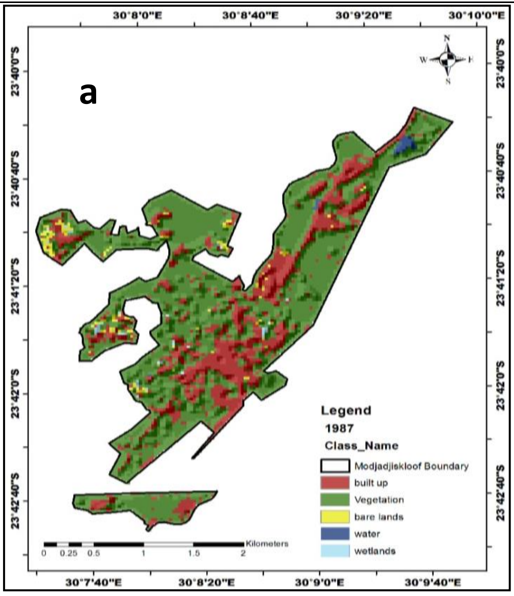
The result of the investigation of the magnitude and extent of transformation of land use and land transformation in Modjadjiskloof in three decades (1987-2017) is presented in Table 5.4. The table is complimented by the spatial pattern mapped in Figures 5.22 (a-d) and 5.23 (a-d).

Table 5.4: Land use and land cover change in Modjadjiskloof town (1987-2017)

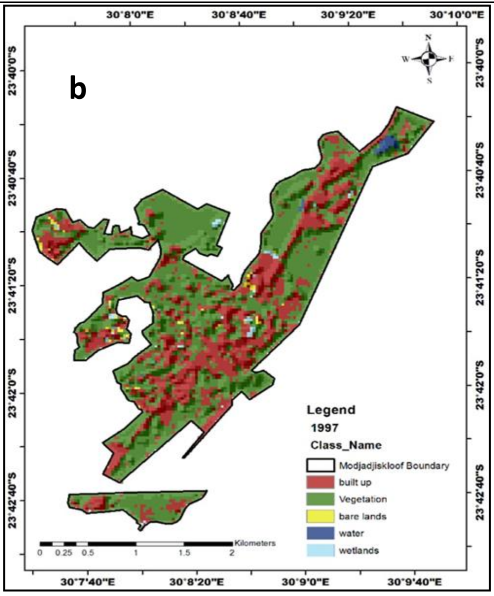
Classification	1987		1997		2007		2017	
	Area (Ha)	**%**	Area(Ha)	**%**	Area(Ha)	**%**	Area (Ha)	**%**
Vegetation	375.39	64.37	413.73	70.94	361.08	61.91	363.3	62.3
Bare lands	5.49	0.94	11.52	1.98	16.29	2.79	4.32	0.74
Water body	3.69	0.63	3.42	0.59	3.15	0.54	3.96	0.7
Built-up	193.32	33.15	151.11	25.91	198	33.95	207.3	35.5
Wetlands	5.31	0.91	3.42	0.59	4.68	0.803	4.32	0.74
TOTAL	**583.2**	**100**	**583.2**	**100**	**583.2**	**100**	**583.2**	**100**

Source: Author's Field Data, 2019

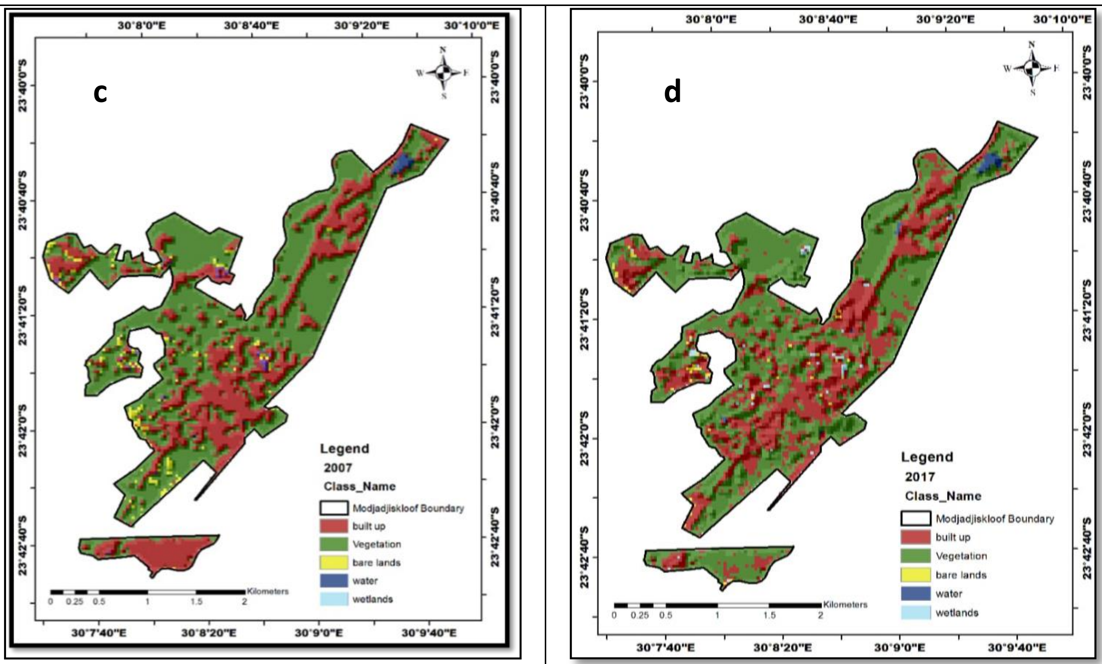
Table 5.4 shows that in 1987, vegetation cover was the largest in the entire land area of the town with coverage of about 375.39ha (64.37%) (Figure 5.23a). This was followed by the built-up area which claimed about 193ha (33.15%). Bare Land and water body respectivelyaccounted for only about 5.49 ha (0.94%) and 3.69 ha (0.63%). The succeeding decade witnessed vegetation cover gaining more space to account for 70.94%, while built-up land cover reduced to 151.11ha. The reason for the decline in the built-up components of the land use in Modjadjiskloof might not necessarily be due to demolition of buildings or dismantling of infrastructure but vegetation out growth that covered some parts of the built-up areas, as could be observed in the images for the year 1997. This was reduced in 2007 to about 61.9ha and about 62.2% in 2017, while the built-up area consistently retained its second largest land use, with 33.95% and 35.5% between 2007 and 2017 accordingly.



Land use and land cover change (1987)



Land use and land cover (1997)



Land use and land cover change (1997) | Land use and land cover change (2017)

Figure 5.22 (a-d): Land use and land cover change (overlay) in Modjadjiskloof town from 1987to 2017(Source: Author's Field Data, 2019)

The Table generally depicts consistent increases in the level of imperviousness from 1987 through to 2017, except for 1997 when there was reduction in built-up coverage.Figures 5.22 (a-d) show the spatial representations of the observed trends in land use transformation at different decades from 1997 to 2007 in Modjadjiskloof Figure 5.22c.

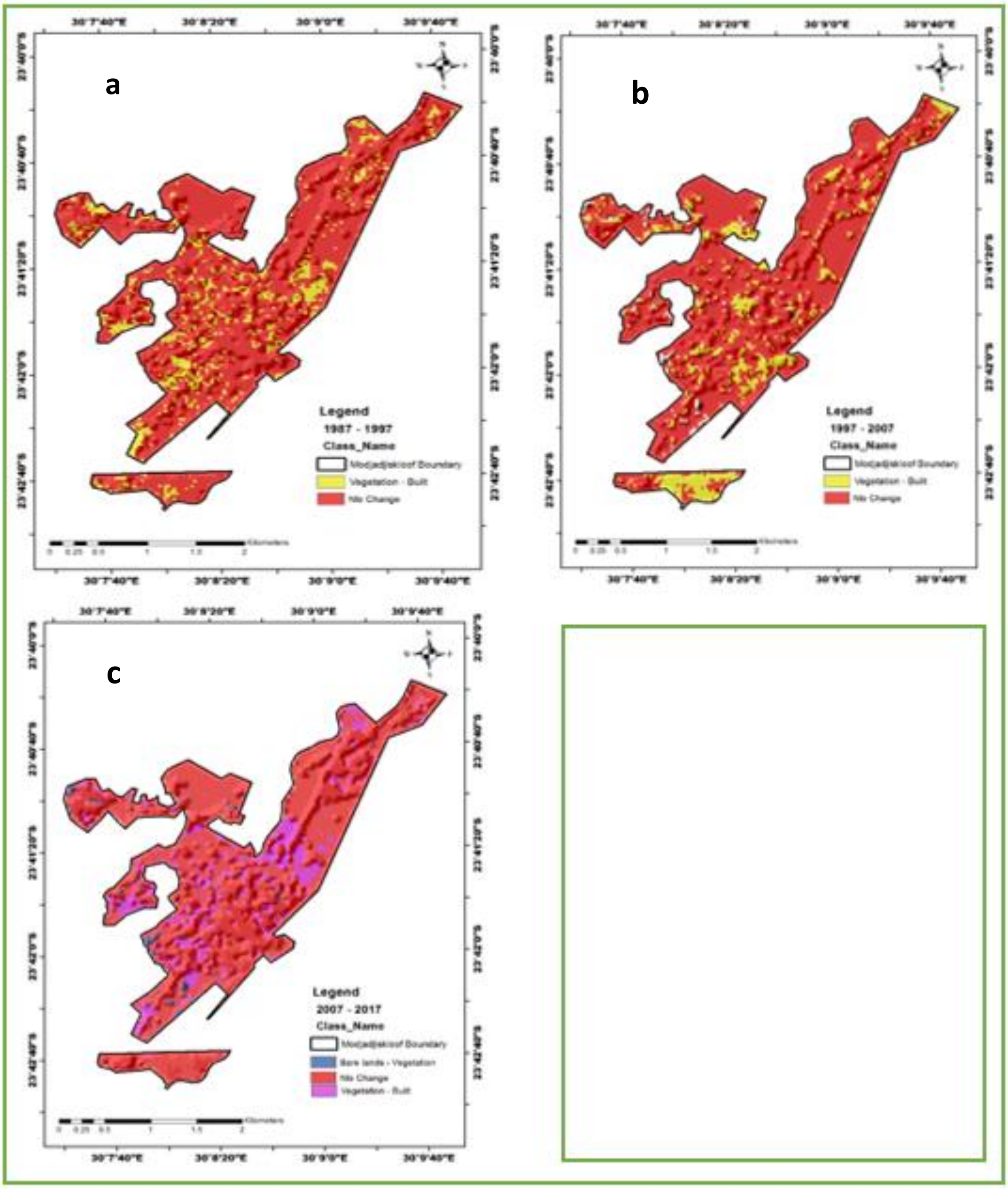


Figure 5.23 (a-c): Land use and land cover change (overlay) in Modjadjiskloof town from 1987to 2017(Source: Author's Field Data, 2019)

It is essential to note from Table 5.5 that a very significant part of ModjadjisKloof, about 14.28%, covering approximately 83.25ha, experienced no changes throughout the period of 1987 and 1997, but very significantly; about 500ha of Modjadjiskloof landscape that was formerly vegetated was consumed and converted to built-up area within same period. Meanwhile no conscious afforestation (tree planting) efforts were recorded between 1987 and 2007, and no change was recorded for any land use transformed to green area. About

14.6% and 14.8% respectively suffered from being green to give way to brown environment or residential development between 1997-2007 and 2007-2017(Figure 5.23a-c).

Table 5.5: Land use and land cover change in Modjadjiskloof town (1987-1997, 1997-2007 and2007-2017)

Classification	1987 – 1997		1997 – 2007		2007-2017	
	Area (Ha)	**%**	Area(Ha)	**%**	Area(Ha)	%
No Change	83.25	14.28	498.06	85.40	487.26	83.56
Vegetation - Built-up	499.95	85.72	85.14	14.60	86.22	14.79
Bare land – Vegetation	-	-	-	-	9.63	1.65
TOTAL	**583.2**	**100**	**583.2**	**100**	**583.2**	**100**

Source: Author's Field Data, 2019

The changes in land use and land cover in Modjadjiskloof in 2017 shows that vegetation slightly recovered from 61.92% in 2007 to 62.3%. Bare land depleted from 2.79% to 0.74%, while built-up area increased from 33.95% to 35.5%.

Plate 5.14: Vegetation being converted to other land use in Modjadjskloof

Plate 5.15 Effects of erosion aided by sloppy topography in Modjadjskloof

Source: Author's Field Data, 2019

Plate 5.14 illustrates how vegetation cover was compromised for other land use in Modjadjskloof, while Plate 5.15 shows a terrain-induced erosion effect compromising building foundations in Modjadjskloof. The result of a Pearson correlation conducted on built-up area are depicted in Figure 5.24.

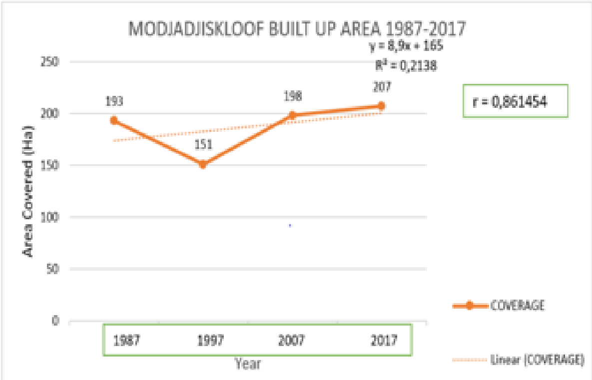


Fig. 5.24: Trend of Percentage Change of Build-up areas in Modjadjiskloof

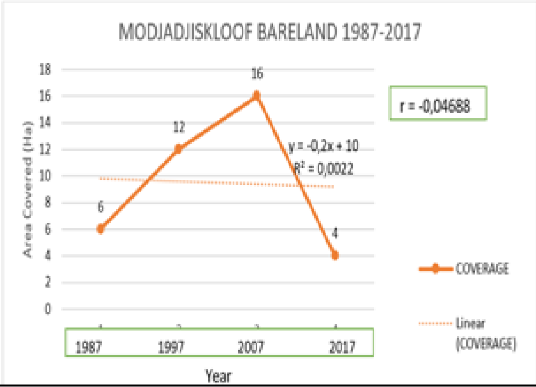


Fig. 5.25: Trend of Percentage Change of Bare land in Modjadjiskloof

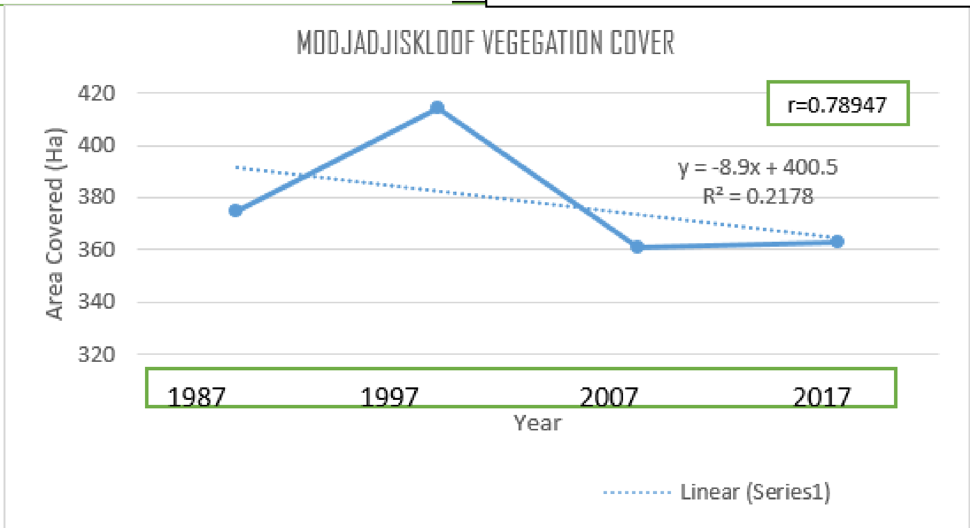


Fig. 5.26: Trend of Percentage Change of Vegetation in Modjadjiskloof

Source: Author's Field Data, 2019

Figure 5.24 indicated increasing trends in built-up areas with time; it shows the coefficient of r = 0.861454. This implies that as time passes, the portion of land occupied by built-up land use increased. Bare land and vegetation declined (Figure 5.25 and 5.26) on the other hand, with r = - 0.04688 and r = - 0.78947 respectively over time implying a significant reduction in bare land but more in vegetation over the three decades.

The slow transformation recorded in Modjadjiskloof may be connected with the rate of its population growth on one hand, and the steep nature of the town's topography which may have equally and significantly influenced the slow rate of its expansion. Plate 5.15 shows a typical terrain as may be more expensive to build on, while ensuring the structure, stability because of a high velocity of terrain-induced runoff. Vegetation regaining its coverage between 2007 and 2017 is a positive development which, if sustained, will substantially safeguard the environment, reduce household's exposure, enhance their coping capacity and invariably lower the vulnerability levels of Modjadjiskloof residents to the extreme events of climate change.

5.3.2.5 Phalaborwa Town

Table 5.6 shows the classification of land use and land cover change in Phalaborwa from 1987-2017.

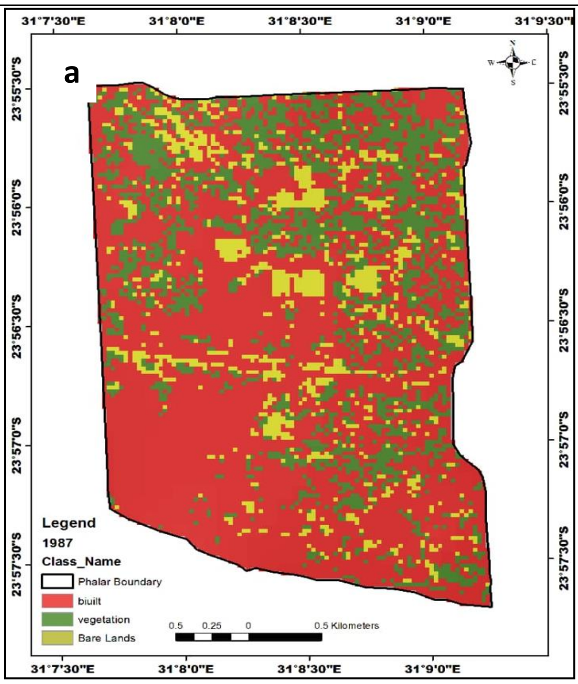
Table 5.6: Land use and land cover change in Phalaborwa town (1987-2017)

Phalaborwa	**1987**		**1997**		**2007**		**2017**	
Classification	Area (Ha)	**%**	Area (Ha)	**%**	Area (Ha)	**%**	Area (Ha)	**%**
Built Up	609.75	64.82	613.44	65.21	664.02	70.59	785.34	83.49
Vegetation	229.77	24.43	246.42	26.20	207.81	22.09	54.18	5.76
Bare Lands	101.16	10.75	80.82	8.59	68.85	7.32	101.16	10.75
TOTAL	**940.68**	**100**	**940.68**	**100**	**940.68**	**100**	**940.68**	**100**

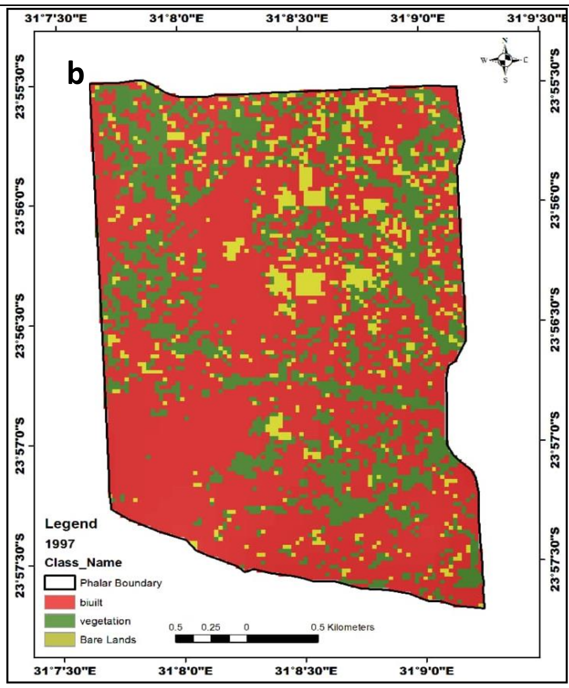
Source: Author's computation, 2019

The table shows that in 1987, Built-up areas covered about 609.75ha (64.82%) of the total land area of Phalaborwa. Vegetation was about 24.43%, amounting to about 229. 77ha. On the other hand, bare lands laid claim to about one tenth of 940.68ha (the total land area) of the Phalaborwa town.

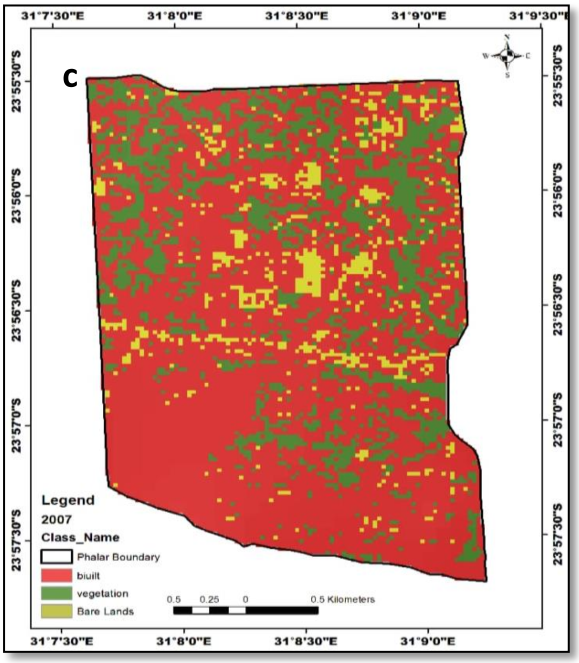
Table 5.6 further showed a gradual increase in the built-up area coverage in 1997 in Phalaborwa of 0.39%. In the subsequent decades the built-up area coverage jumped respectively to 664.02ha (70.59%) and over 80% of the entire land area of the town in 2007 and 2017. Figures 5.35 and 5.36 graphically present the spatial magnitude of the transformations recorded in 1987 in Phalaborwa town.



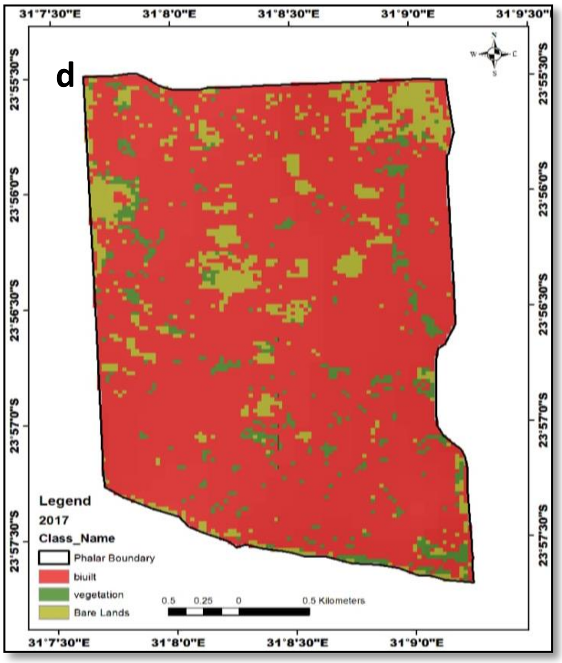
Land use/cover change (1987)



Land use/cover change (1997)



Land use and land cover change (2007)



Land use and land cover change (2017)

Source: Author's Field Data, 2019

Figure. 5.27 (a-d): Land use and land cover change (overlay) in Phalaborwa town from 1987to 2017 (Source: Author's Field Data, 2019)

Result of analysis shows positive changes in the vegetative cover of Phalaborwa. For example, in 1987, the town's vegetation cover was 229.77ha (24.43%) but increased to 26.20% in 1997, due to deliberate efforts by the residents to planting of trees, particularly within the residential areas of the town. Figure 5.27a graphically presents the spatial magnitude of the transformations recorded from 1987 to 1997 in the town. By 2007, however, slightly above (38.6 ha) 4.1% vegetation cover was lost from the previous decade (1997), due to urban expanssion.

Figure 5.27d shows that the year 2017 marks the decade in which the vegetation cover in Phalaborwa suffered the most significant loss to other land uses. At the end of this decade alone in 2017, the coverage of vegetation was compromised from being over 207ha (22.09%) to just 54.18ha (5.76%). Similarly, bare land equally suffered loss of about 2.06%; from 1987 to 1997, it lost a further 1.27%. The loss of bare land might not be too much of a concern, especially if such loss was to vegetation. Unfortunately, it was lost to built-up areas (see Table 5.6 & 5.7). Bare land recuperated in 2017 by about 3.43% from 2007, this is another sign of a loss of vegetation, because the built-up area equally increased during the same period, but only vegetation cover decreased.

Table 5.7: Land use and land cover change in Phalaborwa town (1987-1997, 1997-2007 and 2007-2017)

Classification	1987-1997		1997-2007		2007-2017	
	Area(Ha)	**%**	Area(Ha)	**%**	Area (Ha)	%
No Change	644.31	68.49	720.18	76.56	727.11	77.0
Barelands – Built	49.77	5.29	52.65	5.70	51.66	5.0
Vegatation - Built-up	163.44	17.38	114.21	12.14	106.74	11.0
Vegetation-Barelands	83.16	8.84	53.64	5.70	55.17	6.0
TOTAL	**940.68**	**100**	**940.68**	**100**	**940.68**	**100**

Source: Author's Field Survey, 2019

In a further probe into the magnitude of change among the various land uses,Table 5.7 signifies that quite a good proportion of land uses retained their original state. This was about 68.5% within the first decade under investigation (1987 – 2007). Within the same period, however, 5.7% of bare land was invaded by built-up areas, 17.38% of vegetated landscape was also compromised for built-up areas, with an additional 83.16ha of vegetation cover which was deforested and became bare land. The trend was similar to that of the succeeding decades as equally reported in Table 5.27, that from 1997-2007, 76.6% of Phalaborwa land retained its previous decade use, while 17.84% was converted from both bare land and vegetation to built-up area representing approximately 166.86ha. About 10 years after this 16% (158.40ha) of vegetation and bare land was further consumed by built-up areas by 2017 Table 5.27.

The result of Pearson correlation as illustrated in Figure 5.39 confirmed a strong and positive trend in the relationship between the built-up area and time, with r = 0.9686. This implies that there is a linear relationship in year and built-up area, as year increased, the built-up land cover equally increased.

The scenario obtained for vegetation cover was a negative relationship with time, wherer = -0.82674. By implication, there is inverse relationship between vegetation and time, i.e. as year increased the vegetation cover decreased.

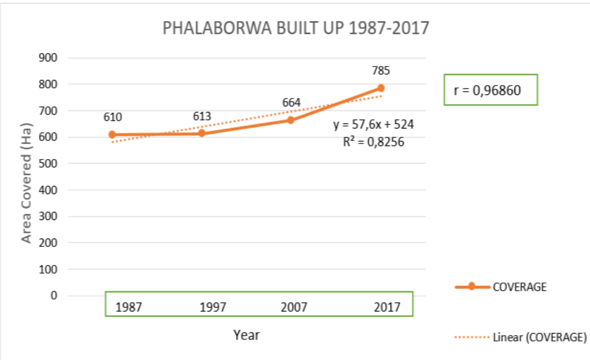


Figure 5.28: Trend of Percentage Change of Built-up Area in Phalaborwa

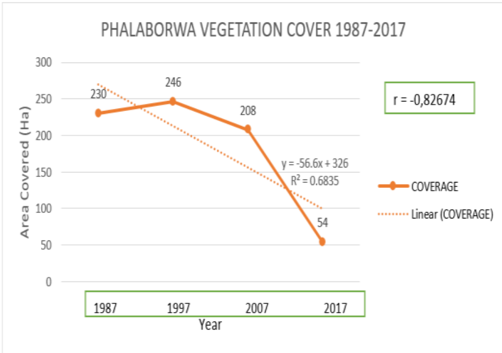


Figure 5.29: Trend of Percentage Change of vegetation in Phalaborwa

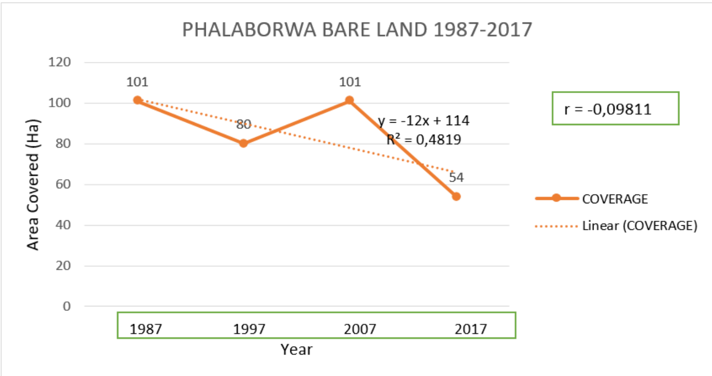


Figure 5.30: Trend of Percentage Change of Bare land in Phalaborwa

Source: Author's Field Survey, 2019

The scenario was similar to that of bare land over time, with r = -0.09811. The correlation result confirmed that the built-up area was the only land use in Phalaborwa with linear relationship with time from 1987-2017. This shows that the built-up area has consistently and significantly impacted on the surface area of the town, consuming green belt and virgin land. Considering the micro climatic nature of the town, a further exposure of the surface may resultantly accelerate heat episodes that can compromise households' capability to adapt to the extreme heat events, leading to higher residents' vulnerability to the changing climate.

5.3.2.6 Giyani

The analysis of land use and land cover change of Giyani town is presented in table 5.8. The visual impression of the result is illustrated in Figures 5.31 to 5.32.

Table 5.8: Land use and land cover change in Giyani town (1987-2017)

Classes	1987		1997		2007		2017	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Built up	357.57	20.3	636.57	36.16	1028.8	58.44	1277.01	72.54
Vegetation	677.43	38.5	714.33	40.58	174.42	9.91	379.53	21.56
Bare lands	725.4	41.2	409.5	23.26	557.19	31.65	103.86	5.90
Total	1760.4	100	1760.4	100	1760.4	100	1760.4	100

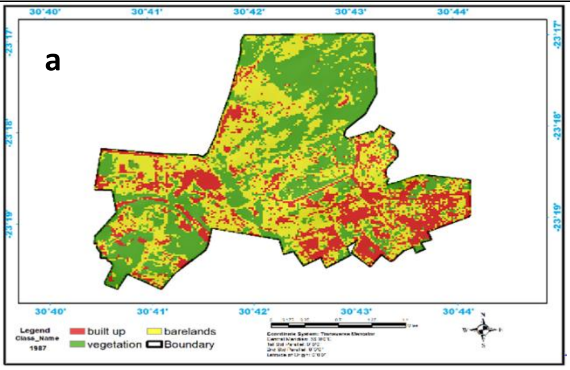
Source: Authors' computation, 2019

Table 5.8 shows a fast-growing built-up sector of Giyani town, far above other land use cover. The Table indicates that out of 1760.4 ha of land occupied by the town, 20.3% (357.57ha) of it was occupied by built-up area, 677.43ha, implying 38.5% was vegetation cover in 1987, while the remaining 725.4 (41.2%) was designated as bare land. Table 5.8 presents the land use and land cover transformation of the town from 1987 to 2017. Figure 5.31a-d depict the spatial transformation of land use from 1987-2017. The figures show the areal extent of coverage by each land use at the end of every decade. The red color depicts a built-up area, green shows vegetation and yellow indicates bare land.

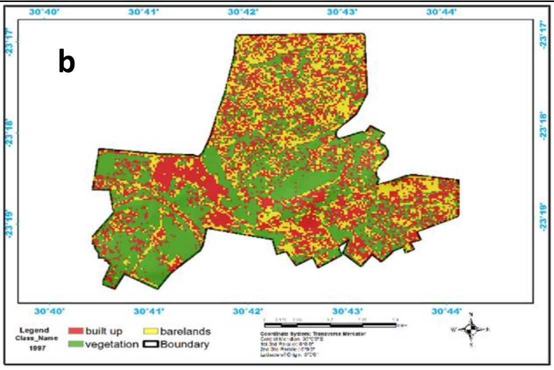
Figure 5.31a shows the graphical representation of the spatial pattern of the land use and land cover changes in Giyani town as of 1987. At the end of the first decade (1997), the state of the land cover was transformed, when built-up cover gained more land (to 36.6%). Vegetation cover equally expanded to claim 40.58% (714ha) approximately, while bare land suffered loss to retain 23.26% implying a reduction to 409.5 in 1997 from 725.4 at the beginning of the decade. Illustrated in Figure 5.41b are the spatial representations of the changes that were recorded in land use in 1997.

Similarly, Figure 5.31c is a visual impression of the summary in Table 5.8.The figure show that built-up areas sharply rose to cover about 58.44% (1028.8ha) of the total land during the period under consideration. Vegetation cover significantly decreased from 40.58%

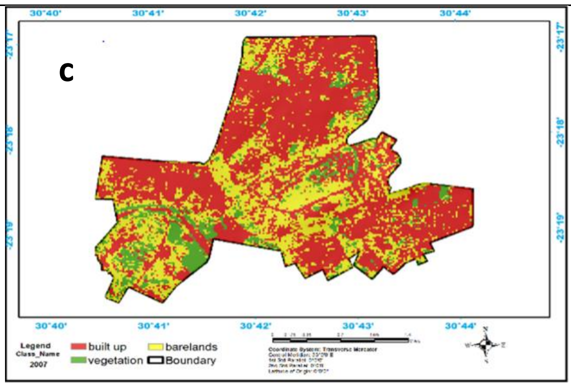
(714.33ha) to 9.91% (174.42ha) within 10 years, whilebare land increased in size from 23.26% to 31.65% over the same period.



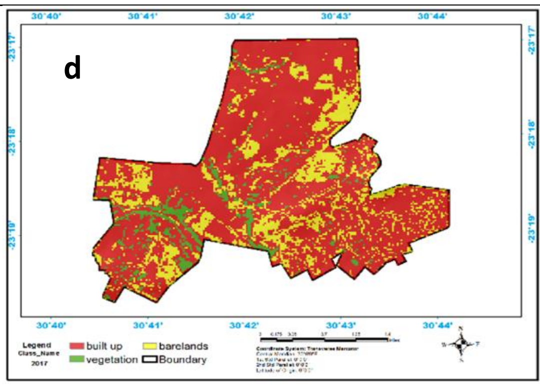
Land use and land cover change (1987)



Land use and land cover change (1997)



Land use and land cover change (2007)



Land use and land cover change (2017)

Source: Author's Field Data, 2019

Figures 5.31 (a-d): Land use and land cover change (overlay) in Giyani town from 1987to 2017 (Source: Author's Field Data, 2019)

Similarly in 2017, built-up area rose by over 200ha (72.54%) in 2007 to about 1277ha in 2017. However, vegetation cover decresed to about 174.42 ha (9.91%) over the same period. On the other hand, bare cover increased to about 31.65% (557.19ha) from 409.5ha (23.26%) compared to the previous decade. Figure 5.31d depicts the changes in land use between 2007 and 2017.

The figure shows that during the decade (2007-217) the landscape was dominated by the built-up area, and the vegetation cover equally increased its share at the expense of the bare land, which was reduced by about 5.9% (103.86ha). By implication the built-up sector of the town has been very consistent in its growth, while vegetated land consequentially has suffered invasion as illustrtrated in Figure 5.32 a-d. A critical look at these figures show the relationship between the changes in the various land uses in Giyani, reveals an increasing trend in the transformation of the built-up section of the town at the expense of vegetation particularly during 1997-2007.

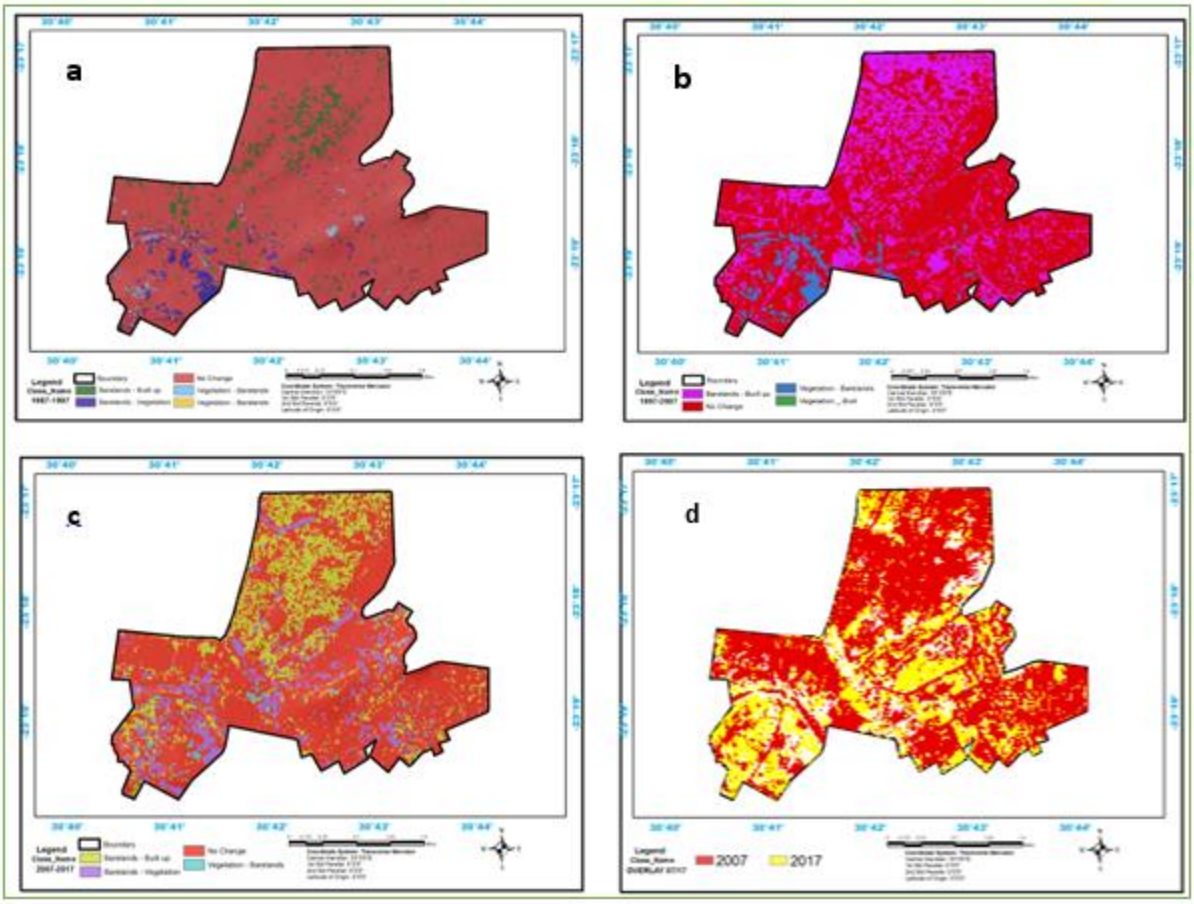


Figure 5.32 (a-c): Land use and land cover change (overlay) in Giyani town from 1987to 2017(Source: Author's Field Data, 2019)

On the other hand, the trends in the transformation of land use with time (years) are equally shownin the results of the Pearson's correlation coefficient during the three decades as illustrated in Figures 5.33-5.35, with r = 0.99645, a linear relationhhip is observed between the built-up areas over the period of 1987-2017 (figure 5.33).

Unlike the built-up areas, and as illustrated in figure 5.34, there is a strong inverse relationship between vegetative cover and time (r = - 0.72085). The observed trend above is as true of bare land as shown in Figure 5.35 with r = - 0.84056, implying a reduction in the sizes of bare land as time increased from 1987-2017.

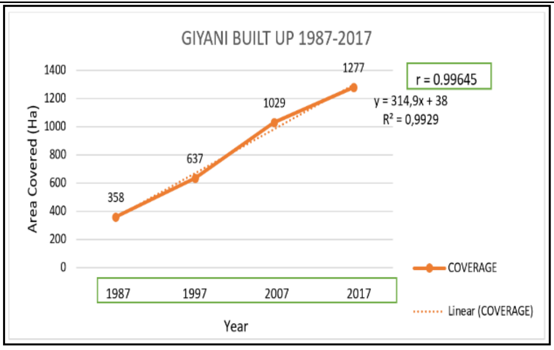


Figure 5.33: Trend of Percentage Change of Bare land in Giyani 1987-2017

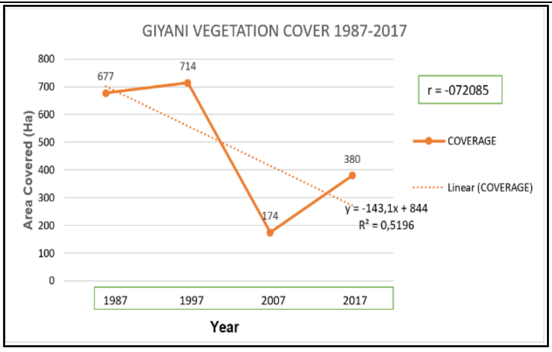


Figure 5.34: Trend of Percentage Change of Vegetation in Giyani town

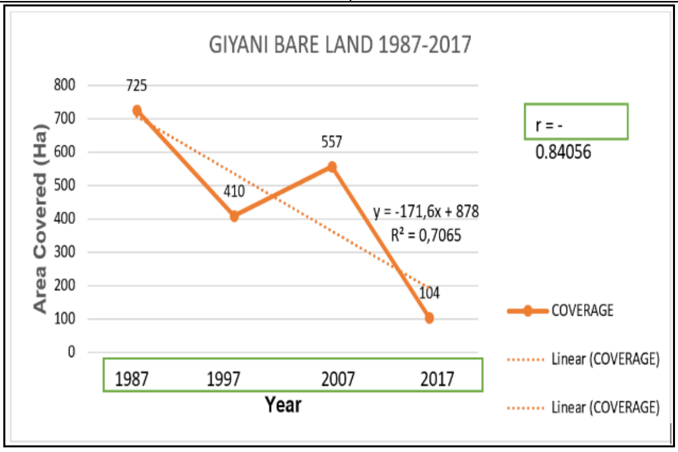


Figure 5.35: Trend of Percentage Change of Vegetation in Giyani town
Source: Author's Field Survey, 2019

The reasons for the recorded rates of transformation in Giyani town land use are not far-fetched, as demographic factors are significantly at play. Equally important are the Departments and Agencies of governments, corporate offices and major commercial outfits that were located in the town during the period of examination. On the other hand, the dual administrative functions performed (Greater Giyani Municipality and Mopani District Headquarters) have drawn attention to new and extensive infrastructure (roads, schools, hospitals). They include new malls, a new stadium, hotels and offices located in different parts of the town which occasioned the steady expansion of the built-up area and consumption of vegetation (Figure 5.32d). On the other hand, firewood remains the main source of energy for the people of Giyani and its hinterland. This has complemented the earlier factors to compromise the vegetation cover and threatened its existence and sustainability. The exposure of the land surface in Giyani town to climatic factors such as heat and rainfall is capable of increasing household exposure, depleting coping capacity and eventually increasing vulnerability among the households in the town.

5.3.3 Validation of Land Use and Land Cover Change

From the validation analysis conducted for the selected towns, the Kappa coefficient for the towns (shown in appendices 9-11) are high, indicating strength of the reliability of the LULC prediction as proof for a near accurate prediction. For instance Kappa coefficient = 0.710715 was recorded for Modjadjiskloof LULC, Tzaneen = 0.710755, Hoedspruit 0.73236, Nkowankowa = 0.709755, while Modjadjiskloof was observed to have 0.710715, Giyani and Phalaborwa Overall Kappa are respectively 0.754018 and 0.509707. The total accuracy was 17.6% (appendices 9-11). The high Kappa coefficient shows that the prediction is highly reliable and can be employed for the 2047 prediction (Jeevalakshmi *et. al.,* 2017).

The low accuracies recorded for some classes may be a function of the set probabilities in CA Markov. Since the prediction/projection under Markov makes use of probabilities are obtained from the cell behavior between two previous LULC classifications, errors are inevitable. For built-up class for example, an increase was noticed from 1987 to 1997. This increase may have been replicated again in 2007 but may have stopped in 2017 due to some reasons which maybe migration or housing policy. Since built-up increased in previous years, the probability of increase was high and the prediction will not only inflate built-up but will also follow the pattern of arrangement of the built-up. Government housing policy may make the prediction unrealistic as building development may be halted in certain direction and focused in an entirely new direction.

5.4 Demographic Characteristics of the Households in Selected Towns in Mopani

In line with the objectives of this study, this section deals with the analysis of the demographic characteristics of the households in the six selected towns in Mopani District. This is to enable a further understanding of the linkages between the household characteristics in the selected towns, their exposure and how changes in climate parameters could affect them. These demographic attributes of the population include but are not restricted to Gender, Age, Marital status, Income etc.

5.4.1 Gender of Respondents

The towns that were selected for the investigation were classified as female and male headed households. Table 5.9 summarises the results of the cross tabulation of household gender and the towns of the respondents.

Tab 5.9: Gender and Towns of Respondents

	Town of Respondents						Total
	Tzaneen	Nkowankowa	Hoedspruit	Modjagis-Kloof	Phalaborwa	Giyani	
	%	%	%	%	%	%	%
Male	46.8	26.3	66.7	60.0	35.7	33.1	35.1
Female	53.2	73.7	33.3	40.0	64.3	66.9	64.9
Total	100	100	100	100	100	100	100

Source: Author's Field Data, 2019

The table shows that household heads across the district were dominated by females. According to the IDP 2019/20 almost all local municipalities in the district of Mopani had more females than males. This is most significant in Greater Giyani and Greater Letaba municipalities. This scenario was equally reflected in the six towns selected.For instance, females accounted for over 53% in Tzaneen town, more than 70% in Nkowankowa (being higher) and more than two in every three household heads in both Phalaborwa and Giyani. However, except in both Hoedspruit and Modjadjiskloof, the males accounted for 60% and females 40%. The higher proportion of female households as compared to the males is a reflection of the influence, of the domestic group's organisation, resulting in the rising number of female-headed households. Here, the African concept of gender roles is becoming irrelevant; moreover, the high proportion of males who were not currently staying with their spouses was another contributing factor to the high proportion of female headed households. For instance, single household heads constituted about 29%, Divorced 4.6%, Widows and widowers 8% (appendix 12). Out of these categories, females constituted the higher proportion (appendix 13). The scenario could equally be attributed to low levels of education and affluence which have occasioned and exacerbated the exodus of men seeking jobs elsewhere.

By implication, females' cultural incapacitation particularly in the African context, occasioned by constraining rights, restricted access to resources, circumscribed mobility and lackof involvement in homes and community decision making may heighten their vulnerable level to climate change (Howard *et al.,* 2012).

5.4.2 Age of Respondents

On the assumption that age plays a significant role in determining levels of vulnerability, according to the study by Sallawu, *et al.,* (2016) this section analysed the age of respondents to enable a further understanding of the linkages with vulnerability. The distribution of age of respondents was thus examined. Table 5.10 presents the distributions of age in the towns.

Table 5.10: Age distribution of respondents in the selected towns

	Town of Respondents						Total
	Tzaneen	**Nkowa-nkowa**	**Hoeds pruit**	**Modjagis-Kloof**	**Phalab orwa**	**Giyani**	
	%	%	%	%	%	%	%
13-19 years	1.3	4.6	0.0	0.0	0.0	1.5	2.2
20-35 years	27.8	50.3	0.0	0.0	29.8	40.0	37.7
36-50 years	59.5	34.3	44.4	50.0	50.0	44.6	44.4
51-65 years	8.9	8.6	50.0	50.0	15.5	10.0	12.5
≤ 66 years	2.5	0.6	5.6	0.0	4.8	0.0	1.6
No Response	0.0	1.7	0.0	0.0	0.0	3.8	1.6
	100.0	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Author's Field Data, 2019

The Mopani IDP 2019/20 version revealed that most of the population groups across the selected study towns were between the ages 15 to 64. This cluster of ages accounted for about 60.30% of the population. It was followed by the category of population under 15 years, which is about 34.40%.

Table 5.10 shows that the household heads that were in their prime ages (20 and 50 years) dominated the selected towns across the district. This category accounted for about 80% of the total sampled population. Across the selected towns, Nkowankowa housed a significant proportion of household heads aged between 20 and 35 years. This group equally accounted for one out of every two persons (50 Percent) of the towns' population. People between the ages of 36 and 50 years, form the major population in Tzaneen, ModjadjisKloof, Phalaborwa and Giyani. While categories between 51 and 65 years were the highest in Hoedspruit and Modjadjiskloof.

There was a higher proportion of not only young, but also those who were economically and socially active, that if well harnessed and facilitated, could be engaged in the initiation of climate change risk sensitisation, mitigation and adaptation initiatives, as well as championing the course in the District of Mopani.

5.4.3 Marital Status of Respondents

To further explore the relationship between the socioeconomic characteristics of households and vulnerability to extreme events of climate change in the six selected towns in Mopani District, the study analyses the marital status of the residents. Table 5.11 reveals the distribution of households' marital status in the selected towns.

Table 5.11: Marital status and towns of respondents

Marital Status	**Tzaneen**	**Nkowa-**	**Hoedspruit**	**Modjadjis-**	**Phalab-orwa**	**Giyani**	**Total**
	%	%	%	%	%	%	%
Married	55.7	60.6	33.3	50	63.1	51.5	56.7
Single	12.7	32.6	38.9	10	28.6	37.7	29.8
Divorced	10.1	1.1	5.6	10	4.8	5.4	4.6
Widow/Widower	13.9	4.6	11.1	0	3.6	1.5	5.2
No Response	0	0.6	5.6	0	0	0.8	0.6
Separated	7.6	0.6	5.6	30	0	2.3	2.8
Others	0	0	0	0	0	0.8	0.2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Author's Field Data, 2019

The table shows that more than average (56.7%) of Mopani residents were married, 29.8% were single, and 5.2% were widows/widowers across the selected towns. With reference to Table 5.11, the study reveals that Nkowankowa and Phalaborwa towns had about three in every five of their residents as married household heads. On the other hand, Hoedspruit and Giyani accounted for 38.9% and 37.7% respectively of single household heads. The situation is the same in Tzaneen and Modjadjiskloof, where they both accounted for about one in every ten divorced household heads.

As further summarized in Table 5.11 and Appendix 13, about 57% of household heads were married, while about 43% was either divorced, single, widowed or separated. The highest proportion of the married household heads was a reflection of their ages within the context of African culture, where at a particular age; one is expected to be married. This high proportion of married households may suggest additional pressure from extra family responsibilities and implies an extra burden for adaptation during and after climate change extreme events.

5.4.4 Highest Qualification of Respondents

In order to examine if there is any linkage between educational attainment and vulnerability and response level of Mopani households to climate change, the respondents were requested to indicate their highest level of education. Table 5.12summases the result of data extracted with the questionnaire.

Table 5.12: The qualifications and towns of respondents

Status	**Tzaneen**	**Nkowa-Nkowa**	**Hoedspruit**	**Modjadjis-kloof**	**Phalaborwa**	**Giyani**
	%	**%**	**%**	**%**	**%**	**%**
No formal education	10.1	2.9	0.0	10	2.4	0.8
Quranic education	0.0	0.0	20.0	18	0.0	0.8
Grade 0-7	13.9	22.3	20.0	30	14.3	9.2
Grade 8-12	10.1	5.1	0.0	12	16.7	16.9
Matric	49.4	36	20	20	39.0	34.6
Certificate/Diploma	7.6	13.1	13.3	4	21.4	14.6
Higher Diploma/ Bachelor/Hon.	5.1	5.4	16.7	3	2.2	6.9
Masters/PhD	2.5	6.6	7.8	3	2.8	13.1
Others	1.3	4.6	2.2	0.0	0.0	2.3
No response	0.0	4.0	0.0	0.0	2	0.8
Total	**100**	**100**	**100**	**100**	**100**	**100**

(Source: Author's Field Data, 2019)

The Figures obtained from the Integrated Development Plan 2019/2020 version show that the literacy level across the municipalities was low. For example, community survey 2016 as reported by the 2019/20 IDP shows that 27.1% of the adult population above 20 years of age did not have any formal educational training in Mopani District.

However, the existence of the ABET programme has made substantial impacts on the illiteracy rate, which has decreased from 37.8% in 2014 to 27.1% in 2016. The study revealed that over 30% had secondary education, and 12% had no formal education. Conversely, only 12.7 % of the adult population completed Matric while 6.5% had any form of education. Table 5.12 further reveals that household heads with higher education attainment were 16.5%in Tzaneen, 37.7%% in Giyani, 33.7% in Nkownkowa, 28.4% Phalaborwa, 40% in Hoedspruit and 10% in Modjadjiskloof.

The high level of secondary school certificate holders may not be unconnected with the complaints about high fees in higher schools of learning and the absence of guarantees of securing a job regardless of level of educational attainment. However, if educational level is well harnessed by doing what is required for the improvement of the system, this may guarantee access and interest in climate change-related information, activities and engagements. These in turn could facilitate the promotion of adaptation actions among the respondents in the selected towns in Mopani District.

5.4.5 Primary Occupation of Respondents

To understand the relationship between the respondents' means of livelihood (occupation) and their adaptive capacity to climate change extreme events, a probe was made into the types of occupation engaged in by the respondents. According to the figures that were obtained from Mopani IDP 2019/20 version, the population of Mopani District is employed in several sectors including: Farming, Mining, Industry, Trade, Transport, Manufacturing, Construction and Government. Civil service is categorized as the largest category, though the figure varies according to municipalities. The second largest employer in the district is the farming. However, at municipality scale, the mining sector employed the second largest in Ba-Phalaborwa with about 19.5%. The unemployed were the highest in Greater Giyani (47%). On a general note, about 39% were unemployed in Mopani district.

Tab. 5.13: Primary occupation and towns of respondents

Primary Occupation	Town of Respondents						Total
	Tzaneen	**Nkowankowa**	**Hoedspruit**	**Modjagiskloof**	**Phalaborwa**	**Giyani**	
	%	%	%	%	%	%	%
Not employed	25.3	13.7	0.0	20.0	38.1	27.7	23.0
Farming	0.0	5.1	72.2	0.0	2.4	5.4	6.3
Mining	2.5	11.4	0.0	0.0	15.5	3.8	8.1
Artisans	6.3	6.9	0.0	10.0	2.4	7.7	6.0
Self Employed	17.7	20.0	11.1	10.0	8.3	23.8	18.1
Trading/Business	20.3	5.1	0.0	20.0	7.1	13.1	10.1
Professionals	22.8	13.7	16.7	0.0	7.1	11.5	13.3
Civil Servant	1.3	21.7	0.0	0.0	15.5	3.8	11.5
Timber industry	0.0	0.0	0.0	40.0	0.0	0.0	0.8
Others	2.5	0.6	0.0	0.0	0.0	3.1	1.4
No Response	1.3	1.7	0.0	0.0	3.6	0.0	1.4
Total	100	100.0	100	100.0	100	100	100.0

(Source: Author's Field Data, 2019)

It is further revealed that 60% of the unemployed population in Mopani were women. However, Table 5.13 reveals this result of the field survey conducted among the household heads in the six selected towns in Mopani District Municipality.

Table 5.13 shows that the unemployed population dominated in almost all the selected towns, with more than one out of every five household heads in Mopani District being job seekers, except in Hoedspruit which may be a reflection of the sampled population. This is followed in Tzaneen town, by the professionals (22.8%) and traders (20.3%). In Giyani, following the unemployed which dominated as a category, self-employed was the second dominant group accounting for about 23%. However, in Modjadjiskloof town timber industry accounted for 40% of the sampled population. The Table further reveals that more than 13% of Nkowankowa households were in search of a means of livelihood, while about the same proportion were professionals.

The level of unemployment may be traced to the illiteracy level of the population, coupled with high expectations of young people in terms of their first paying job salaries, rather than what they could themselves do when entering the labour market. This is contrary to firms' preference in employing experienced hands (older people) who have to sometimes be on the job. The non-availability of the large industrial sector and the possibility of saturation in the public sector make new entrants fewer.

However, the fact that most of the population across the six selected towns were job seekers is a strong signal and threatens adaptive capacity to climate change among the households. This would have resultant influence on the vulnerability level in cases where the households were exposed to climate change extreme events in the six selected towns in Mopani District.

5.4.6 Households Monthly Income from Primary Source

In their study on income levels of households Canberra Group, (2011) it is shown that people are regarded as not vulnerable when their disposable income is more than 10% of their total income. Income being a major determinant of the overall standards of living of households and their affordability levels in the district. This must be an important factor to be considered when unpacking the vulnerability level of households to climate change, as well as when setting targets for adaptation. IDP 2020 reported that the majority of the people in the district labour force (about 89.1%) of the population in the Greater Giyani Municipality (though living in the rural areas) earned less than R800 per month. The situation in Greater Letaba was reportedly more worrisome, where 92.2% of the population earned less than

R800 per month. In Ba-Phalaborwa, it was 75% of the labour force that were in this category. But our investigation shows that the low level of this is attributable to urbanization level, as well as the presence of mines in Ba-Phalaborwa (community Survey, 2016). On the other hand, about 45% of Mopani District had no income. According to the IDP 2019/20, 28% earned between R1-R400 and 13% earned between R801-R1600 per month and about 1% earned above R12, 000 a month.

The IDP further empasised the presence of a high level of indigent population in the district (74.1%). However, acros the local municipalities this was equally found to be high, with Greater Tzaaneen (79.3%), Greater Giyani (63.3%), Greater Letaba (85.7%) and Maruleng and Ba-Phalaborwa respectively (62.7%) and (66.2%). See Appendix 14

From further investigation, Table 5.14 presents the categories of income of household heads in the selected towns of Mopani District. This shows that households with no income accounted for the highest proportion of the entire households, with about 40% from Phalaborwa, 32.3% in Giyani, and 27% in Tzaneen and Hoedspruit which accounted for only 27.8% of population with no income. The reason may not be separable from the general unavailability of jobs across all sectors in the country and the saturation in public service, being a major employer of labour in the district apart from self-employed and professionals

Tab. 5.14: Total income from Primary source and household towns

Town of Respondents Total							
	Tzaneen	Nkowa-nkowa	Hoeds-pruits	Modjadjis-kloof	Phalabo-rwa	Giyani	Total
	%	%	%	%	%	%	%
< R500	0.0	0.0	3.0	0.0	2.4	8.8%	0.6
R501 - <R5,000	15.1	14.9	12.0	20	2.4	10.8	15.5
R5,000 - R10,000	10.2	14.9	3.0	20	15.5	23.1	17.7
R10,001 - R15,000	10.1	28.6	7.0	0.0	3.6	5.8	15.9
R15,001 - 20,000	11.4	17.7	20.0	0.0	4.8	6.2	12.5
R20,001 - R25,000	6.3	8.0	0.0	0.0	6.0	5.4	6.3
R25,001 - R30,000	5.1	0.0	5.0	0.0	6.0	3.1	2.6
R30,000 - R35,000	6.3	0.6	8.0	0.0	8.3	2.3	3.2
R35,001 - R40,000	3.8	0.0	22.2	10	2.4	1.5	2.4
Above R40,000	3.8	0.0	17.8	30	3.6	0.8	2.8
No response	0.0	0.6	0.0	0.0	4.8	0.0	1.0
No Income	27.8	14.9	2.0	20	40.5	32.3	24.4
Total	100	100	100.0	100	100	100	100

(Source: Author's Field Data, 2019)

Similarly, a significant proportion of the respondents earned between R501-R5000 per month. In this category; Tzaneen town accounted for 15.1%, Nkowankowa 14.9 Percent, while Phalaborwa accounted for only 2.4% of that category. However, Hoedspruit town recorded the highest category (22.2%) of household heads that earned between R35,001 – R45,000 per month.

With about 24% of household heads without income and an additional 16.1% of earners of <R5000 implies a narrow probability for sustainable livelihood as-well-as additional economic engagement. This suggested a limited coping capacity in case of extreme events of climate change, thus, inferring a higher vulnerability among this category. However, for the respondents whose earnings were about ≥R10 000, signifies a higher capability for livelihood diversification and enhanced adaptive capacity that suggest a lower vulnerability to climate change in the district. This finding validates the submission of Piya *et al.,* (2011) and Apata *et al.,* (2010) implying a lower vulnerability to climate change impacts.

5.4.6.1 Households income diversification

In furtherance to the primary income analysis, household heads with streams of income were requested to indicate their understanding of the influence that multiple income has over vulnerability adaptation to climate change. Table 5.15 presents income diversification levels of households in the selected towns' as a determinant of vulnerability.

Table 5.15: Households income diversification and towns of residents

Income Diversification	Tzaneen	Nkowa-nkowa	Hoedspruit	Modjadj-iskloof	Phalab-orwa	Giyani	Mopani
Have multiple Income (Yes)	36.7	63.4	0	60	52.4	46.9	50.6
Have no multiple Income (No)	63.3	36.6	100	40	47.6	53.1	49.4
Total (%)	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(Source: Author's Field Data, 2019)

According to Table 5.15, 50.6% of the Mopani District respondents were engaged in multiple economic activities. In the selected towns, only Nkowankowa town had 63% of households with multiple sources of income dominating the population, while Giyani had 47%. The households in Tzaneen with no other income besides that from primary source accounted for about 63% and 40% in Modjadjiskloof. Hoedspruit on the other accounted for 100% of the households with no other income apart from a basic income, being the highest across the towns. About 52% of respondents had sundary incomes apart from the primary income in Phalaborwa. By implication income diversification buffers the impact of environmental disasters by facilitating a switch over from one source of income to another, in case one of them is affected by climate change adversities. It equally increases the income of households and invariably strengthens their coping capability. Thus, high income level and livelihood diversification are expected to boost households' coping capability across the six towns under study. The findings here is supported by those of Yamba *et al.,* (2017)

5.4.7 Length of Stay of Households in their Residences

In order to further understand the linkages between the household duration of stay in their localities and their vulnerability and adaptation levels to climate change in the six selected towns of study, residents were requested to indicate the number of years they have resided in their towns of location. Table 5.16 presents the summary of the results on the distribution of household heads according to how long they have resided in their various localities.

Table 5.16: Duration of stay in localities and towns of respondents

Duration of stay in the locality	Tzaneen	Nkowankowa	Hoedspruit	Modjagiskloof	Phalaborwa	Giyani	Total
	%	%	%	%	%	%	%
1-3 Years	13.9	12.6	0.0	10.0	9.5	6.2	10.1
4-6 Years	6.3	16.6	0.0	10.0	13.1	6.9	11.1
7-10 Years	7.6	5.7	0.0	0.0	7.1	5.4	5.8
10 Year	49.4	34.3	100	70.0	60.7	60.0	51.0
Since Birth	22.8	30.9	0.0	10.0	9.5	21.5	22.0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(Source: Author's Field Data, 2019)

Table 5.16 shows that households which had resided for more than ten years, accounted for over 50% in the district of Mopani, but this varied among the town. All respondents residing in Hoedspruit had retained their abode for more than ten years, while about 70% of Modjadjiskloof household's heads, and about 60% of Phalaborwa residents had equally stayed that long. However, over 30% of residents of Nkowankowa have lived in the town since they were born Several others had also lived in the towns since when they were born, while 21.5% in Giyani and none of Hoedspruit surveyed residents were born in the towns.

This implies that the duration of stay at location of residence reflected the number of years residents have been exposed to the micro climatic conditions of such towns by the virtue of their home locations. The summary in Table 5.16, and the climatic conditions that were experienced in these towns (as described earlier in chapter four) reveal that they are characterized by incessant upward temperature trends and erratic precipitation occasioning heat waves, flash floods and drought. One can therefore infer that significantly, households across the six selected towns of study have experienced high exposure levels, which might imply a high vulnerability level, especially for low income earners or household heads with no income at all.

5.4.8 Disabilities among Households

The study accorded attention to the less privileged in the district to understand the level of their vulnerability and to examine the strategies they put in place to cope with the dangers associated with the extreme events of climate change. Different categories and types of disability were identified by the district and local municipalities and the attention being given to the needs of these special people. Among the several attempts were the five special schools in the district that cater for the learners with special needs, in addition to the two-flagship life-care centres in the district.

Figure 5.26 presents the level of disability in the six selected towns of study. The figure shows that no respondents indicated having a form of disability in both Hoedspruit and Modjadjiskloof, while more than nine in every ten households investigated were able bodied in Nkowankowa. This is similar to what is obtainable in Phalaborwa, Giyani and Tzaneen towns.

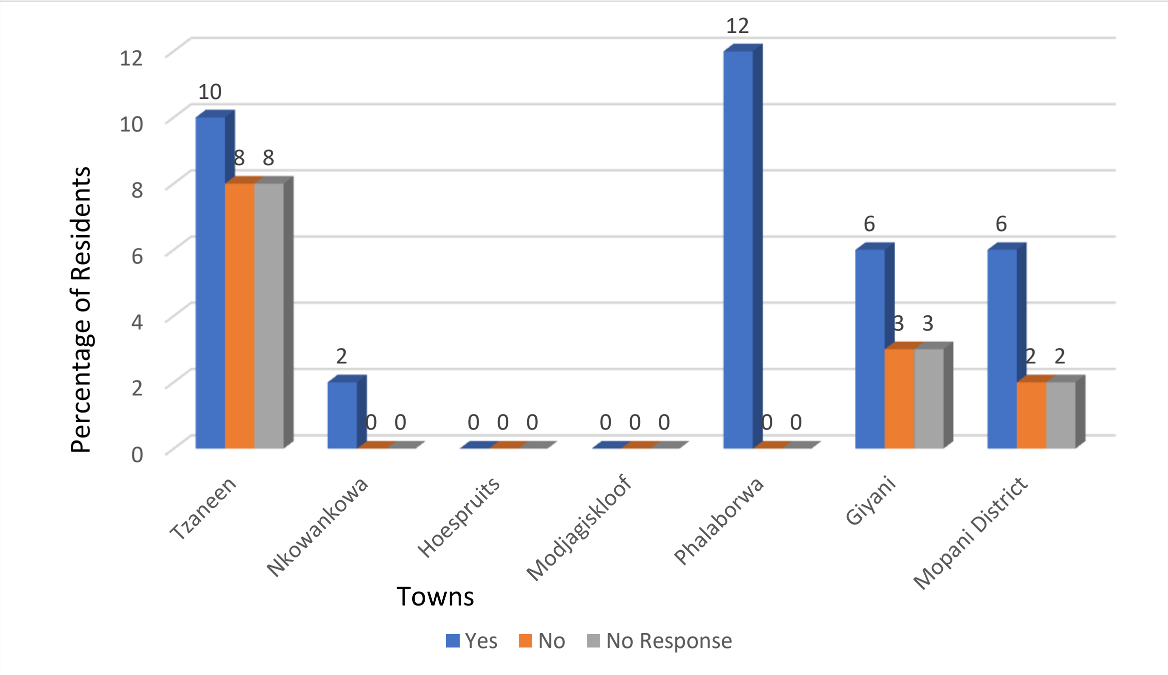


Figure 5.36: Disability among Households
(Source: Author's Field Data, 2019)

However, the study further reveals that the shortage of supporting infrastructure in most schools is still a serious challenge, apart from the major challenges that the people with disabilities in the district faced. These include, but were not limited to, lack of skills, lack of employment opportunities as well as support devices (such as wheelchairs, walking sticks, hearing aids, magnified glasses, etc.). Another challenge relates to a lack of capacity within public institutions in handling disability in an integrated manner due to a lack of understanding by the majority of people, for example a lack of Braille resources. This significantly will heighten the sensitivity level of the disabled household heads, compromise their adaptive capability and worsen their vulnerability level.

5.5 Access to basic services in Mopani District

The integrated Development Plan of Mopani District indicated the improvements made in the provision of basic services for the people of the district, it was equally acknowledged that much more was still desired, especially, when the available services were compared to the population that they were meant to serve. However, the backlog was still huge, and more resources were still needed to improve the situation. Backlogs existed in terms of the number of facilities and services. These included the following:

5.5.1Heath facilities

The health service is categorized into several types and levels, but generally, clinics without water pose a serious concern to the effect that these amenities cannot be utilized to full potential across the district according to the Mopani District IDP 2019/20. Staff members were working under conditions that do “not reflect the image of health services”; these conditions had repelled skilled workers.

At municipal level, Maruleng Local Municipality was rated the best served with 1 clinic per every 6,841 persons, followed by Greater Giyani with 9 526 in the district. Out of the four gateway clinics, located in four hospitals, only Sekororo, was fully functional, then Letaba, Nkhensani and Maphutha-Malatji were still in the establishment.

5.5.2 Educational facilities

The study reveals that there was a total of 451 primary schools in existence across the district municipality with Greater Tzaneen accounting for the largest share. The schools had a total of approximately 194,000 learners accommodated in 4273 classrooms, implying a 45:1 pupil-classroom ratio. Similarly, a total of 261 secondary schools were located across Mopani District Municipality, with Greater Tzaneen equally accounting for the majority (79 or 30.3%). There is thus a serious shortage of schools, and more specifically, classrooms in almost all the local municipality areas for both primary as well as secondary schools. The district needs total classrooms of about 2378 (Community Survey, 2019, in IDP 2019/20). To complement the facilities, infrastructure such as electricity, water, and sanitation were also needed in many schools across the district municipality area. The study further revealed that the buildings in the majority of the schools were in deplorable states.

5.5.3 Sport Facilities

All sporting facilities according to MDIDP 2016 were in need of major repair, while there was the need to build new grandstands, turfed soccer fields and functional irrigation systems for maintenance. Shortages were identified in the areas of soccer fields and athletics tracks, indoor sports facilities, facilities for netball, basketball, softball, cricket, hockey, swimming and volleyball. The study further unpacked that the existing facilities were not properly maintained and needed to be upgraded.

5.5.4 Housing

A majority of Mopani residents were living without land and housing; many according to the findings have no access to portable water and sanitation. A significant proportion still could not afford sustainable energy sources. The Spatial Development Framework 2019 as well as IDP 2019/20 painted a scenario, that out of 84, 654 houses that were required in Mopani District, 12.4% were needed in Greater Giyani, 9.1% Greater Letaba, 8% in Greater Tzaneen, 4.9% in Phalaborwa and 4.35 in Maruleng. On the other hand, the RDP housing backlog shows that of the 26,735 units required, 11,119 were required at Greater Giyani Municipality, 7879 at Greater Letaba, 5388 at Greater Tzaneen and Ba-Phalaborwa, and Maruleng shared 1466 and 883 respectively.

5.5.5 Other Basic Services (Sanitation, Water, Electricity, and Refuse Removal)

Table 5.17 shows the summary of the access and backlog of basic services across the district by local municipalities. The Table reveals that the provision of adequate municipal infrastructure remains a challenge throughout the district. From the Table, 85% of Mopani population had access to sanitation, while 15% did not. Out of 296,320 households in the

Table 5.17 Basic Services access and backlog in all household in the district

Services	Households	Access	Access	Backlog	Backlog
Sanitation	296,320	251,976	85%	44344	15%
Water		249925	84.3%	46395	15.7%
Electricity		257798	87.0%	38522	13%
Refuse Removal		55,300	18.7%	-	81.3%
Road		1313,64km (paved)	38.8%	2071.83km (gravel)	61.2%

(Source: Mopani District Municipality IDP 2019/2020)

district 5.7% still lacked access to a potable water supply for domestic and other uses. On the other hand, while about 87.3% of the entire household had access to electricity supply, 13% still lived without this refuse evacuation services. Refuse removal was identified as one of the major challenges to which more than four in every five households in Mopani still did not have access.

The paucity in the availability of the services was partly a reflection of factors ranging from population increase, due to birth and migration, shortage of budgetary allocation, due to competing needs of the people of the district. However, by implication households that are short served with basic services are likely to be highly vulnerable to climate change extreme events.

5.6 Chapter Summary

This chapter examined the locational characteristics of the six selected towns to determine the topographical nature, land use and their transformations as well as the socioeconomic characteristics of residents of the selected towns. The examination of the locational characteristics was considered useful to the understanding of their nature and dynamics in relation to their influence on household vulnerability level.

The results of the findings revealed that the topographies of the towns are generally low lying and undulating relief, except Modjadjiskloof with steep slope terrain. The low lying nature of the topographies of the towns was revealed to have tendencies of influencing surface runoff/floods at varying frequencies and intensities with debris especially during downpours. This situation has esultant implications of threatening buildings, road and drainage infrastructure, lives and livelihood, which may invariably influence households' vulnerability.

The chapter further demonstrates with regards to land transformation in the six selected towns in Mopani a steady increase in the built-up areas, throughout the three decades under examination (1987-2017). Vegetation cover on the other hand was depleted consistently. However the extent of the transformation in land use in each of the towns varied accordingly. This result implies that there was increased deforestation, through continuous urbanization that was characterized by impervious cover and wood energy sourcing among other factors. These developments have tendencies to significantly expose the land surface to continuously trap heat, resulting in environmental warming resulting in discomforts among the residents. The exposure of the land surface equally implies the likelihood of an enhanced surface runoff and flooding in these towns. The phenomena can trigger household's exposure as well as compromise their coping capability to heavy downpour and extreme heat events, leading to higher residents' vulnerability to the changing climate.

Upon investigation, across Mopani District and in agreement with the report of IDP 2019/20, the study reveals a higher proportion of female headed households in the selected towns of the district, with varying proportions from town to town, except in Hoedspruit and Modjadjiskloof that presented a contrary result with higer male household-heads. The higher proportion of female households in the district is a reflection of the influence of domestic group's organisation, which may imply higher vulnerability resulting from additional pressure on family needs and wants. This can be compounded by cultural incapacitation of women, particularly in Africa where women rights are constrained, access to resources are restricted, with circumscribed mobility and limited involvement in homes and community decision making.

Furthermore, the chapter uncovered the domination of household heads in their prime ages (20-50) in the district. This implied a higher potential to harness through engagement in climate change risk sensitization, mitigation, adaptation and other initiatives. With respect to marital status, married household heads was the highest (more than one in every two).However, household heads were relatively educated across the selected towns in the district. By implication, while higher married household head may suggest higher sensitivity and vulnerability that may be occasioned by family pressure and demands, higher educational attainment implies a guaranteed access to climate change-related information that is capable of facilitating early warnings and the propagation of adaptation policies and actions among the populace in the selected towns and the Mopani District.

The chapter further shows that a significant proportion of Mopani households were engaged in non-climate fed economic activities, with self-employed, professionals and civil servants dominated the work force in the district suggesting low vulnerability. However, with about half of the district respondents earning incomes from multiple sources signifies high income level, suggesting the potentials for boost in households' coping capabilities that will influence households' vulnerability to climate change. Meanwhile, more than half of the population of the district had resided in their homes for more than a decade, while about 22% were residents from birth. This was a reflection of the length of years, residents had been exposed to the micro climatic conditions of such towns; by virtue of their home locations, the longer the length of stay, the higher the exposure to climate change extreme events reported in chapter four. This section concluded with the analysis of the backlogs of services in the district, which was partly a reflection of factors ranging from population increase, shortage of budgetary allocation due to competing needs of the people of the district.By implication, households that were short served with basic services suggest high vulnerability to climate change extreme events.

Having assessed the existing situation (terrains, socioeconomic characteristics of households and access to services) in the district and that of the selected towns and their influences on households' vulnerability to climate-related extreme events, the succeeding chapter analyses the magnitude of household and community vulnerability. Based on UN Habitat, (2011) expression, households' vulnerability cross spatial scales was analised.

CHAPTER SIX

MAGNITUDE OF HOUSEHOLD AND COMMUNITY VULNERABILITY TO CLIMATE CHANGE IN MOPANI

6.1 Introduction

This chapter addresses objective two and three by analysing the indicators that relate to household and community vulnerability to climate change extreme events as well as their spatial variations. The components of vulnerability that have influence on households and community vulnerability were investigated, to determine their levels and magnitudes. This analysis is anchored on the UN Habitat, (2011) report that states that households and community vulnerability is the subtraction of the capacity to adapt from the summation of exposure and sensitivity to hazard. The analysis in this chapter therefore examines the magnitude of households and community vulnerability to hazards occasioned by climate change with particular reference to the six selected towns in Mopani District Municipality. Vulnerability was analysed using the mean score to determine the weight of the contribution of the indicators to vulnerability and the effects on the residents of the six selected towns. The findings and the concluding part of the chapter attempts to link the patterns and levels of socioeconomic attributes that contribute to household and community vulnerability to climate change.The findings on the vulnerability magnitude of the households and communities in the six towns were plotted on a spatial scale to determine the spatial variation of the magnitude of the vulnerability on households and the communities

6.2 Households and Communities Vulnerability in Mopani District

The magnitude of households and communities vulnerability was estimated by subtracting the score of capacity to cope (adaptive capacity) from the summation of the overall hazard scores of the ratings on both exposure and sensitivity. The study applied an Ordered Logit Regression Model to examine the extent of household vulnerability using three categories: low, moderate and high vulnerability. Multivariate Analysis of Variance (MANOVA) and Pairwise Correlations were adopted respectively to explain if any statistically significant difference existed in households' level of exposure across the selected towns, as well as to examine the relationship between households' primary income and their sensitivity levels. Correlation coefficients were used to examine the relationships.

6.2.1 Overall Hazard Score

From the hypothesized environmentally related hazard indicators, such as an increase in temperature (heat waves), occurrence of floods and prevalence of climate-prone diseases, among others, Household's Exposure Index (HEI) as well as Household's Sensitivity Index (HSI) scores were computed and presented separately, summarized and collated. The results are presented according to the magnitude of occurrences. Hazard (exposure) was computed and expressed as 'Not Exposed', 'Just Exposed', 'Exposed', while Hazard (sensitivity) was on the other hand calculated and presented as 'Not Sensitive', 'Sensitive', 'Very Sensitive') across various levels of vulnerability (District, Town and their neighbouhoods). The summation and the mean scores (HEI+HSI) across the same levels were derived. The results are presented as in section 6.2.1.1.

6.2.1.1 Households' Hazard (Exposure) Index in Mopani District by Towns

In line with the assessment of households' levels of exposure at different scales, the magnitude of households' exposure to climate change hazards was examined and result presented in Table 6.1.

Table 6.1: Household's level of exposure across the towns in Mopani

	TOWN						
	Tzaneen	**Nkowa-nkowa**	**Hoedspruit**	**Modjadjis-kloof**	**Phalab-orwa**	**Giyani**	**Total**
Exposure	%	%	%	%	%	%	%
Not Exposed	5.06	3.42	33.33	40	10.71	8.5	8.1
Just Exposed	53.17	54.29	16.67	0	32.14	55.4	48.2
Exposed	41.77	42.29	50	60	57.14	36.1	43.7
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

p=0.000 (Source: Author's Computations, 2019)

Table 6.1 reveals generally high exposure levels among households, with 91.9% in Mopani District. With varying levels in the selected towns, Nkowankowa town has the highest proportion (96.58%) of its households in the exposed category, followed by Giyani and Phalaborwa respectively with 91.5% and 82.14%. ModjadjisKloof town has the least, but also high exposed households with about 60%. The cumulative proportion of households not exposed across the district was however low (8.1%). This shows a clear indication of very high level of exposure to climate change hazards in the six selected towns in Mopani District. Table 6.4 thus shows the household levels of exposure to climate change hazards in the six study locations.

The high levels of exposure across the six selected towns were a reflection of the combination of several factors. These included the similar climatic belts that the towns shared that have subjected them to a climate that is characterised by rising temperature and reducing precipitation. This had resulted and subjected the households in the six selected towns to climate extreme events such as heat waves and flash floods, the conditions under which several households have lived for decades. It can also be adduced to lowly topographical attributes they also shared. The terrains that are capable of enhancing surface runoff, particularly Modjadjiskloof with an erosion-prone topography have not only threatened lives but have compromised the integrity of buildings and other landed properties. The increased trend in the consumption of vegetation cover by built-up land use, increased impervious surfaces in the towns and lack of compensation for the lost vegetation has equally conspired to aggravate the urban heat island, subjecting the residents of the six towns to unbearable heat episodes.

Figure 6.1 presents the mean scores of exposures of households to climate change in the six selected towns. The figure shows that Modjadjiskloof residents were more exposed to climate change, with an average of 2.4 exposure followed by Phalaborwa town with 2.339

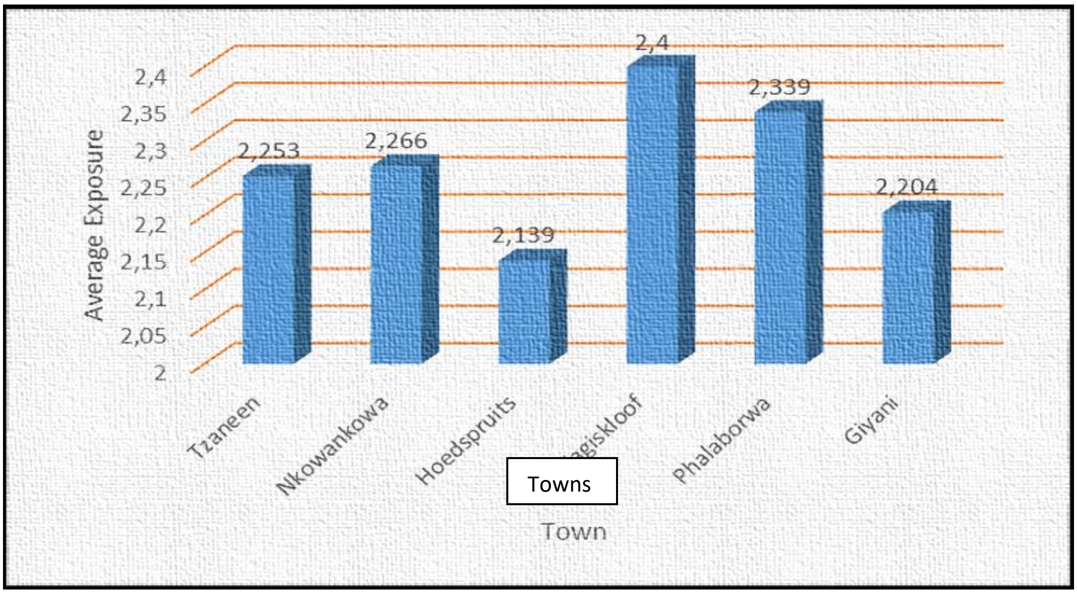


Fig: 6.1: Average Hazard (Exposure) Score Across Town in Mopani District
(Source: Author's Computation, 2019)

as compared to Hoedspruit with only 2.138. The Chi-square test showing the result of the relationship between household level of exposure and the six selected towns is in Table 6.2

Table 6.2: Chi-Square Tests of Household's level of exposure across the towns

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	322.542[a]	195	.000
Likelihood Ratio	285.025	195	.000
Linear-by-Linear Association	21.665	1	.000
N of Valid Cases	496		
a. 210 cells (87.5%) have expected count less than 5. The minimum expected count is .02.			

(Source: Author's Computation, 2019)

However, on the other hand, the results obtained from the Chi-Square tests to determine the interdependence of household exposure and the six selected towns in terms of variation is indicated in Table 6.2. This has a value of X^2=322.542, and p = 0.00, <0.05, implying that, there was a statistically significant relationship between the exposure level of households across the six selected towns in Mopani District.

6.2.1.2 Households' exposure level in neighbourhoods across the selected towns

In order to analyse the level of households' exposure at neighbourhood level in the six selected towns in Mopani District, the household intensities of exposure to climate change was examined and spatially delineated in neighbourhoods.

6.2.1.2.1 Households' level of exposure to climate change hazards in Tzaneen town

To enable the spatial representation of the households' exposure result, Figure 6.2 depicts the exposure levels of households in the neighbourhoods of Tzaneen.

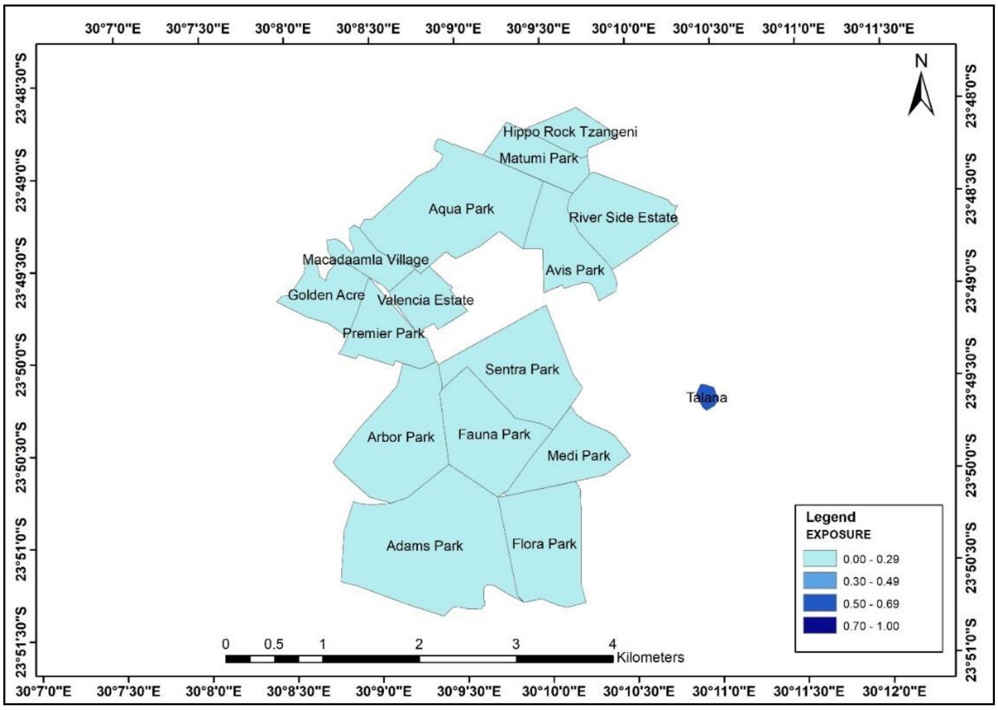


Figure 6.2: Households Exposure across Neighbourhoods of Tzaneen Town (Source: Author's Field Data, 2019)

The level of households' exposure to climate change hazard in Tzaneen town by neighbourhood ranges from 0-29%. All the neighbourhoods had less than 30% exposure, except Talana where households' exposure to climate change hazard ranges from 30-49%. From Figure 6.2, it canbe seen that neighbourhoods such as Matumi Park, River Side Estate, Santra Park, Valencia Estate, Macadamia Village and Arbor Park had a higher level of exposure, while Avis Park, Golden Park, Adams Park, Flora Park, Medi Park, Fauna Park and Premier Park, and Golden Arce neighbourhoods had a lower level of exposure as a result of the type of building material used for construction. Building materials used for housing construction played a major role in cushioning the magnitude of households' exposure to climate change hazards in Tzaneen.

The reasons for Talana neighbourhood's higher level of exposure may be explained by the existing housing conditions (lower in standard to Reconstruction and Development Programme (RDP)). These houses were built with temporary building materials which have the tendency to aggravate heat or have no capacity to withstand both rain or wind storms. For example Plate 6.1a& b shows the type of building materials used in places like Talana neighbourhood (corrugated iron sheets, plastics and planks) that fell short of the capacity to withstand harsh weather conditions and lack the capacity to protect its inhabitants against the climatic factors.

Plate 6.1 (A-D): Array of images influencing exposure in Tzaneen town
(Source: Author's Field Photo, 2019)

In addition to the low quality of building materials used by the residents of Talana, certain parts of Tzaneen were covered with concrete pavements as shown in Plates 6.1c and d while some parts of the surface surfer from exposure to climatic factors see plate 6.1d. These aggravate heat as well as erosion in the town. The problem in Plate 6.1d is a factor that equally enhances the level of household exposure to climate change hazard due to exposure of land bareness, thus exposing the residents to dry dust during hot periods and muddy impasse during raining season. However, Appendix 14a in contrast to Plate 6.1d shows blocked drainage with weeds, which impaired the free flow of runoff water. The problem is that the overgrown weeds had blocked the water channel which will result into overflowing of water during downpours, thus, compounding the problem of household exposure to floods.

6.2.1.2.2 Households' Level of Exposure to Climate change Hazards in Nkowankowa Town

The neighbourhood assessment of the level of households' exposure to climate change hazard was examined and presented in Figure 6.3. The Figure shows the spatial differences by neighbourhood in households' exposure to climate change in Nkowankowa. From the figure, it is shown, as indicated by the intensities of the colour notation that neighbourhood Section A and B had the lowest exposure level to climate hazards, while Section C and D were more exposed to climate change.

The figure shows that Section C and D (neighbourhood) of Nkowankowa town were the most exposed neighbourhoods to climate change hazard. Exposure to climate change in section C and D ranges from 0.30 to 0.49 (30-49%). However, Section A and B were the least exposed neighbourhoods with <30% of residents in the exposed category.

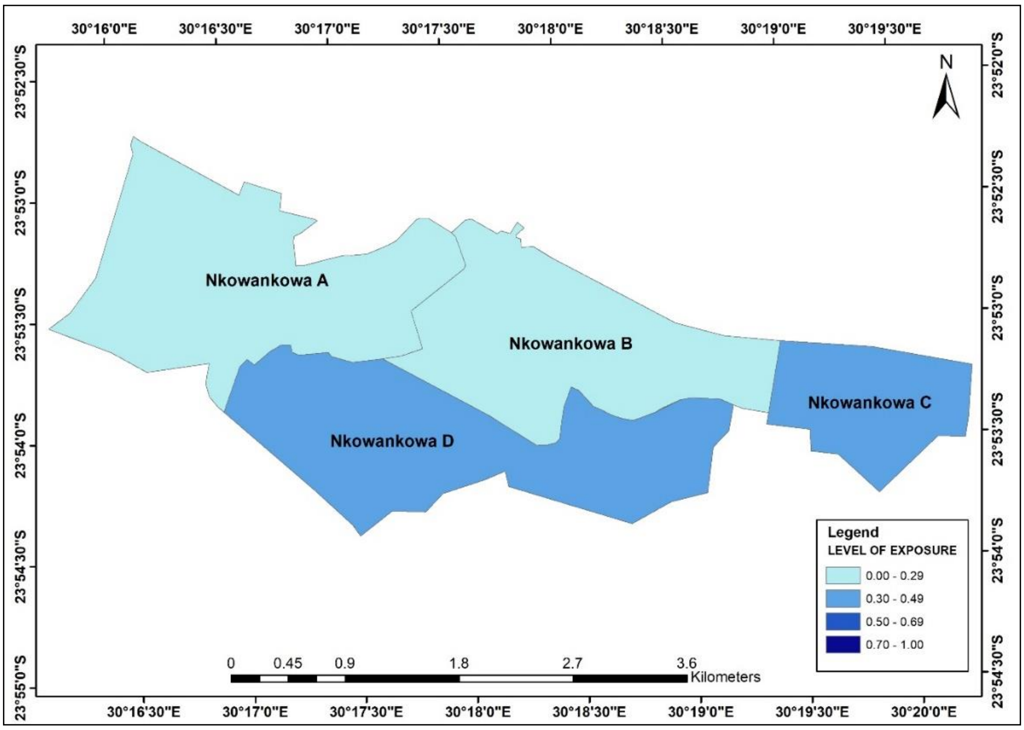


Figure 6.3: Households Exposure across Neighbourhoods of Nkowankowa Town (Source: Author's Field Data, 2019)

The higher exposure level of Section C and D (neighbourhood) households reflected their character of being in an unproclaim section of the town, thus the neighbourhood was under the administration of the traditional authority. It was occupied predominantly by low-income groups which took advantage of cheap land, with reduced administrative bottlenecks, thus buildings are informal and mostly unauthorized. Section D was though, partially serviced by the Local Municipality, yet it is characterized with a paucity of basic facilities and services. This situation has aggravated the households' exposure to the incidence of extreme climate change events and hazards in Nkowankowa. Further into the investigation of households' exposure in Nkowankowa, it was uncovered that a lack of drainages on some roads, coupled with the waterlogged nature of the terrain, and poorly covered vegetation of Section D had complemented other factors to frequently enhance flash floods. These factors have aggravated the neighbourhood exposure to climate related hazards than other parts of the town.

Similarly, environmental quality plays a fundamental role in mitigating the magnitude of households' exposure to climate change hazards. For instance, Plate 6.2a shows a part of Nkowankowa Section A, where leaking sewage constitutes an environmental risk to nearby inhabitants, particularly children (the most vulnerable) who play around and sometimes with overflowing sewage from the broken sewer. This has contributed to the exposure of the households in Section A (neighbourhood) of Nkowankowa to risk of climate change related diseases.

The busted sewer line pollutes the downstream water that flows to connect other rivers in the district. The consumption of water sourced from this water course for domestic purposes implies health risk and exposure to disease. Plates 6.2a and b are typical examples of pollution in Nkowankowa town that have been left unattended to and have consequently gained spatial spread, endangering lives of households in terms of exposure to the climate change diseases and hazards. Further to this reason is the concrete cover that dominates some parts of section A, at the CBD that is capable of increasing heat episodes and exacerbating surface runoff during a downpour (see Plate 6.2c).

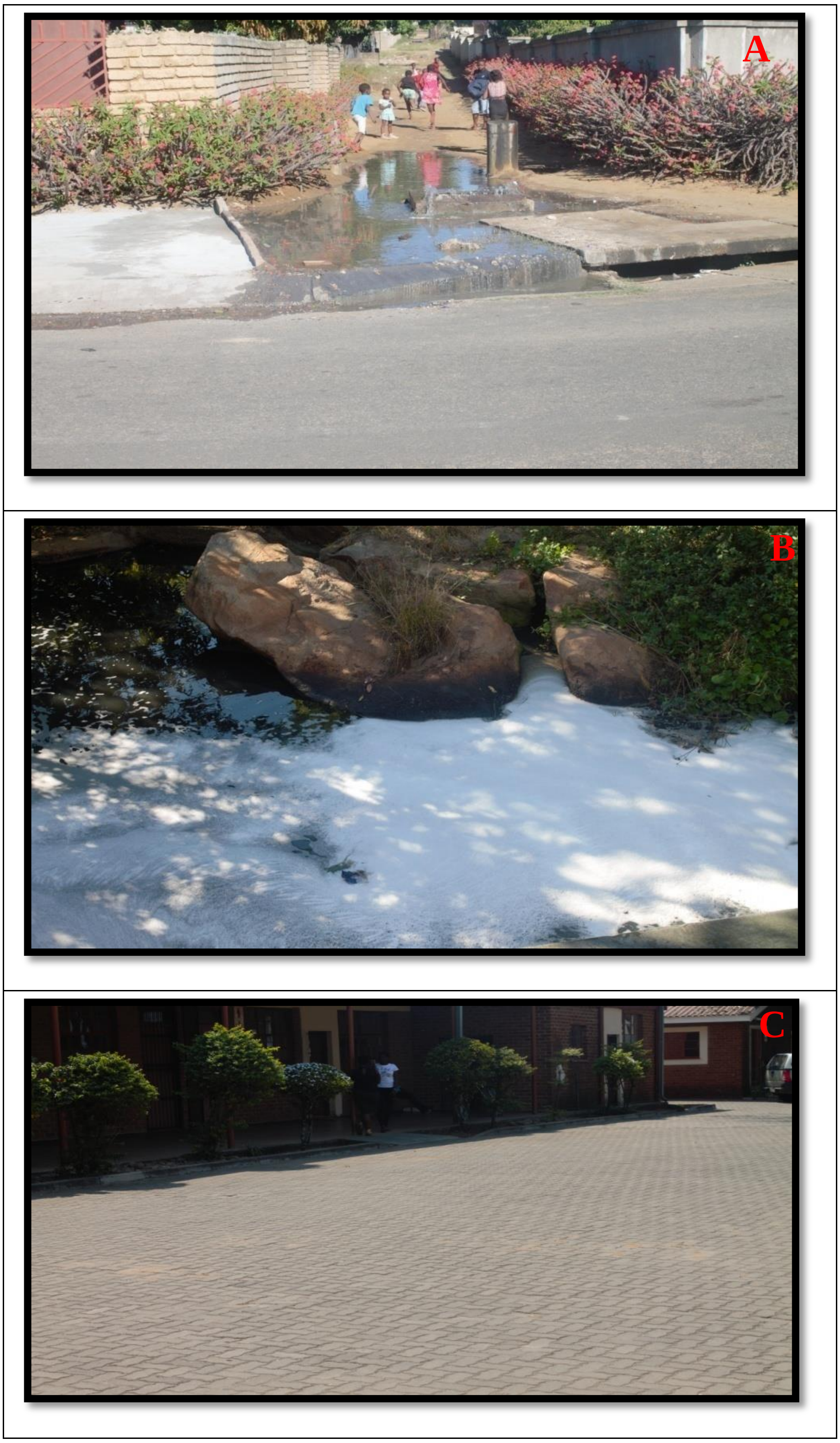


Plate 6.2: Array of images influencing exposure across Nkowankowa
(Source: Author's Field Photo, 2019)

6.2.1.2.3 Households' Level of Exposure to Climate Change Hazards in Hoedspruit Town

The spatial implication of household exposure to climate change at neighbourhood level is presented in Figure 6.4.

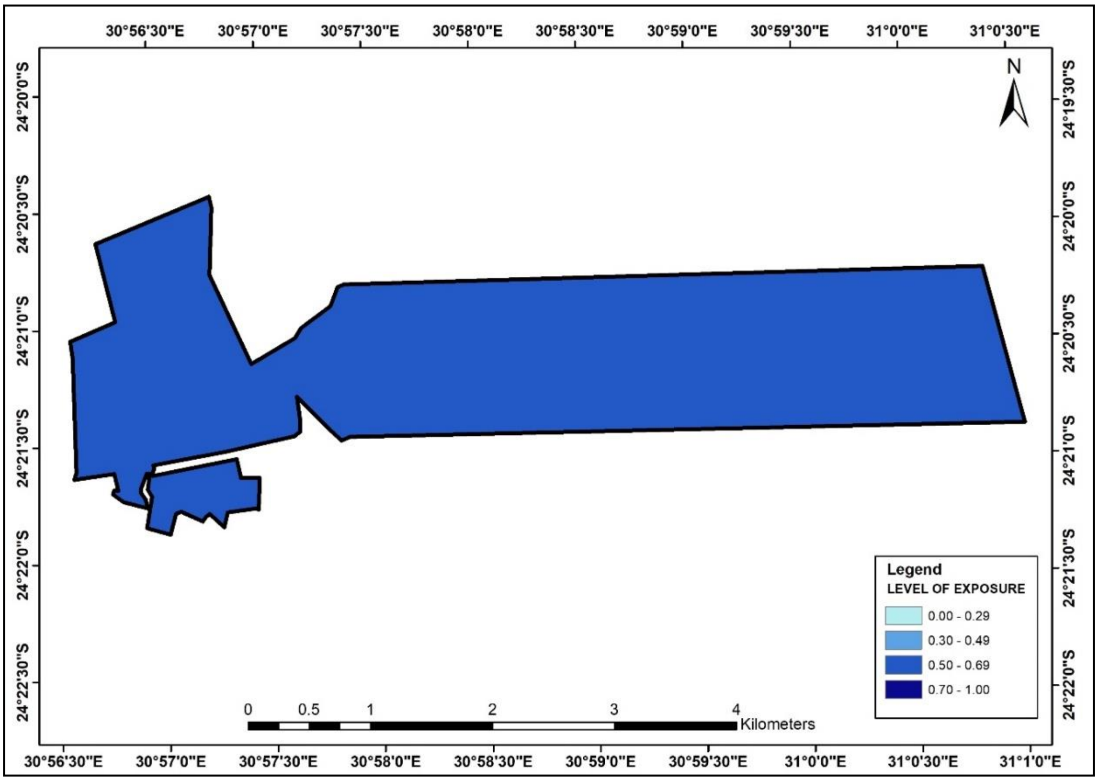


Figure 6.4 Households exposure across Neighbourhoods of Hoedspruit Town (Source: Author's Field Survey, 2019)

The case of Hoedspruit with respect to neighbourhood spatial analysis was a peculiar one. Hoedspruit has no dichotomized neighbourhood; it has a singular neighbourhood constituent. Hoedspruit contains only one section, which made an inter neighbourhood exposure variation impossible. However, to show the intensity of exposure in the singular neighbourhood, Figure 6.3 shows that 50-69% of households in the town are exposed to the climate change hazards occasioned by their length of stay in the town.

6.2.1.2.4 Households' Level of Exposure to Climate Change Hazards in Modjadjiskloof Town

In Modjadjiskloof, as regards the assessment of the spatial variation in the exposure level of the households, the town was stratified into just two distinct neighbourhoods (the main Modjadjiskloof town and the Mogkgopa Hostel). The result of the analysis is presented in Figure 6.5.

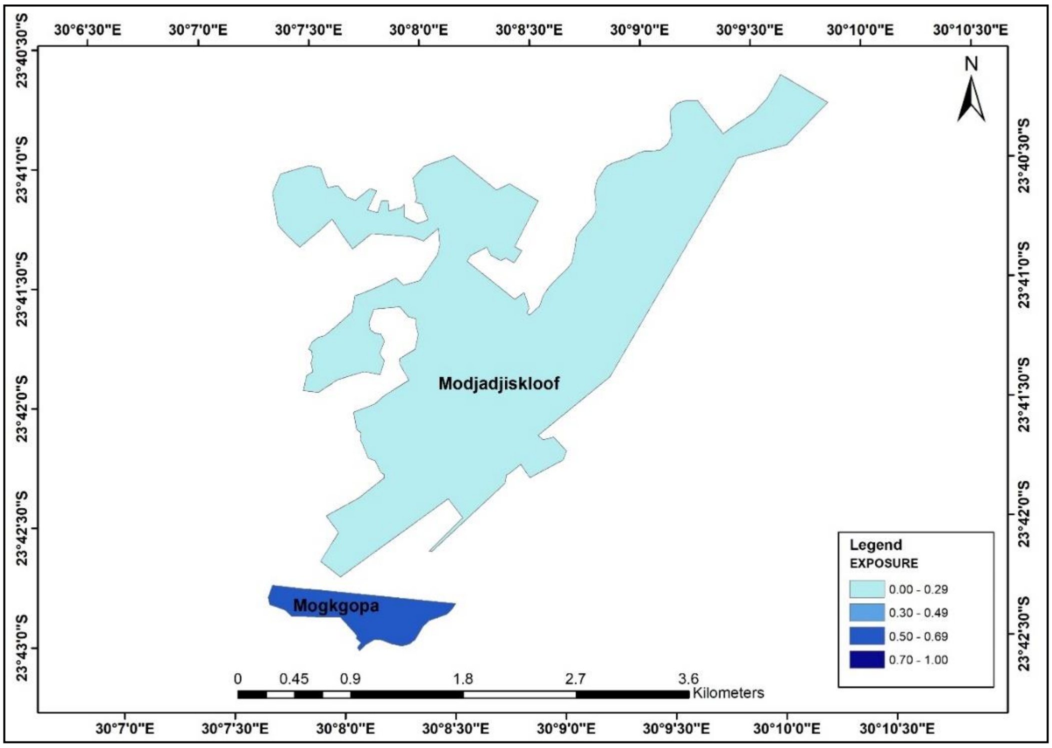


Figure 6.5: Households Exposure across Neighbourhoods of Modjadjiskloof Town
(Source: Author's Field Survey, 2019)

The Modjadjiskloof main town had less exposure to climate change, only about one-tenth of her households are exposed to climate related hazards. Conversely, the exposure level of households in Mogkgopa to the extreme climate change events was higher (50-69%). Figure 6.5 indicated the intensity of this variation in colour, and it depicts a higher level of exposure in Mogkgopa Hostel. The higher level of households' exposure in Mogkgopa neighbourhood can best be described as a reflection of the type of houses the residents were accommodated in. Plate 6.3a shows a typical shelter in Mogkgopa; these houses were not only informal, but they were below the RDP level. The buildings lack basic ancillary service (toilets, bathroom, kitchen etc.).

This has consequently been harmful to the households particularly to the aged and children who may not be capable of moving a far distance to access these auxiliary facilities. The quality of the shelter runs short of providing adequate protection to the lives of the inhabitants against climatic factors. Environment played a major role in curtailing exposure to climate change; however, the quality of the Mogkgopa neighbourhood was deplorable. The level of exposure in the Modjdadjiskloof main town reflected the type of houses and the quality of the environment households lived in (see Plate 6.3c). Further, to the level of exposure of Modjadjiskloof main town, the study uncovered that the topographical situation (steep slopes) of some parts of the town promoted erosion which was responsible for the households' exposure level in that neighbourhood of the town (see Plate 6.3d). The typical Mogkgopa environment exposes households to health dangers, particularly children and the elderly. In Madjadjiskloof main neighbourhoods, Households' exposure to erosion-prone topography was prominent; it has consistently endangered lives and properties of households through exacerbated surface runoff during downpours.

Plate 6.3: Array of images influencing exposure in acrossModjadjisklooftown
(Source: Author's Field Survey, 2019)

6.2.1.2.5 Households' Level of Exposure to climate Change Hazards in Phalaborwa Town

The level of household exposure level to climate change extreme events in Phalaborwa's eight delineated neighbourhood is presented in Figure 6.6.

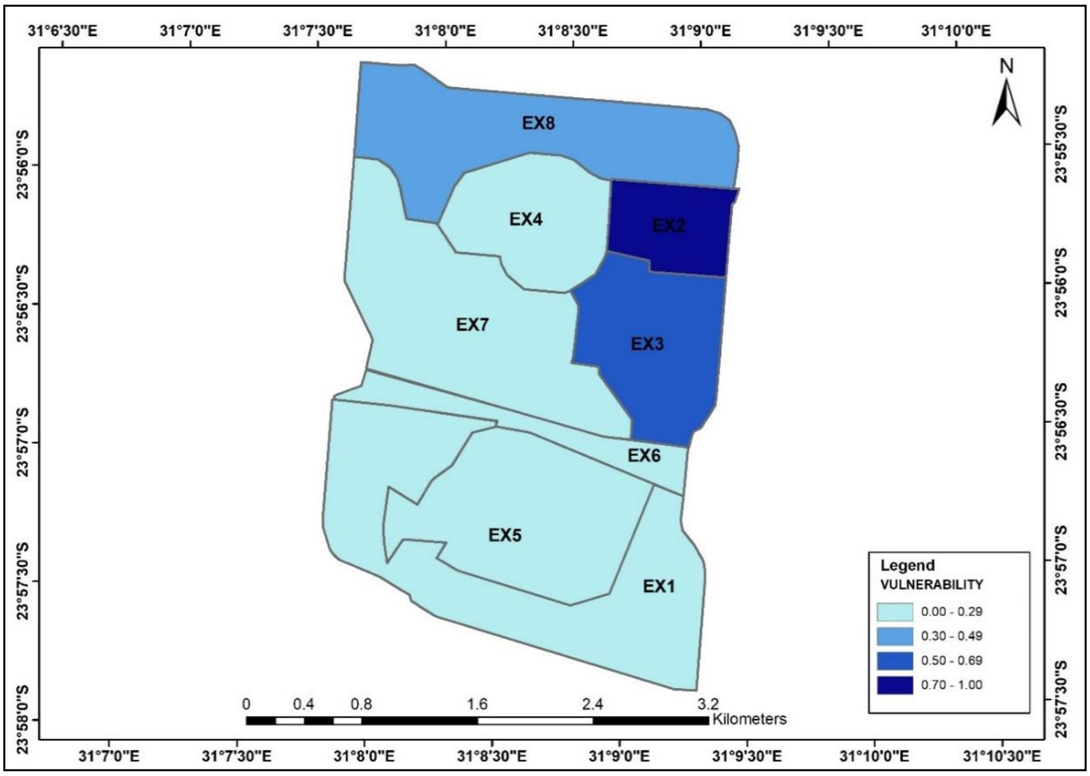


Figure 6.6: Households Exposure across Neighbourhoods of Phalaborwa Town
Source: Author's Field Survey, 2019

The analysis as depicted in figure 6.6 shows varying intensities of exposure across the different parts of the town. All the neighbourhoods had low level of exposure (0-29%) to climate related hazards, except extension 3, where households were exposed to 30-49% of extreme events and hazards of climate change.

The household exposure results obtained from these neighbourhoods reflected their nature of occupation (use). For example, Extensions 2, 3 and 8 were predominantly residential where a majority of the households in the town reside (in higher density). The relatively lower level was explained by the fortification of the neighbourhood with trees, shrubs and green vegetation, which has protected the neighbourhood against the adversities of the extreme climate change events. However, the micro climatic condition of the town played a pivotal role in the level of exposure across the town of Phalaborwa.

However, Extensions 1, 4, 6 and 7 with a low-level household exposure equally replicate their nature of occupation which was largely schools, public offices, commercial centres, State Departments, municipal offices, hospitals and the like; residential build up was not prominent. Hence the research was home-based, and household centred, as reflected in the results. Nonetheless, the level of exposure was occasioned by the microclimate of the town, equally complemented by the concrete nature of the landscapes that characterised the public and commercial spaces. This was coupled with a lack of drainage on roads which are some of the main causes in these neighbourhoods in Phalaborwa town. These have induced heat islands and exacerbating surface run off in the town, invariably increasing the household level of exposure to climate change events.

6.2.1.2.6 Households' level of exposure to climate change hazards in Giyani Town

An investigation into the level of exposure of households in Giyani across its six neighbourhoods is shown in Figure 6.7. Giyani Sections E is the neighbourhood with the highest proportion of households (30-49%). On the contrary, climate change exposure in all other neighbourhoods was less than 30%. This implies that less than 30% of the households were exposed to extreme climate related events.

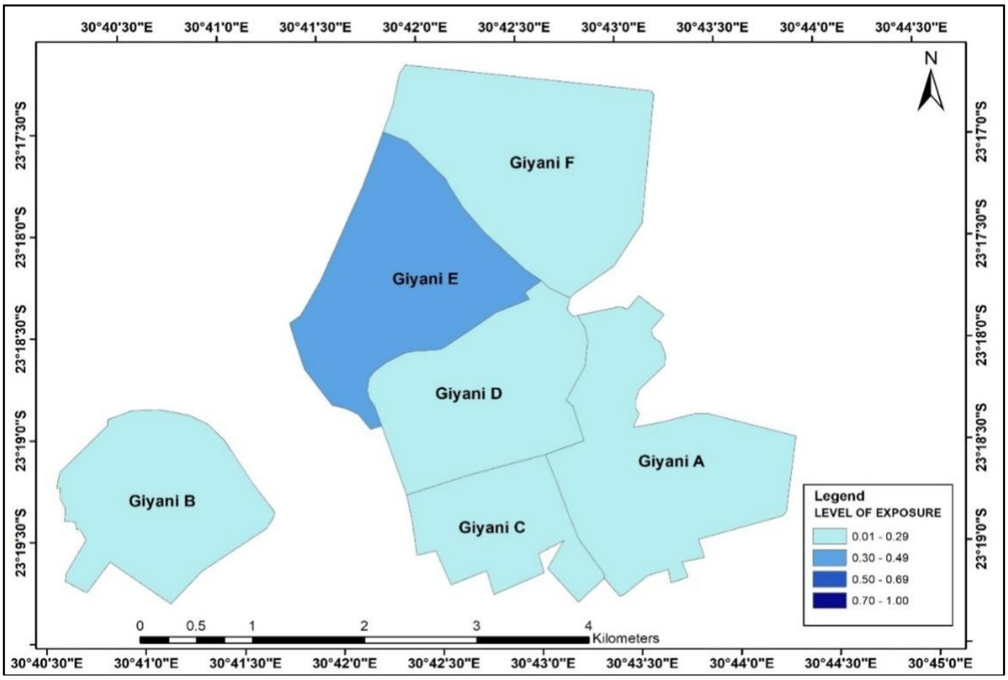


Figure 6.7: Households Exposure across Neighbourhoods of Giyani Town
(Source: Author's Field Survey, 2019)

The study further uncovered that the trend in the exposure levels generally in Giyani cannot be divorced from the climatic condition of the town, couple with the duration of stay in residents' places of abode (majority over 10 years), implying the length of time such households have been subjected to climate related extreme events. Vegetation consumption leading to land surface exposure has largely contributed to heat episodes. At the same time, the rate of urbanization has largely contributed to increased imperviousness, forest depletion and consequently higher exposure levels of households in the administrative seat of the Greater Giyani municipality

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6.2.1.3. Level of significance in Households' Exposure Index in the Study Area

In the first place a critical examination of the spatial levels of exposure of households in the six towns was undertaken. This established the spatial variation in exposure index among households to enable analysis of the level of significance in the variations across the selected towns in Mopani District. The study equally examined variations in the household exposure levels in the district. The results of the field investigation are presented in Table 6.3 where the Analysis of Variance (ANOVA) was thereafter discussed.

Table 6.3: ANOVA: Spatial variation in the Household Exposure index between towns across Mopani District

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	871.822	5	174.364	10.104	.000
Within Groups	8456.092	490	17.257		
Total	9327.915	495			

(Source: Author's Field Data, 2019)

From Table 6.3, with F = 10.104 and r = 0.000 there are spatial variation in the mean score of households exposure in all the six selected towns and that the variation are statistically significantWhile determining whether differences exist between the mean exposure indexes in the selected towns, statistical significance

It is however; particularly important to note that there are variations in the exposure level depending on the spatial scale under consideration. For instance the result of the ANOVA that was conducted to ascertain the existence of variation in household exposure, against the spatial scale depicted at individual towns level, the significant level differed from town to town (while it was significant in some, it was not in others).

6.2.2 Households' Hazard (Sensitivity) Index in Selected Towns

It was important to analyse the households' sensitivity index of climate change in selected Mopani towns. The results of the analysis are presented in Table 6.4.

Table 6.4: Variations in Households' Sensitivity Index in Mopani

Sensitivity	Tzaneen	Nkowa-nkowa	Hoedspruit	Modjadjis-Kloof	Phalab-orwa	Giyani	Total
	N %	N %	N %	N %	N %	N %	N %
Not Sensitive	65(82.3)	145 (82.9)	4 (22.2)	10 (100)	78 (92.9)	96 (73.85)	398 (80.24)
Sensitive	14 (17.7)	30 (17.1)	7(38.9)	0 (0)	5 (6)	28 (21.54)	84 (16.94)
Very Sensitive	0 (0)	0 (0)	7 (38.9)	0 (0)	1 (1.2)	6 (4.62)	14 (2.82)
Total	**79 (100)**	**175 (100)**	**18 (100)**	**10 (100)**	**84 (100)**	**130(100)**	**496 (100)**

(Source: Author's Computations, 2019)

The table shows that 80.24% of the district population were not sensitive to hazards. In all the six towns except Hoedspruit, the observed sensitivity was generally low. Only Hoedspruit had a very considerable low proportion of the population (22.2%) that were not sensitive, while Phalaborwa has the highest with 92.9% of the population. These results were substantiated by the results obtained from the Chi-square test with $X^2 = 351.332$, df= 190, p = .000, <0.05, implying a statistically significance at 0.05 confidence level. It means therefore that household sensitivity index is significantly different from town to town in the district. This variation reflects the frequency and intensity of the occurrence of floods, the prevalence of climate related diseases as well-as the severity of loss during disasters. Hoedspruit with significant households in climate related livelihoods was prone to a high impact during floods.

6.2.2.1 Households' hazard (sensitivity) index in Mopani by neighbourhoods

Presented in this section is the analysis of the sensitivity index to climate change investigation conducted in the neighbourhood of the selected Mopani towns' households. Upon investigation of sensitivity levels of the respective neighbourhoods of the six selected towns the results are presented in Figures 6.7 to 6.12.

The study shows the sensitivity level of neighbourhoods in Tzaneen. Figure 6.7a revealed that the sensitivity level in Tzaneen town is low. All the neighbourhoods were within 0-29% (0.0-0.29) sensitivity level. Although, low level of sensitivity is reported in the neighbourhoods, the level of sensitivity varied from one neighbourhood to the other.

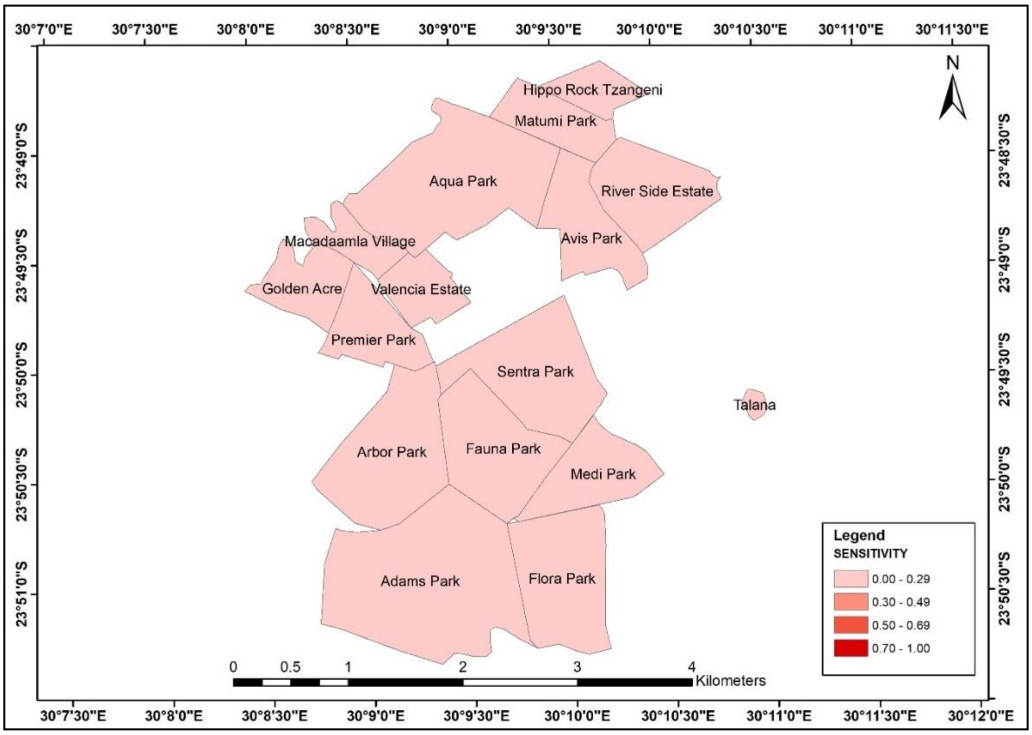

Fig 6.7a: Households Sensitivity across Neighbourhoods of Tzaneen Town
(Source: Author's Field Survey, 2019)

In Nkowankowa town the analysis shows that all the neighbourhoods had 0-29% sensitivity level. This is an indication that the sensitivity level in all the neighbourhoods is low. Figure 6.8 depicts the spatial variations in the sensitivity index of households in Nkowankowa. The figure's notation indicated a generally sensitivity across the town, that is Sections A -D.

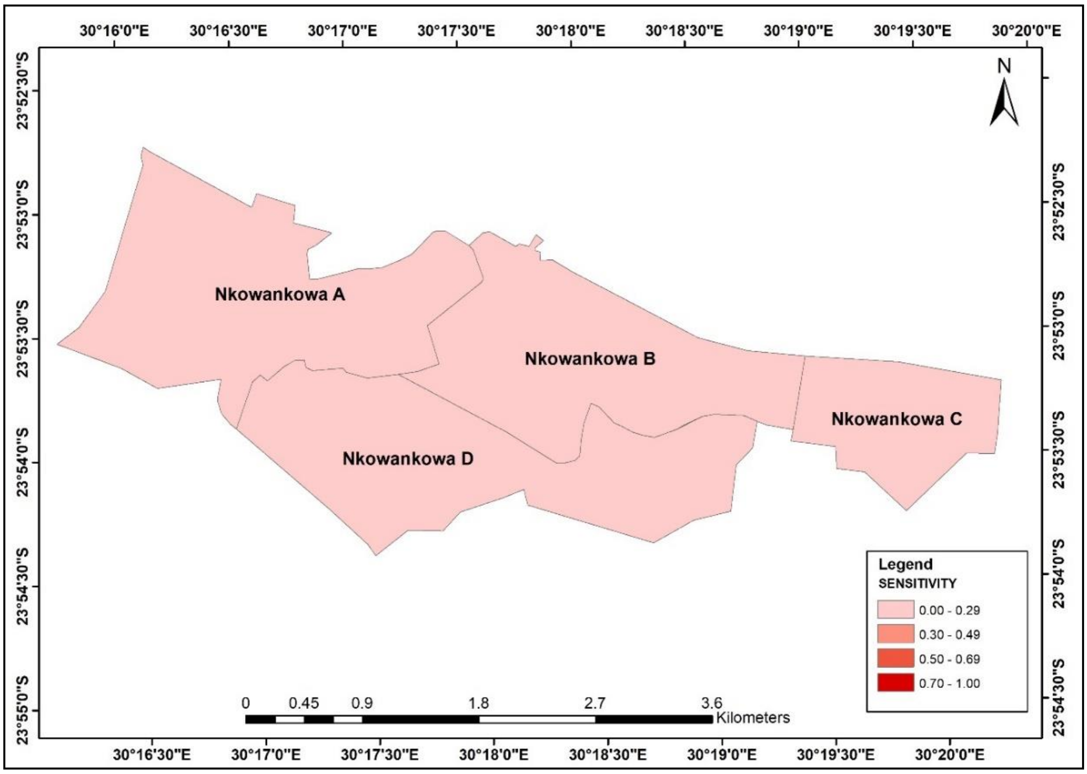

Figure 6.8: Households Sensitivity across Neighbourhoods of Nkowankowa Town (Source: Author's Field Survey, 2019)

The assessment of the sensitivity level of households to climate change hazards was examined in this section. Figure 6.9 depicts the households' sensitivity levels as shown in varying colours to show the variation in the intensities of the sensitivity index. From the Figure, Hoedspruit with a mono neighbourhood presented a homogeneous sensitivity index across the town. The sensitivity index within the Hoedspruit town indicated a high sensitivity level of 0.7-1.0. This was the highest when compared to other towns across the district.

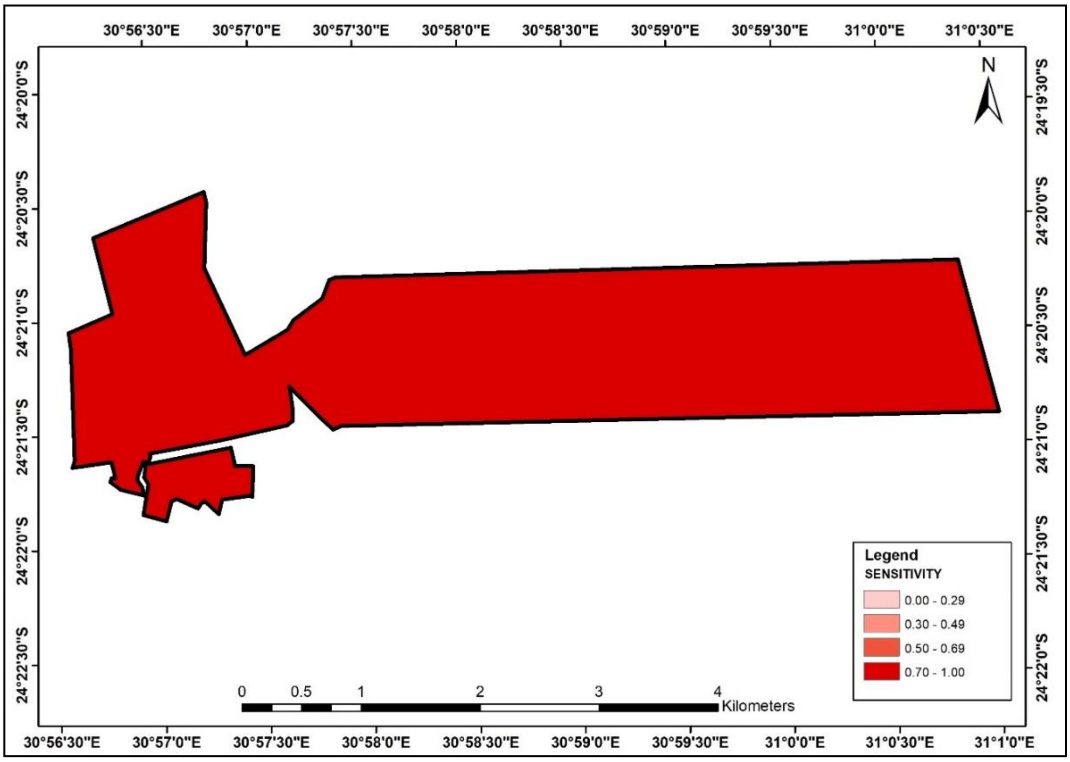

Figure 6.9: Households Sensitivity across Neighbourhoods of Hoedspruit Town (Source: Author's Field Survey, 2019)

The high sensitivity index of Hoedspruit was attributed to the climate sensitive nature of business conducted by significant members of the household in the town. Farming formed one of the major economic activities in the town. Another supporting fact was the incidence of major flooding that rocked the town in 2016 affecting many farmers who are residents of Hoedspruit. Small farmers were not spared from their produce getting ravaged by incessant drops in precipitation at one time or another in the region. These had collaboratively influenced the high sensitivity index of the town and have influenced the vulnerability level.

In Modjadjiskloof, the sensitivity analysis showed that virtually no household is sensitive to climate change hazards. Figure 6.10 shows that both neighbourhoods that constitute the town are not sensitive to the extreme events of climate change. This scenario will best be answered by reviewing the nature of economic activities of the households in the neighbourhoods.

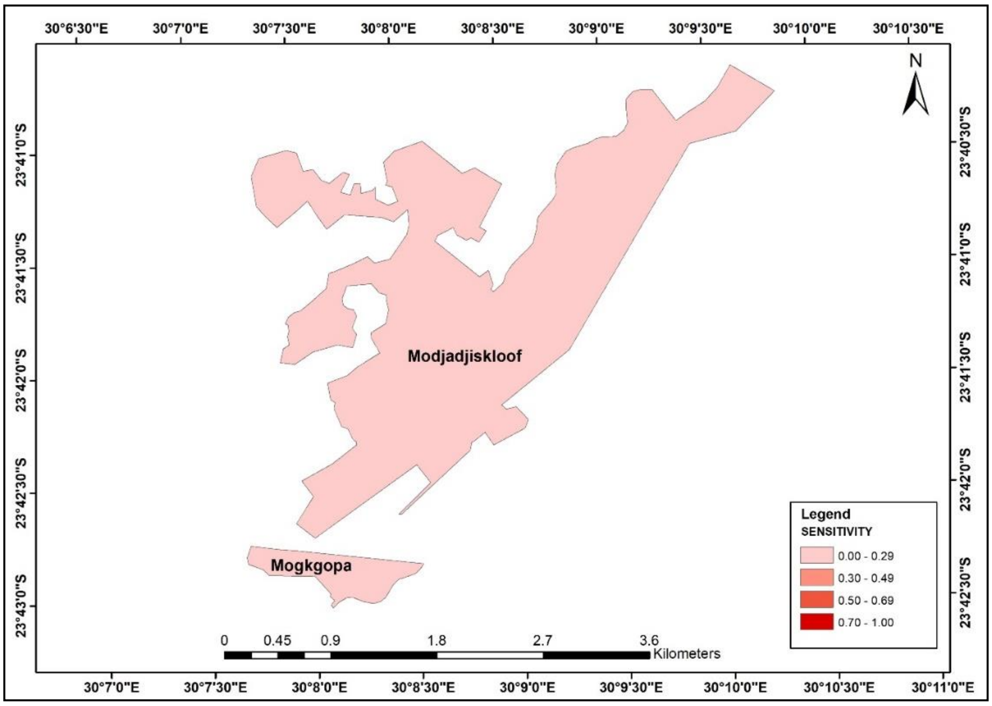

Figure 6.10: Households Sensitivity across Neighbourhoods of Modjadjiskloof Town(Source: Author's Field Data, 2019)

From the chapter 5, Table 5.11 indicated that 40% of Modjadjiskloof households are employed in timber industry and woodwork, another 20% in trading and 10% is self-employed. The implication of this was that, almost all of them do not engage in economic activities that are sensitive to climate. The impacts of climate change are rather felt by owners of the timber industries but not directly on the employees.

The study on the sensitivity of households in Phalaborwa showed a very low index across the mine town like other towns in the district. Figure 6.11 shows that all neighbourhoods (extension 1 - 8 were found to be the between 0-29% sensitive to climate change hazards. Although, notwithstanding the low sensitivity level recorded across the town, there are occurrence of variation in sensitivity among the neighbourhood.

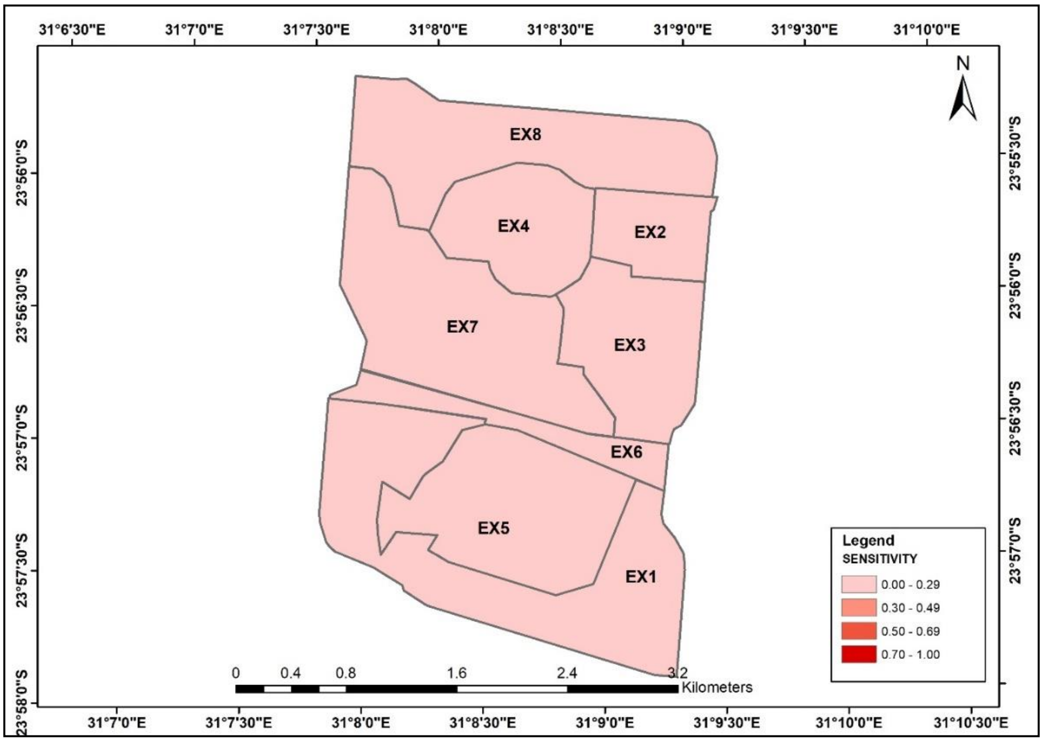

Figure 6.11: Households Sensitivity across Neighbourhoods of Phalaborwa
(Source: Author's Field Data, 2019)

The low Sensitivity index in Phalaborwa was equally explained by the economic activities which most households engaged in for a living. Mining and several other secondary economic engagements formed the major means of livelihood and that may not be directly climate sensitive. This is coupled with the robust primary health care system in the district as well as the local municipal level. Furthermore, several respondents had not personally suffered a loss due to the incidence of climate change related disasters.

The sensitivity index as analysed in Giyani is presented in Figure 6.12 to graphically depict the spatial distribution of the households' sensitivity levels in Giyani town.The figure shows that all the neighbourhoods (Section) had very low level of sensitivity, ranging from 0-29%. Figure 6.12 presents the spatial variation regarding sensitivity index, according to neighbourhood.

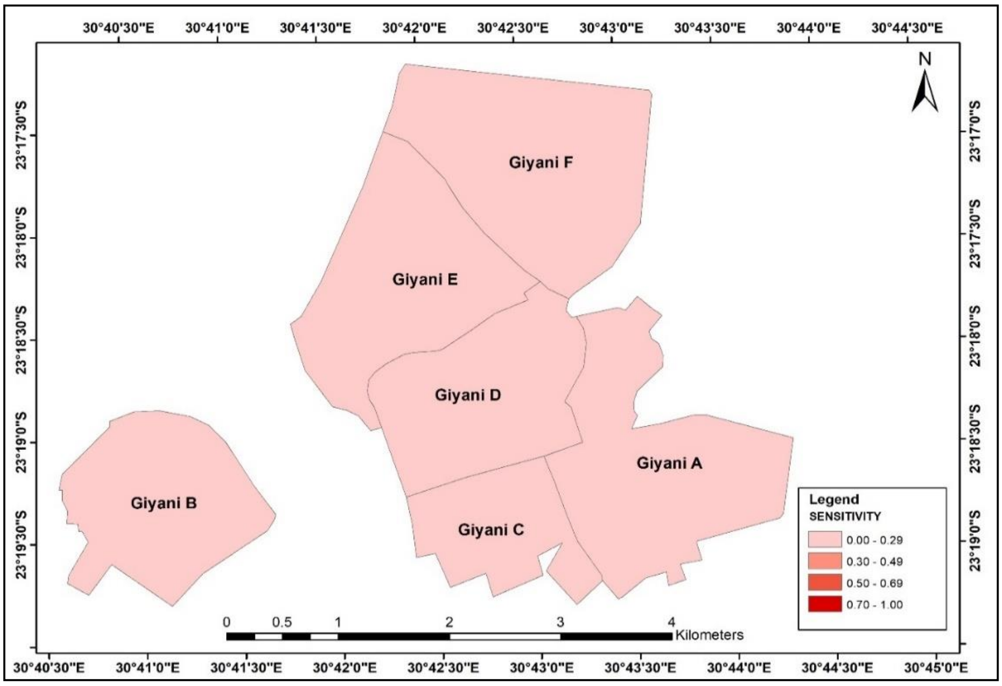

Figure 6.12: Households Sensitivity across Neighbourhoods of Giyani Town
(Source: Author's Field Data, 2019)

6.2.3. Households' adaptive capacity index in Mopani

This section highlights the results of the distribution of the households' adaptive capacity at different spatial levels in line with the established threshold in section 3.8.3.3.

6.2.3.1 Households' Adaptive Capacity Index in Mopani across Towns

From the results obtained from the analysis of households' adaptive capacity that is summarised in Table 6.5, the bulk of the respondents (76%) had varying levels of capacities

Table 6.5: Distribution of household's adaptive capacity across towns in Mopani

Capacity	Tzaneen		Nkowa-nkowa		Hoeds-pruit		Modjadjis-kloof		Phalab-orwa		Giyani		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Very Much Capable	10	12.7	8	4.6	1	5.55	3	30	5	6	19	14.62	45	**9.1**
Very Capable	40	51	68	38.9	6	33.3	3	30	31	37	29	22.31	185	**37.30**
Capable	18	22.8	49	28	4	22.22	0	0	30	36	49	37.69	150	**30.24**
Not Capable	10	12.7	50	28.6	5	27.8	4	40	18	21.4	27	20.77	111	**22.4**
Not Capable at All	1	1.3	0	0	2	11.1	0	0	0	0	6	4.62	9	**1.41**
Total	**79**	**100**	**175**	**100**	**18**	**100**	**10**	**100**	**84**	**100**	**130**	**100**	**496**	**100**

(Source: Author's Field Data, 2019)

to adapt to climate change impacts. Tzaneen town had the highest adaptability rating with an aggregate of 86.5%. Modjadjiskloof, of the six selected towns however, had the least adaptive capacity (28%) followed by Nkowankowa with 40% (see Table 6.5).

The low level of household adaptive capacity reflects the socioeconomic attributes of the household heads in the selected towns across the district, from a lack of jobs to a lack of income by significant proportions of the households. This to a significant extent influenced the possession of certain personal gadgets that are necessary to strengthen the individual household's capability. For instance, the quality of the environment in neighbourhoods like Section D in Nkowankowa, Magkogpa in Modjajiskloof, and Talana in Tzaneen had contributed to the reduced adaptive capacity levels of the inhabitants of these neighbourhoods. Further to these reasons were the housing shortages and high backlogs of basic services in the selected towns in Mopani District as identified in the IDPs

6.2.3.1.1 Households' adaptive capacity index in Mopani across neighbourhoods

To understand the spatial variations in adaptive capacity of households to climate change hazards in the six selected towns' neighbourhoods across Mopani District, the analysis of adaptive capacity of households was conducted. Figure 6.13 to Figure 6.19 show the results of the spatial analysis of households' adaptive capacities in the selected towns, represented graphically.

6.2.3.1.2 Households' Adaptive Capacity Index in Tzaneen Town's Neigbour-hoods

Further analysis into the spatial distribution of adaptability of households among towns and across the neighbourhood is depicted in Figure 6.13. Households in Matumi park, Hippo rock Tzangeni, River side estate and Premier Park had the highest level of adaptive capacity to climate change. Households in the neighbourhoods had adaptive capacity of between 30-49%, which is a fair level of adaptive capacity to climate change.

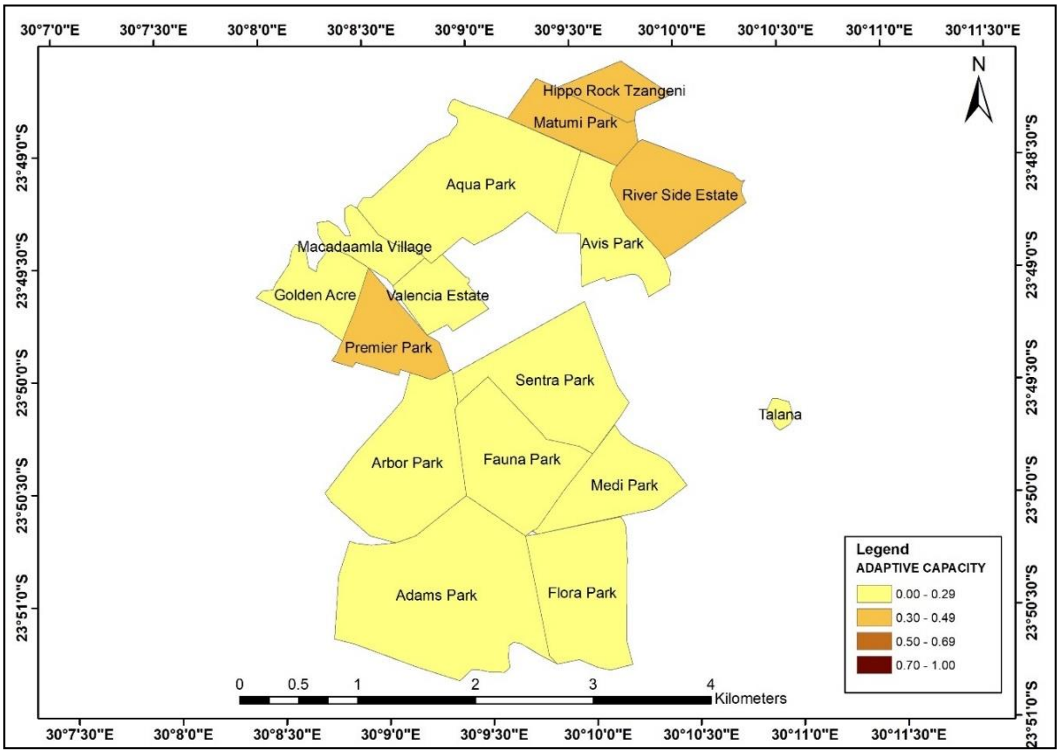

Figure 6.13: Households Adaptive Capacity across Neighbourhoods of Tzaneen Town (Source: Author's Field Data, 2019)

All other neighbourhoods in Tzaneen had a low adaptive capacity of less than one-third. The adaptive capacity of the neighbourhoods was in the range of 0-29%. The high level of adaptability recorded in Tzaneen town was best explained by the high level of educational attainment, a quality environment, low poverty levels and higher personal and community assets possessions. These factors enhanced coping capability and invariably influencing vulnerability level.

6.2.3.1.3 Households' Adaptive Capacity Index in Nkowankowa Town's Neigbourhoods

The result of the analysis of spatial variability of adaptive capacity of households to climate change extreme events across neighbourhoods in Nkowankowa is shown in Figure 6.14. The figure shows that all the four neighbourhoods in Nkowankowa, that is, Sections A - D of the town had low adaptive capacity which ranged from 0% to 29%. The capacity of the households to adapt to extreme climate change event was low; less than 29% of the households had the ability to adapt to climate related hazards. The low level of adaptive cap-

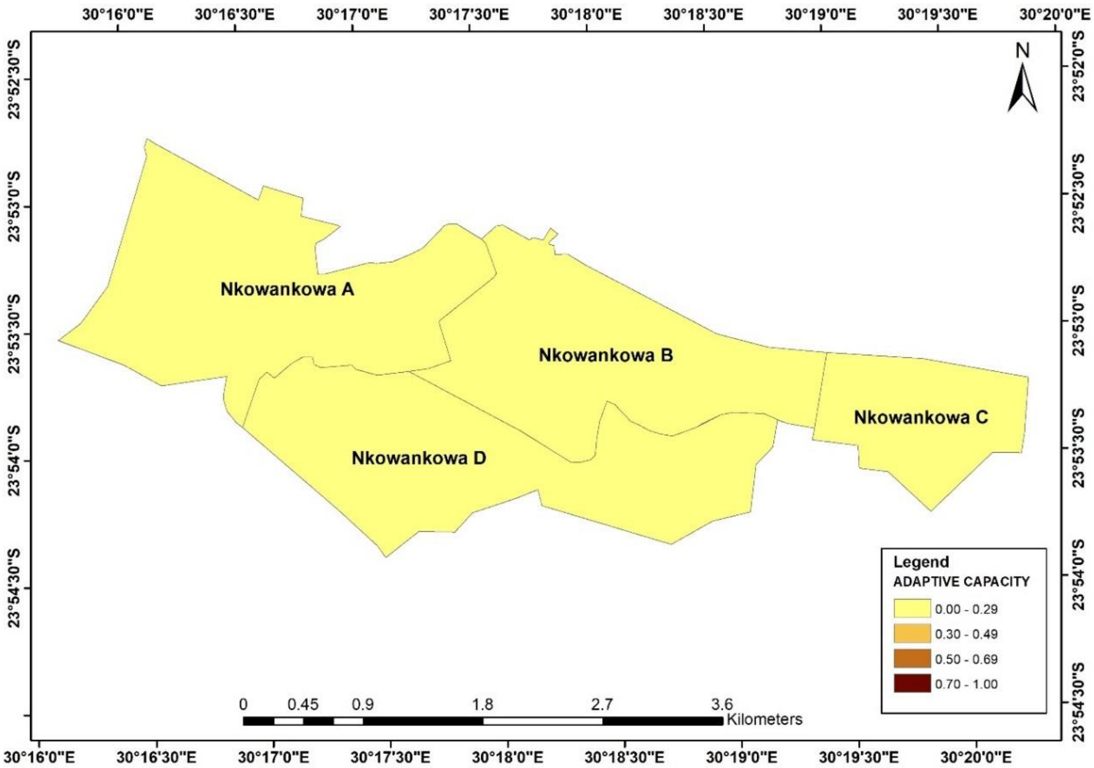

Figure 6.14: Households Adaptive Capacity across Neighbourhoods of Nkowankowa Town (Source: Author's Field Data, 2019)

acity recorded in the neighbourhoods (Section) was not only occasioned by the socioeconomic peculiarities of the households in these neighbourhoods with significantly low-income earners. Rather it is also a reflection of their limited personal assets, and home auxiliary and community services that were available to cushion the effects of climate related hazards.

6.2.3.1.4 Households' Adaptive Capacity Index in Hoedspruit Town'sNeighbourhoods

The analysis of Hoedspruit presented a homogenous neighbourhood as regards the spatial distribution of households' adaptive capacity. The spatial representation of the findings is depicted in Figure 6.15 which shows that Hoedspruit had about 60% of households with the capacity to adapt to climate change hazards. The proportion of households with low capability of adapting to climate change hazard in Hoedspruit is considered high, and may not be unconnected to low-income levels, and mono economic activities among households (no multiple sources of income) that could facilitate or serve as a buffer in case climate change hazards occurred.

Figure 6.15: Households Adaptive Capacity across Neighbourhoods of Hoedspruit Town (Source: Author's Field Data, 2019)

6.2.3.1.5 Households' Adaptive Capacity Index in Modjadjiskloof Town's Neigbourhoods

Regarding the examination of the spatial variation of household adaptive capacity to climate change hazard in Modjadjiskloof neighbourhoods; Figure 6.16 reveals the adaptive capacity of households in Modjadjiskloof, The Figures shows that Mogkgopa neighbourhood had a low level of adaptive capacity to climate related hazards. Households with compromised adaptive capacity in Mogkgopa ranged between 50-69%. Apart from the low quality environment, the bulk of the households in the neighbourhood were not only unemployed, but they were low-income earners. However, the adaptive capacity of households in main Modjadjiskloof was high, with households with compromised adaptive capacity in the neighbourhood in the range of 0-29%.

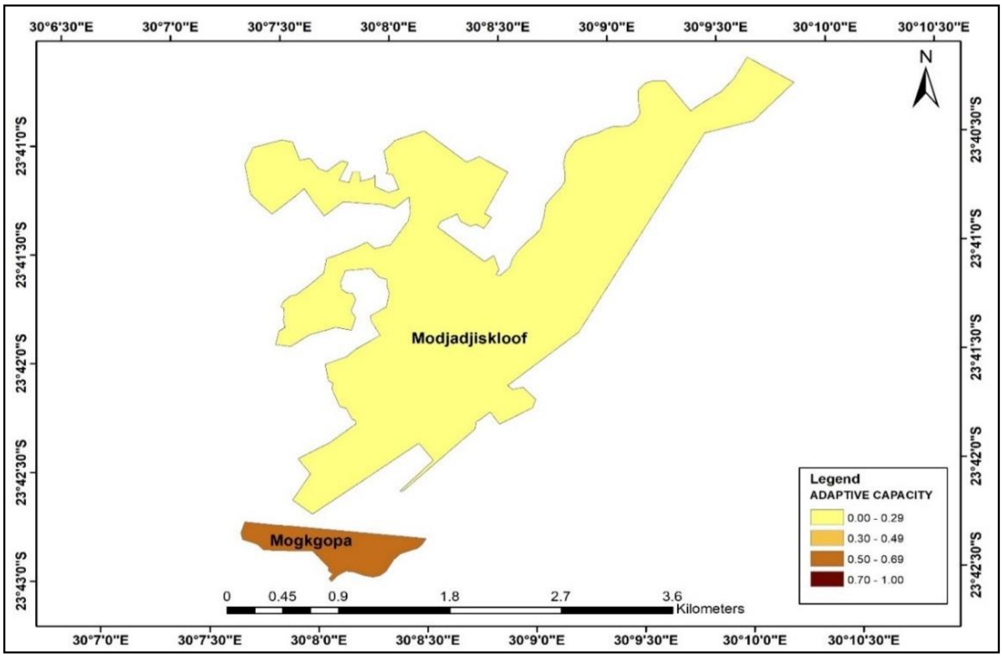

Fig 6.16: Households Adaptive Capacity across Neighbourhoods of Modjadjiskloof Town (Source: Author's Field Survey, 2019)

6.2.3.1.6 Households' Adaptive Capacity Index in Phalaborwa Towns Neigbourhoods

According to the analysis of the adaptive capacity of households, Figure 6.17 presents the spatial variation of the capability of the neighbourhoods to cope with climate

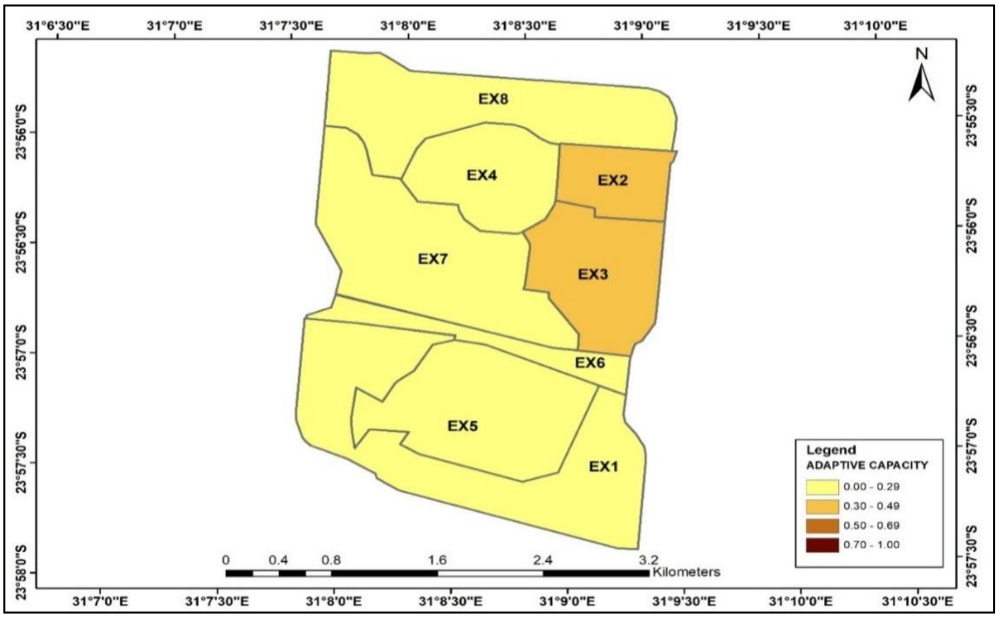

Fig 6.17: Households Adaptive Capacity across Neighbourhoods of Phalaborwa Town(Source: Author's Field Survey, 2019)

change hazards in Phalaborwa.

This Figure reveals that the capability to cope with climate change hazards by households in Ext 2 and 3 neighbourhoods was the highest, with between 50% to 69% of its households very capable of adapting to climate change hazards, while the coping capacity of households in the other remaining Extensions (neighbourhoods) followed with 29% households.

The high adaptive capacity level recorded was a reflection of the combination of factors, such as high-income levels, higher literacy levels, as well as quality environment which have boosted the households' capability of the neighbourhoods. However, access to basic services and individual household assets possession was equally high to facilitate and enhance the households' adaptive capacity to climate change hazards in the entire Phalaborwa town.

6.2.3.1.7 Households' Adaptive Capacity Index in Giyani Towns Neigbourhoods

In Giyani, Figure 6.18 shows that Giyani's six neighbourhoods vary in their adaptive capacities to climate stress and adversities. For instance, the figure depicts that Giyani Section

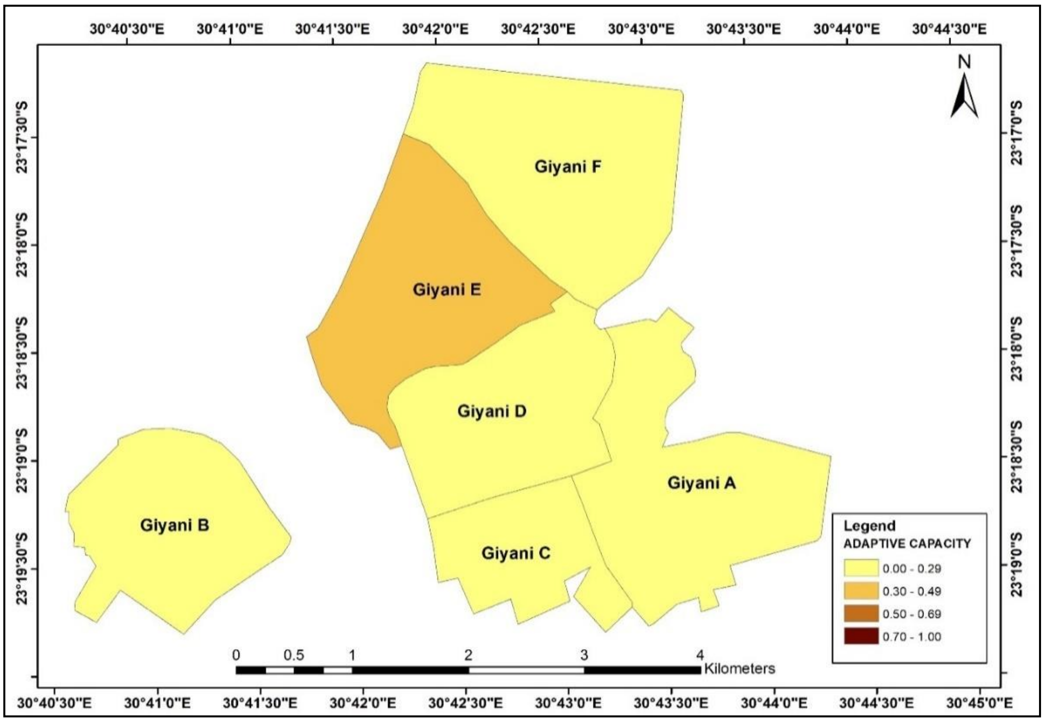

Fig 6.18: Households Adaptive Capacity across Neighbourhoods of Giyani Town
(Source: Author's Field Survey, 2019)

E had the highest capacity, with 30-49% of households having the capacity to cope with climate change hazards. Other neighbourhoods (Sections) in Giyani had low adaptive capacity, with 0-29% of households in the neighbourhood having the capacity to cope with climate change hazards.

The high capability recorded in Giyani was attributed to the availability of some community services such as electricity, schools, shopping malls, primary health institutions, among others. However, potable water had been a serious challenge to the households in various locations of the town. Furthermore, the variation in the adaptability of households in different neighbourhoods of the town did not only mirror the income levels but also the variation in the quality of the environment in which households reside.

6.2.3.2 Significance of Variation in Households' Adaptive Capacity in Mopani District Neighbourhoods

The study found it very essential to conduct a critical assessment of the spatial implications of the spread of the coping capacities to climate change of the households in the six towns. The study tested the spatial variation in adaptive capacity among households across neighbourhoods to examine the existence or otherwise of any statistically significant variation and presented these results in Table 6.6.

Table 6.6: Anova result of variations between household adaptive capacities across neighbourhoods in selected towns in Mopani District

Town					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3318.381	5	663.676	9.816	.000
Within Groups	33129.859	490	67.612		
Total	36448.240	495			

Source: Author's Field Data, 2019

From Table 6.6, the result shows the differences between the adaptive capacity index and its significance level in the neighbourhoods across the Mopani Districts by ANOVA test. From the result, obtained from Table 6.6, with $F = 9.816$ and $p = 0.000$ (<0.05), it can then be concluded that the adaptive capacity mean (index) across residential neighbourhoods in the six selected towns in Mopani District varied and the variation were statistically significant.

6.2.3.3: Correlations between Households' Sensitivity Index and Some Socioeconomic Factors

Considering the relationship between household's sensitivity index to some socioeconomic attributes of the households in the district, the study conducted Pearson's Correlations to examine whether relationships existed between these variables as well as other relevant attributes. The socioeconomic variables were correlated, and the result is presented in Table 6.7.

Table 6.7: Correlation between some Households' socioeconomic factors and their Sensitivity Levels

Socioeconomic variables		Monthly Income	Sensitivity	Age	Gend-er	Highest Qualificat-ion	Duration of stay in the locality
Monthly Income	Pearson Correlation	1	.020	.037	-.071	-.208**	.061
	Sig. (2-tailed)		.655	.416	.117	.000	.173
	N	496	496	496	496	496	496
Sensitivity	Pearson Correlation	.020	1	-.123**	.024	-.087	.149**
	Sig. (2-tailed)	.655		.006	.600	.053	.001
	N	496	496	496	496	496	496
Age	Pearson Correlation	.037	-.123**	1	-.197**	.006	.072
	Sig. (2-tailed)	.416	.006		.000	.890	.107
	N	496	496	496	496	496	496
Gender	Pearson Correlation	-.071	.024	-.197**	1	.004	-.080
	Sig. (2-tailed)	.117	.600	.000		.928	.075
	N	496	496	496	496	496	496
Highest Qualification	Pearson Correlation	-.208**	-.087	.006	.004	1	.068
	Sig. (2-tailed)	.000	.053	.890	.928		.133
	N	496	496	496	496	496	496
Duration of stay in the locality	Pearson Correlation	.061	.149**	.072	-.080	.068	1
	Sig. (2-tailed)	.173	.001	.107	.075	.133	
	N	496	496	496	496	496	496

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author's Field Data, 2019

Table 6.7 presents the Pearson Correlation results and shows that, with r = 0.2, with p= 0.655. The relationship was positive, though the correlation coefficient was not statistically significant. This implies that there is no statistically significant relationship between primary income and household sensitivity.

Similarly, with r = 0.123, the relationship between Age of household and their sensitivity levels are equally moving in the same direction, that as Age increases, sensitivity level equally increases. However, with p = 0.006, the Correlation is found to be statistically significant. It therefore implies that a unit increase in the age of respondents increases the log odd of the sensitivity index by 0.123, signifying that the older the respondent, the higher the sensitivity level of the households to climate change hazards.

A further examination of the correlation between both Highest qualification and duration of stay in the locality and household's sensitivity levels revealed r = -0.87 which shows that both variables (highest qualification and sensitivity level are in opposite directions). By implication, as qualification increased the sensitivity level reduced, occasioned by high level of awareness and an informed precautionary actions among the educated to tame the negative impacts of climate hazards. However, with p = 0.053 the correlation was established to be statistically insignificant. Furthermore, the correlation between duration of stay in locality was positive (in the same direction) and statistically significant at r = 0.149, with p = 0.001. This result implies that the longer the duration of stay by households' in their places of abode, the higher the household sensitivity to climate change extreme events. See Table 6.7.

6.2.4 Households' Aggregate Vulnerability Index

As earlier discussed, vulnerability is the tendency to be adversely affected by climate-related adverse effects. These adverse effects include exposure, sensitivity as well as adaptive capacity earlier examined. These are components from different theoretical approaches. Since the vulnerability is dynamic and time operational at diverse scales, the analysis shows that several factors are responsible. On this note we examined household vulnerability across different levels including the district local municipalities, towns, neighbourhoods, and residential densities.

6.2.4.1 Households' Aggregate Vulnerability Index across Towns

Table 6.8 summarised vulnerability indexes across the selected towns and shows that vulnerability across the District of Mopani is generally high with about 67.14% households being vulnerable.

The situation is similar across the towns except Hoedspruit which has 56% highly vulnerable households and 33.3% moderately vulnerable residents. Other towns had above

Table 6.8 Distribution of household's aggregate vulnerability index across towns

	Towns						
Vulnerability	Tzaneen %	Nkowa-nkowa %	Hoedspruit %	Modjadjis-kloof %	Phalaborwa %	Giyani %	**Total** %
Lowly Vulnerable	10.13	12.00	11.11	30	3.57	16.92	**13.51**
Moderately Vulnerable	11.39	19.43	33.33	10	22.62	20.77	**19.36**
Highly Vulnerable	78.48	68.57	55.56	60	73.81	62.31	**67.14**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(Source: Author's Computations, 2019)

six in every ten of the residing households highly vulnerable (Table 6.8). As highlighted under vulnerability at municipal level, the six selected towns have their peculiarities regarding the responsible factors contributing to their levels of vulnerability to climate change hazards. On a general note, the degree of vulnerability observed in Tzaneen cannot be divorced from factors that range from system failure (several drainages were blocked), poor housing and environmental conditions in neighbourhoods like Talana as well as impervious surface cover. On the other hand, Nkowankowa town equally faced the challenges of flash floods in Section D because of the waterlogged nature of the terrain, sewer leakages and impervious land uses. However topography accounts for the major challenges that are faced by the core areas of Modjadjiskloof, while Mogkgope hostel was characterized by a normal settlement lacking several basis services, with poor and unfit shelters and a filthy environment. The case of Giyani was more of urban expansion resulting in forests compromised, surface exposure to heat and erosion. While Hoedspuit and Phalaborwa were the resultant effects of imperviousness and livelihood engagements. However, the six selected towns were all affected by their micro climates as well as the influence of the regional climate system.

6.2.4.2 Households' Aggregate Vulnerability Index across Neighbourhood

In order to establish the spatial patterns of households' aggregate vulnerability indexes in the neigbourhoods of Tzaneen, Nkowankowa, Hoedspruit, Modjadjiskloof, Phalaborwa and Giyani towns, the shape file representation of the households were plotted and shown in Figures 6.19 to 6.24. The results of the analyses were presented as follows.

6.2.4.2.1 Household's Aggregate Vulnerability Index in Tzaneen Town Neighbourhoods

The spatial distribution of household aggregate vulnerability in Tzaneen neighbourhoods was analysed to determine the differences spatially as shown in Figure 6.19.

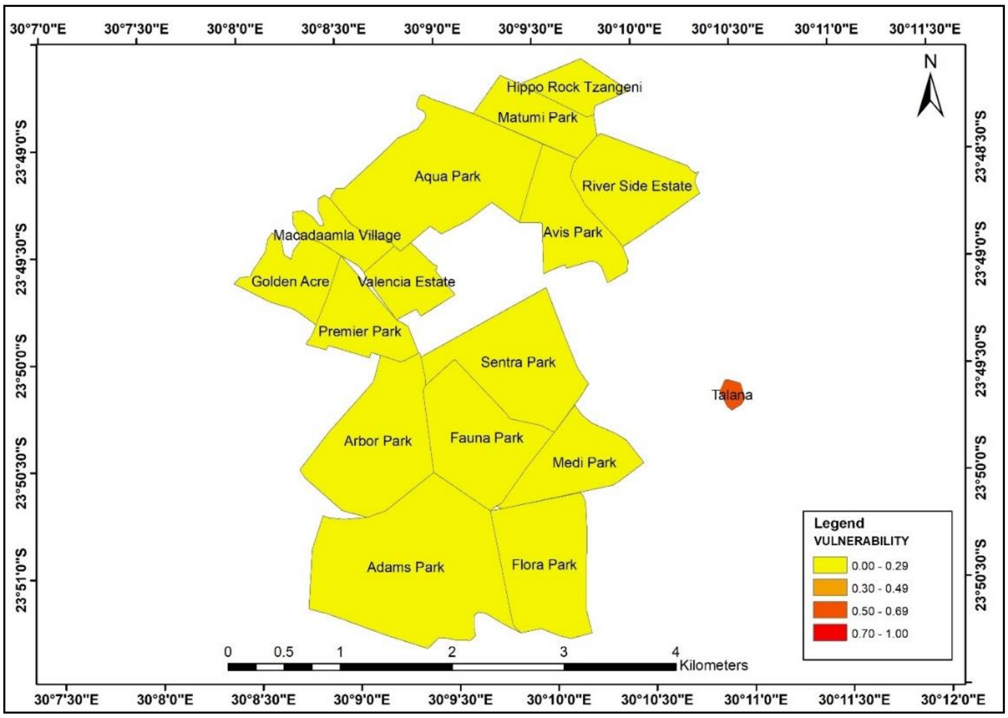

Figure 6.19: Households Aggregate Vulnerability across Neighbourhoods of Tzaneen Town (Source: Author's Field Data, 2019)

Every other neighbourhood had low vulnerability to climate change (0-29%), except Talana which had a high level of vulnerability to climate related hazards with between 50-69% of her households being vulnerable to climate change events.

The results show that the spatial variation in the vulnerability index across the neighbourhoods of Tzaneen mirrored the environmental condition of the neighbourhoods as well as the socioeconomic characteristics of the households in the various neighbourhoods. For instance, Talana that accounted for the highest vulnerability level (50-69%) to climate change hazards is characterized by low-income households with most job seekers and casual labourers occupying poor houses and poor environmental conditions as well as lacking basic services and having zero insurance cover.

6.2.4.2.2 Household's aggregate vulnerability index in Nkowankowa town neighbourhoods

Figure 6.20 shows that Section D was the neighbourhood with the highest proportion of vulnerable households (between 50% and 69%) and Section C, between 30% and 49%. Section A and B had between 0% and 17%.

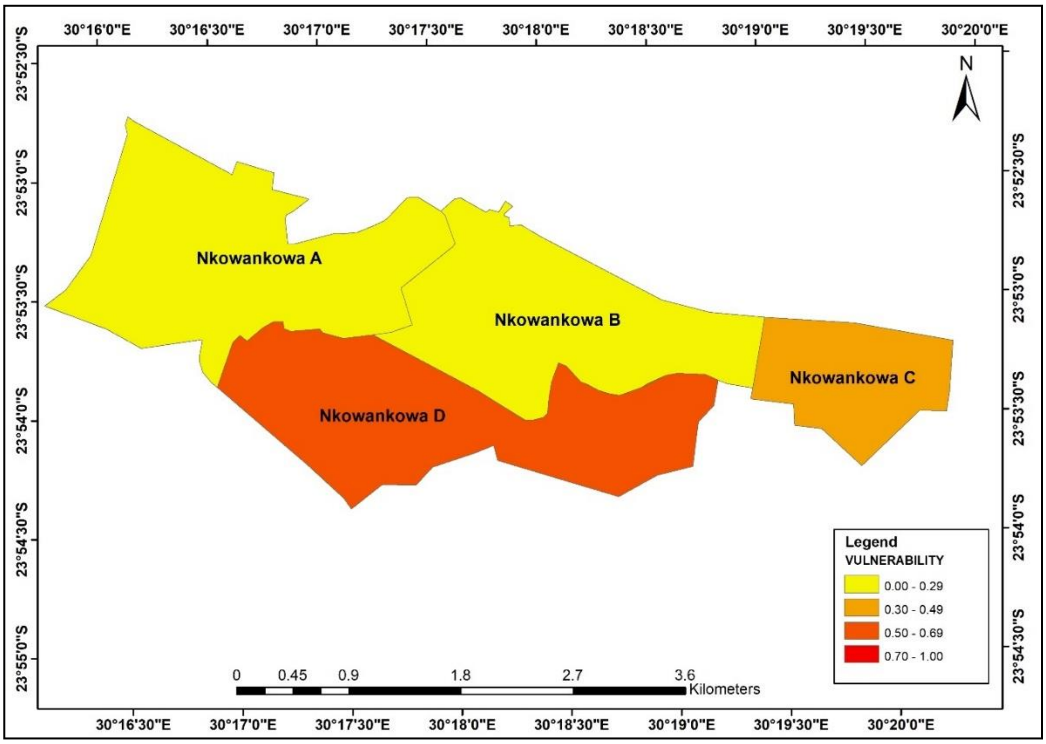

Figure 6.20: Households Vulnerability across Neighbourhoods of Nkowankowa Town(Source: Author's Field Data, 2019)

The peculiarities in the socioeconomic attributes of the households in Nkowankowa and the general environmental conditions reflected the levels of vulnerability across the neighbourhoods. For example, Sections C and D that accounted for the highest vulnerable households in Nkowankowa town were unproclaim neighbourhoods dominated by low income and job seeking households, poorly serviced and partly waterlogged. These conditions among others have aided the high levels of vulnerability indexes in these neighbourhoods. Conversely, Sections A and B, (particularly section B) were dominated by high income households, quality environment, sound building structure and high proportion of personal asset share. These conditions have equally reflected in the lowly vulnerability level in the Section B neighbourhoods of Nkowankowa.

6.2.4.2.3 Household's Aggregate Vulnerability Index in Hoedspruit town Neighbourhood

The result of the analysis of aggregate vulnerability levels of households in Hoedspruit, like in the previous variables presents a unitary neighbourhood. The spatial representation is presented in Figure 6.21.

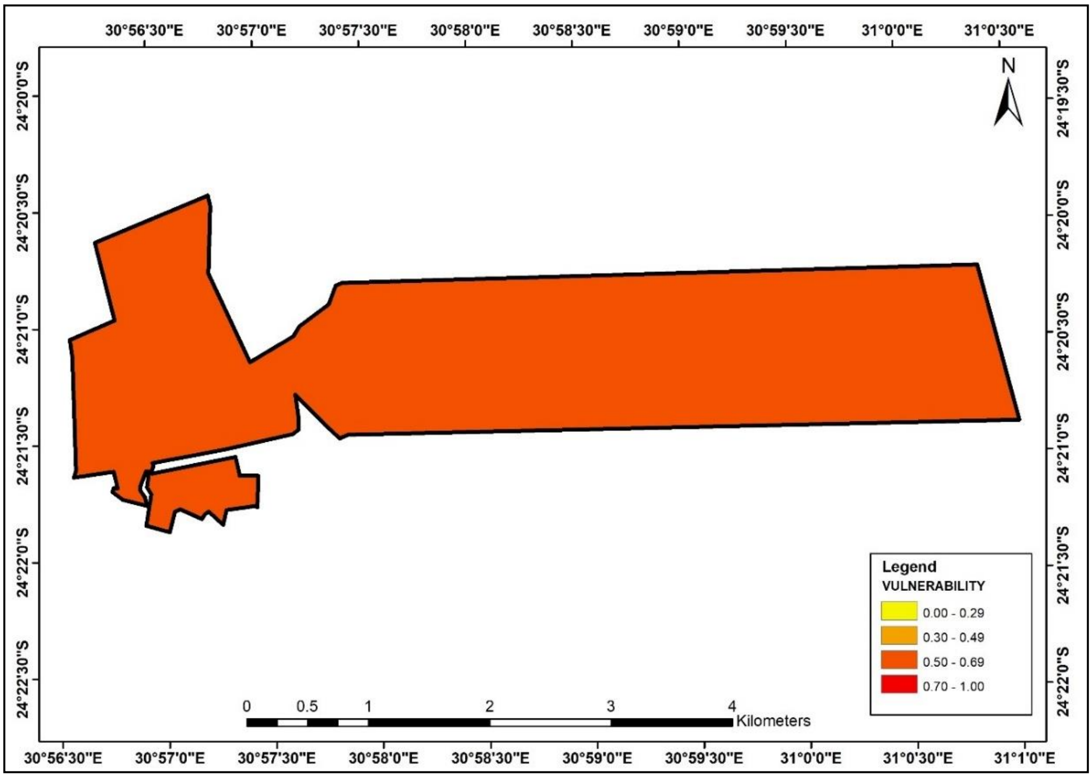

Figure 6.21: Households Aggregate Vulnerability across Neighbourhoods of Hoedspruit Town (Source: Author's Field Data, 2019)

From Figure 6.21, Hoedspruit shows a unitary neighbourhood. The figure reveals that Hoedspruit had about 50-69% of households vulnerable to the extreme events of climate change. This proportion is considered high and cannot be divorced from the typology of the economic activities which the bulk of the households engage in, which were farming and service-oriented businesses. In addition, Hoedspruit is the only one of the six selected towns where no households engaged in multiple income sources which would have served as a buffer at the time of need.

6.2.4.2.4 Household's Aggregate Vulnerability Index in Modjadjiskloof Town Neigbourhoods

The results of the examination of the spatial variation of household vulnerability level to climate change hazards in Modjadjiskloof neighbourhoods are depicted in Figure 6.22. This Figure reveals that 0-29% of the town's population were vulnerable to climate change hazards in Modjadjiskloof, while 50-69% of the residents of Mogkgopa vulnerable to climate

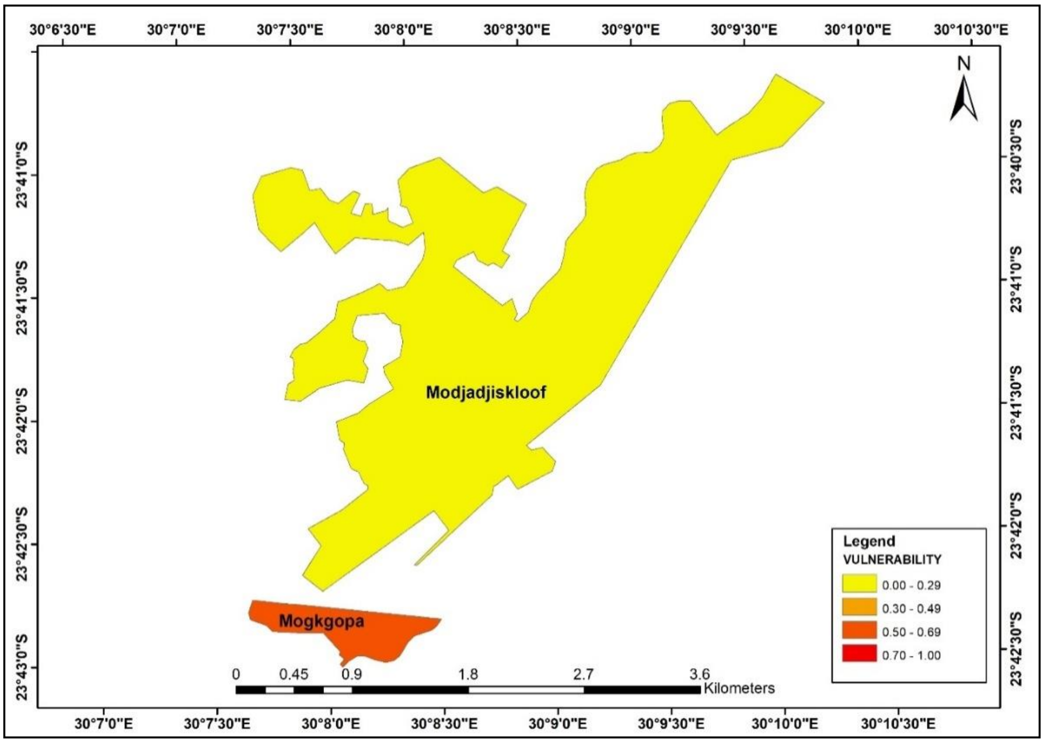

Figure 6.22: Households Aggregate Vulnerability across Neighbourhoods of Modjadjiskloof (Source: Author's Field Data, 2019)

change hazards. The higher proportion of vulnerabilities of Mogkgopa neighbourhood to climate change hazards cannot be divorced from the poor housing and general environmental conditions of the neighbourhood, characterized by informal settlements with a paucity of basic services, high poverty households and dominated by migrants.

6.2.4.2.5 Household's aggregate vulnerability index in Phalaborwa town neigbourhoods

Following the analysis of the distribution of household vulnerability level to climate change extreme events in Phalaborwa, the spatial representation of the results is depicted in

Figure 6.23. The figure shows that Phalaborwa Extensions 2 and 3 were the most vulnerable neighbourhoods with about 30% and 39%, followed by those in Extensions 1, and 4 with 0% and 29%. Figure 6.23 illustrates vulnerability index of the various neighbourhoods in Phalaborwa.

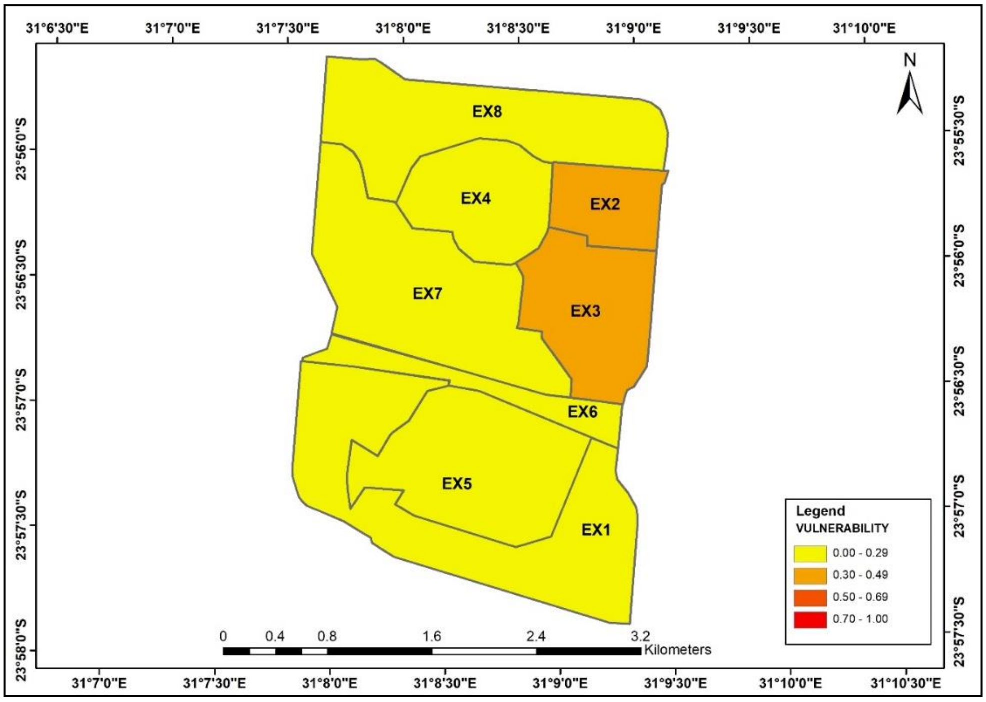

Figure 6.23: Households Aggregate across Neighbourhoods of Phalaborwa Town
(Source: Author's Field Survey, 2019)

The spatial variation in the vulnerability level of households to climate extreme events in Phalaborwa neighbourhoods was a reflection of the land use zoning in the town. While extensions 2, 3 and 8 were predominantly residential, extensions 5 and 6 were mainly public/semi-public and commercial dominated land uses, and extension 7 was partially residential. Since the research was home based in nature, it was expected to get feedback more from residentially dominated neighbourhoods. However, the influence of factors such as socioeconomic and environmental quality cannot be overruled.

6.2.4.2.6 Household's Aggregate Vulnerability Index in Giyani Town Neigbourhoods

The results of the investigation into the vulnerability level of households to climate change hazards in Giyani across it six neighbourhoods are shown in Figure 6.6.

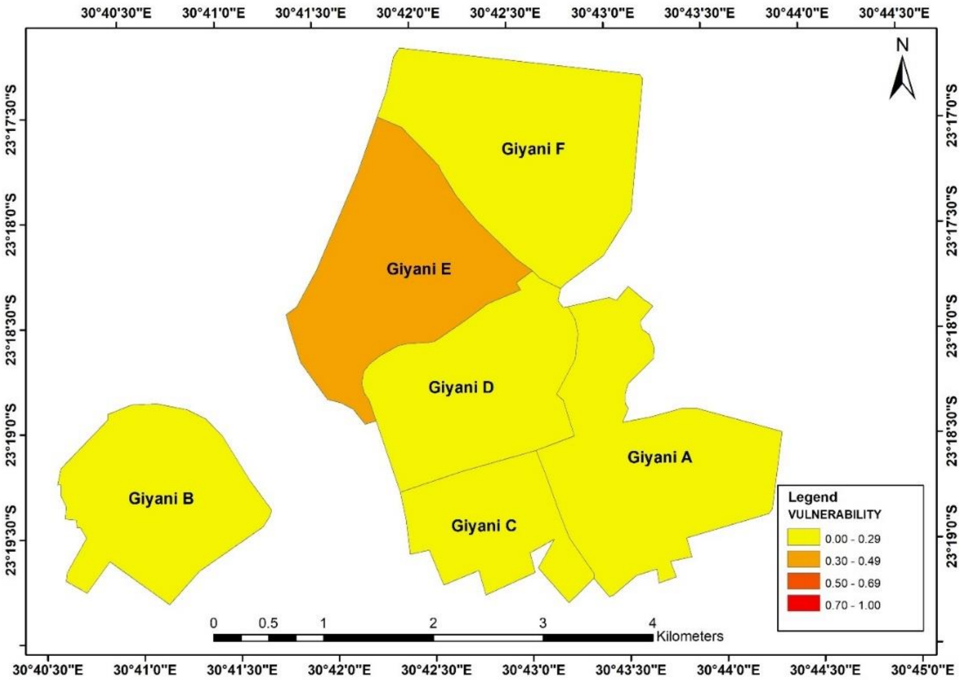

Figure 6.24: Households Aggregate across Neighbourhoods of Giyani Town
(Source: Author's Field Data, 2019)

Giyani Section E had the highest level of vulnerability to climate change related hazards. About 30% to 49% of the households in the neighbourhood were vulnerable. Climate change vulnerability in Section A-D, and F was low, less than 30% of the households in these neighbourhoods are vulnerable climate change factors. This trend was best explained by the exposure level of households in Giyani, coupled with their compromised adaptive capacities with vegetation threatened by the built-up areas and wood energy sourcing had collaboratively influenced higher vulnerability across the neighbourhoods in the town.

The high vulnerability index recorded at various spatial scales in the selected towns in the district cannot be divorced from the high exposure and low adaptability among households in some neighbourhoods. The potentials of increasing climate change impacts through an increasing extent of risk from the prevailing hazards in these selected small and medium towns in the coming decades, suggest a higher vulnerability particularly among the poor. These impacts may be in the form of devastating heat episodes and acute shortages of fresh water as well-as frequent and intensified floods and droughts. The poor, the old and children are groups to be more hit, though disproportionately. The poor group may be affected more because of their higher exposure to climatic factors occasioned by the location and condition of their homes (e.g. unsafe site occupation and makeshift housing, absence of hazard-reducing infrastructure and inability to afford a better quality or less dangeroushousinglocation). They, in most cases receive less attention or state presence (e.g. in the provision of assistance or intervention) Most of the ‘houses’, apart from being short of structural soundness, equally lack legal and financial protection, such as insurance and security of tenure.

6.3 The nexus between household socioeconomic attributes and vulnerability index

This section discusses the relationship between Household socioeconomic characteristics and Households’ Vulnerability Index in Mopani District. A number of socioeconomic variables were hypothesized to (examine) if they have influence on households’ vulnerability index with respect to climate change. These variables include household head’s, age, gender, and educational attainment, as-well-as income and livelihood diversification. The dependent variable used is the household vulnerability index.

6.3.1 Age of Respondents and Households’ Vulnerability

The results of the relationship between age of household heads and their level of vulnerability is summarised and presented in Table 6.9. The Table presents the Ordered Logistic Regression result of the relationship between household head age and the vulnerability level to climate change based on the established threshold in section 3.8.3.4.

The regression results for Mopani District as summarised in the table shows that a point increase in the age of respondents increases Household Vulnerability Index by0.333 points. This implies that the older the head of household, the higher the Household’s Vulnerability index to climate change. A similar result was obtained for Nkowankowa where a point increase in age of head of household increases HVI by 2.345 points. Both models the overall Mopani District and Nkowankowa town are good fit, measured by their respective Wald Chi-square that are statistically significant with Chi^2 = 5.44

Table 6.9 Ordered Logistic Regression resultof Age of Household Heads and Vulnerability Index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	**Mopani**	**Tzaneen**	**Nkowankowa**	**Hoedspruit**	**Modjadji-kloof**	**Phalaborwa**	**Giyani**
Age	0.333**	0.222	2.345***	-0.000	-0.320	0.0417	0.0180
	(0.143)	(0.337)	(0.466)	(0.712)	(1.347)	(0.327)	(0.229)
Observations	496	79	175	18	10	84	130
Pseudo R^2	0.01	0.003	0.197	0.00	0.004	0.000	0.000
Wald Chi^2	5.44**	0.43	25.38***	0.00	0.06	0.02	0.01
*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*							

Source: Author's Field Data, 2019

and 25.38 respectively and p = 0.05. However, the results obtained for other towns (Tzaneen, Hoedspruit, Modjadjiskloof, Phalaborwa and Giyani) show that household head age does not have significant relationships with HVI. The R^2 values for all the models are low, indicating that age only accounts for just a small quantity (0.00 to 2%) variation in household vulnerability. It is only in Nkowankwa that age explains 19% of HVI variance.

6.3.2 Gender of Respondents and Households' Vulnerability

The ordered logistic regression result in Table 6.10 presents the influence of Gender on the household vulnerability level to climate change in Mopani, as well as in the selected towns.

Table 6.10 Ordered Logistic Regression resultof Gender of Household Heads and Vulnerability Index

VARIABLES	**Mopani**	**Tzaneen**	**Nkowankowa**	**Hoedspruit**	**Modjadjis-kloof**	**Phalaborwa**	**Giyani**
Gender	-0.210	-0.498	-0.0827	1.609	0.320	-0.212	-0.0680
	(0.193)	(0.563)	(0.364)	(1.536)	(1.318)	(0.500)	(0.389)
Observations	496	79	175	18	10	84	130
Pseudo R^2	0.001	0.008	0.000	0.060	0.004	0.001	0.000
Wald Chi^2	1.18	0.78	0.05	1.10	0.06	0.18	0.03
*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*							

Source: Author's Field Data, 2019

Analysis of gender in Table 6.10 shows that household head Gender relate negatively (decreasing trend) but with an insignificant impact on household vulnerability to climate change in Mopani District, with a Wald Chi^2 value of 1.18, at p = 0.05 on one hand.

On the other hand, the results for the selected towns show, an insignificant relationship with Wald Chi^{2}for Tzaneen accounting for (0.78), Nkowankowa (0.05), Hoedspruit (1.10), and Modjadjiskloof, Phalaborwa and Giyani being 0.06, 0.18 and 0.03 respectively at p=0.05 . The regression coefficient (R^2) across the towns as well as the district are very low, (Mopani=0.001, Tzaneen 0.008, Nkowankowa =0.000 Hoedspruit= (0.060), Modjadjiskloof (0.004) Phalaborwa = 0.001 and Giyani=0.000) implying that Gender only explains a proportion of household vulnerability index in the selected towns.

6.3.3 Marital Status of Respondents and Households' Vulnerability

In analysing the impacts of marital status on household vulnerability, the variable, marital status was dichotomous to currently married =1, not currently married = 0, and this includes every other category of marital status besides being currently married. The results as summarised in table 6.11 show a positive relationship where a point increase for being

Tab 6.11 Ordered Logistic Regression resultof Marital Status of Household Heads and Vulnerability Index

VARIABLES	(1) Mopani	(2) Tzaneen	(3) Nkowankowa	(4) Hoedspruit	(5) Modjadjis-kloof	(6) Phalaborwa	(7) Giyani
Marital Status	0.535***	0.757	0.618*	-0.456	0.320	-0.0374	0.352
	(0.190)	(0.556)	(0.338)	(1.162)	(1.347)	(0.515)	(0.357)
Observations	496	79	175	18	10	84	130
Pseudo R^2	0.009	0.018	0.012	0.006	0.004	0.000	0.004
Wald Chi^2	7.95***	1.86	3.34*	0.15	0.06	0.01	0.98

*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*

Source: Author's Field Data, 2019

married in Mopani District increases HVI by 0.535 point; it shows a statistically significant variation, with Wald Chi^2 = 7.95, with a low regression coefficient R^2 = 0.009. The result implies that households with married heads had higher HVI than those household heads who were not married.

The relationship across towns shown in Table 6.11 in Nkowankowa town, reveals that a point increases in being a married head of the household Increases HVI by 0.618 points. This implies that the more the numbers of married household members, the higher the HVI to climate change in Nkowankowa, though and the socioeconomic factor (marital status) is statistically insignificant related to HVI. The models of both Mopani District and Nkowankowa town depicts as earlier indicated, a statistically significant scenario, and are all good fits with respective to significant Wald Chi^2 values. The regression coefficient (R^2) for the two are low, indicating that marital status can only account for <1% and 1.9% HVI in Mopani and Nkowankowa respectively.

The results obtained for other towns (Tzaneen, Hoedspruit, Modjadjiskloof, Phalaborwa and Giyani) were contrary, with their respective CHi^2 values of 1.86 (Tzaneen), 0.15 (Hoedspruit), 0.06 (Modjadjiskloof), 0.01 (Phalaborwa) and 0.98 (Giyani) showing insignificant relationships. The regression coefficients (R^2) for these towns were also equally very low, implying that marital status can only explain a small variation in HVI across these towns ranging from 0% Giyani to about 1.8% in Tzaneen. By implication, marital status does not have a significant impact on household vulnerability in these towns.

By implication, there are variation in the values and the low regression coefficients recorded across this towns and the district is an indication that several other factors play significant role as indicators of vulnerability in these towns.

6.3.4 Number of Male Children and Households' Vulnerability

In Table 6.12 the summary of ordered logistic regression result of the relationship between the number of male children and Household Vulnerability Index to climate change are presented.

The table shows that a point increase in the number of male children in a household reduces the HVI in Mopani by 0.204 points and in Nkowankowa by 0.363. This implies that more male children in a household, lowers the HVI. However, for other towns, the values show that a point increase in the number of male children in a household reduces the HVI in Mopani by 0.204 points and in Nkowankowa by 0.363. The result implies that the higher the number of male children, the lower the HVI. This implies that more male children in a household, lowers the HVI. However, for other towns, the number of male children did not

Table 6.12 Ordered Logistic Regression resultof Household Number of Male Childand Vulnerability Index

VARIABLES	Mopani	Tzaneen	Nkowankowa	Hoedspruit	Modjadijs-kloof	Phalaborwa	Giyani
Male children no.	-0.204***	-0.298	-0.363***	-0.162	0.251	0.0696	-0.137
	(0.0723)	(0.249)	(0.112)	(0.383)	(0.749)	(0.236)	(0.130)
Observations	496	79	175	18	10	84	130
Pseudo R^2	0.01	0.014	0.035	0.004	0.006	0.001	0.005
Wald Chi^2	8.00***	1.43	10.46***	0.18	0.11	0.09	1.10
Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.							

Source: Author's Field Data, 2019

significantly relate with HVI. The results for the two models (Mopani and Nkowankowa) depict statistically significant scenarios and good fits with Chi^2 values 8.00 (Mopani) and 10.46 (Nkownakowa).

Meanwhile, in the cases of Tzaneen (-0.298), Hoedspruit (-0.162) and Giyani (-0.137) towns, the HVI decreases but not significant, like equally the cases of Modjadjiskloof (0.251) and Phalaborwa (0.069) indicating an increasing HVI as a result of increase in the number of male children but equally not significant. For the regression coefficients (R^2) for these towns were equally very low, implying that increase in the numbers of male children can only account for small variation in HVI across these towns ranging with proportion ranging from less than 1% in Hoedspruit, Giyani, Phalaborwa and Modjadjiskloof towns to a slightly above 1% in Tzaneen town.

6.3.5 Households' Number of Female Children and Households' Vulnerability

The ordered logistic regression result summarised in Table 6.13 shows that the relationship between the number of female children and household vulnerability to climate change across the entire Mopani District, as well as in each of the selected towns does not have a significant relationship with household vulnerability index.

A Chi^2 value of 0.37 for (Mopani District), Tzaneen (0.00), Nkowankowa (1.04), Hoedspruit (1.24), Modjadjiskloof (0.26), Phalaborwa (0.17), and Giyani (1.52) respectively, do not show significant values. This implies that there is no statistically significant relationship between the numbers of female children in households and HVI in the

Table 6.13 Ordered Logistic Regression resultof Number of female Childrenand Households' Vulnerability Index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	**Mopani**	**Tzaneen**	**Nkowankowa**	**Hoedspruit**	**Mskloof**	**Phalaborwa**	**Giyani**
Female Children no.	-0.0486	0.00703	-0.122	0.509	0.398	0.0974	-0.219
	(0.0801)	(0.234)	(0.119)	(0.456)	(0.786)	(0.238)	(0.178)
Observations	496	79	175	18	10	84	130
Pseudo R^2	0.001	0.000	0.004	0.053	0.026	0.002	0.009
Wald Chi^2	0.37	0.00	1.04	1.24	0.26	0.17	1.52
*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%,** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%*							

Source: Author's Field Data, 2019

six selected towns. R^2 values for all the models are low, indicating that the number of female children only shows a very low Households' Vulnerability to Climate change across Mopani and the towns.

6.3.6 Educational Qualification and Households' Vulnerability

A regression analysis of the educational qualification of households against HVI across Mopani District, as well as the selected towns was undertaken. The results are summarised in table 6.14.

Table 6.14 Ordered Logistic Regression resultof Educational Qualification and Vulnerability Index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	**Mopani**	**Tzaneen**	**Nkowankowa**	**Hoedspruit**	**Modjadjiskloof**	**Phalaborwa**	**Giyani**
Education	-0.0706	0.384*	-0.253***	0.0708	-0.788*	-0.0793	0.299***
	(0.0527)	(0.205)	(0.0835)	(0.414)	(0.460)	(0.154)	(0.112)
Observations	496	79	175	18	10	84	130
Pseudo R^2	0.002	0.052	0.027	0.001	0.228	0.003	0.031
Wald Chi^2	1.79	3.50*	9.20***	0.03	2.93*	0.27	7.12***
*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*							

Source: Author's Field Data, 2019

The results of the examination across the towns as shown in table 6.30 shows that in Tzaneen a point increase in the educational qualification of household head increases HVI by

0.384.This is unlike the negative trend in the result obtainable for Nkowankowa which implies that a point increase in the educational qualification in Nkowankowa reduces HVI by 0.253 points. This implies that the higher the educational qualification, the lower the HVI to climate change Nkowankowa. The results in the table further show a negative relationship between these two variables in Modjadjiskloof and Giyani towns. It is important to note that the results in Tzaneen, Nkowankowa, Modjadjiskloof and Giyani models show statistically significant scenarios and good fit, with Chi^2 values 3.50, 9.20, 2.93, and 7.12., respectively. However, the R^2 value is low (2.7% in Nkowankowa, <1% in Hoedspruit, Tzaneen and Phalaborwa and 3% in Giyani) indicating that educational qualification only explains small variation in the HVI across the towns, except for Modjadjiskloof 22.8% variation that educational qualification explains. The implication of this result is that in Hoedspruit, Phalaborwa and that of Mopani educational qualification does not show a significant relationship with household vulnerability to climate change.

6.3.7 Primary income of Households and Households' Vulnerability

Income is considered an important socioeconomic component of vulnerability and was examined against HVI to establish their relationship. Table 6.15 summarises and presents the ordered logistic regression results which show that income from primary source shows a significant negative relationship with HVI to climate change in Mopani District as a whole.

Table 6.15 Ordered Logistic Regression result of Primary Income and Households' Vulnerability Index

VARIABLES	Mopani	Tzaneen	Nkowankowa	Modjadjiskloof	Phalaborwa	Giyani
Primary Income	-0.147***	-0.0389	-0.244**	-0.332	-0.103	-0.0428
	(0.0341)	(0.0833)	(0.104)	(0.213)	(0.0804)	(0.0715)
Observations	486	79	174	10	80	125
Pseudo R^2	0.023	0.002	0.023	0.213	0.017	0.001
Wald Chi^2	18.56***	0.22	5.47**	2.44	1.64	0.36
*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*						

(Source: Author's Field Data, 2019)

The result indicates that a point increase in income reduced HVI to climate change in the District of Mopani by 0.147 points. It implies that the higher the primary income the lower the HVI. However, the results of the examination across towns show that a point reduction in income in Nkowankowa town increases HVI to climate change. The relationship is statistically significant, with Ch^2 value of 5.47, at significant level at p = 0.05 with the models (Mopani and Nowankowa) in good fit. On the other hand, the R^2 values of the two models was low (0.023 and 0.023) implying that primary income only explains a small 2.3% of variation in HVI in both Mopani and Nkowankowa. The results of other towns such as Modjadjiskloof, Phalaborwa Giyani and Tzaneen, as summarised in Table 6.15 shows no significant relationship between income and HVI to climate change. The results obtained for other towns show that an increase in primary income does not have a significant relationship with HVI.

6.3.8 Secondary income and Households' Vulnerability

The relationship between secondary income and Households' Vulnerability Index was examined using ordered logistic regression, and the result as presented in Table 6.16 reveals that no town has a significant relationship between secondary income and HVI. Although, they all indicated a decreasing trend (Tzaneen, Nkowankowa, Phalaborwa and Mopani district) but increasing trend in Giyani with no indication of significance.

Table 6.16 Ordered Logistic Regression result of Household Secondary Income and Vulnerability Index

VARIABLES	Mopani	Tzaneen	Nkowankowa	Phalaborwa	Giyani
Sec. Income	-0.00721	-0.282	-0.137	-0.0921	0.0199
	(0.0786)	(0.216)	(0.145)	(0.187)	(0.133)
Observations	470	77	159	84	122
Pseudo R^2	0.000	0.014	0.005	0.002	0.000
Wald Chi^2	0.01	1.71	0.88	0.24	0.02

*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*

Source: Author's Field Data, 2019

The significant Chi^2 values is shown in Table 6.16. The regression coefficients (R^2) are low across the District and equally the towns, implying that secondary income only explains a small variation in HVI between 0% and 1.4%.

6.3.9 Length of Stay and Households' Vulnerability

An investigation into the relationship between duration of stay and Households' Vulnerability Index is summarised in Table 6.17.

Table 6.17 Ordered Logistic Regression result of Length of stay in locality and Vulnerability Index

	(1)	(2)	(3)	(5)	(6)	(7)
VARIABLES	**Mopani**	**Tzaneen**	**Nkowankowa**	**Modjadjiskloof**	**Phalaborwa**	**Giyani**
Length of Stay	-0.142	-0.528	0.244*	-1.067***	-0.283	-0.616***
	(0.0870)	(0.331)	(0.138)	(0.318)	(0.252)	(0.228)
Observations	496	79	175	10	84	130
Pseudo R^2	0.004	0.039	0.016	0.110	0.013	0.041
Wald Chi^2	2.68	2.54	3.16*	11.26***	1.26	7.26***

*Note: Robust standard errors in parentheses; *** means p<0.01 and significant impact at 1%, ** means p<0.05 and significant impact at 5%, * means p<0.1 and significant impact at 10%.*

Source: Author's Field Data, 2019

The Table shows that in Nkowankowa there is a positive significant relationship between length of stay and HVI. A point increase in length of stay increases the HVI to climate change. The result implies that the longer the length of stay in place of residence by household, the higher the HVI to climate change in Nkowankowa. However, in towns like Modjadjiskloof and Giyani, the results show a statistically insignificant negative relationship between length of stay in the locality and HVI, implying the longer the duration of stay in residents by households the lower the HVI to climate change, though statistically insignificant.

With this result one can infer that the longer the duration of stay in locality by household, the lower the HVI to climate change in both Modjadjisklof and Giyani. The longer the length of stay of residents, the higher the HVI to climate change in Nkowankowa. However, length of stay in locality does not significantly relate with HVI to climate change in Mopani as a District, Tzaneen, and Phalaborwa towns.

6.4: Livelihood diversification and Household vulnerability in Mopani

Aside from the consideration of the influence of household income on their level of vulnerability, the study further examined the influence that a diversified means of livelihood of the households exert on the vulnerability index across the district of Mopani. The Livelihood Diversification Index was based on the assumption that households with income from a diversified source have the opportunity to distribute hazards resulting from climate change among the income sources. The study further revealed that those with higher income were also those with diversified incomes implying higher coping capacity. This was confirmed by Nhuan et al., (2015) in a study on the relationship between livelihood diversification and household vulnerability.

6.4.1: Livelihood Diversification and vulnerability Index

Table 6.18 presents the Ordered logit regression result of the impact of livelihood diversification on vulnerability. This analysis verifies the existence or otherwise of any influence as well as its magnitude (either negative or positive) of households to climate change in Mopani district. The results in Table 6.18 represent estimations for Mopani district (in column 1), Tzaneen, Nkowankowa, Modjadjiskloof, Phalaborwa and Giyani (in columns 2,

Table. 6.18: Livelihood Diversification Index and vulnerability Index

VARIABLE	Mopani	Tzaneen	Nkowankowa	Modjadjis-kloof	Phalaborwa	Giyani
LDI	-0.729*	-3.092*	0.103	-9.238***	-0.391	-1.29*
	(0.414)	(1.679)	(0.800)	(2.796)	(0.911)	(0.768)
Observations	496	79	175	10	84	130
Pseudo R^2	0.003 *(0.3%)*	0.043 *(4.3%)*	-	0.242 *(24.2%)*	-	0.011 *(1.1%)*
Wald Chi^2	3.10*	3.39*	0.02	10.91***	0.18	2.80*
Note: Robust standard errors in parentheses; *** p<0.01, significant at 1%; ** p<0.05, significant at 5%; * p<0.1, significant at 10%						

Source: Author's Computations, 2019

3, 4, 5 and 6). For Mopani district, a point increase in livelihood diversification index reduces vulnerability index by 0.729 points. This implies that the more diversified the livelihood of a household, the lesser the vulnerability to climate change. Similar results were obtained for Tzaneen, Modjajiskloof and Giyani. For these three towns, a point increase in livelihood diversification index reduces the vulnerability index by 3.092, 9.238, and 1.29 points respectively. On the other hand, contrary results were obtained for Nkowankowa and Phalaborwa, where the livelihood diversification index does not significantly affect the vulnerability index. This implies that livelihood diversification has no influence on the household vulnerability in these two towns. The types of secondary economic activities diversified into and the amount of income generated from them might not be substantial enough to significantly influence HVI in these two towns.

The results obtained from the four models depict statistically significant scenarios and all in good fit, with Chi-squared values of 3.10, 3.39, 10.91, and 2.80%, while the latter two models are not statistically significant. R-squared value for all the models is quite low, indicating that livelihood diversification explained only a low percentage of variation in household vulnerability. However, in Modjadjiskloof, the R-squared value of 0.242 indicates that livelihood diversification explains about 24.2 percent of variance in household vulnerability. This implies that livelihood diversification as a factor influencing HVI in the town is not a sole influencing factor, but other factors were certainly involved in the influence.

6.5 Chapter Summary

This chapter analysed indicators that relate to household and community vulnerability to climate change extreme events. These include human, economic, social, ecological and environmental vulnerability indicators.

The result of the analysis of the household level of exposure to climate within Mopani district shows that exposure to climate change hazards among households was generally high in Mopani district. Nkowankowa town had the highest proportion of its households in the exposed category, followed by Giyani and Phalaborwa respectively. Meanwhile, ModjadjisKloof town has the least exposure level among others, but high exposed households.

The similarity in the exposure rate was partly explained by the similar regional climate the selected towns shared, while other peculiarities of the individual towns such as terrain, socioeconomic status of households, and forest depletion among other factors occasioned the variation in the levels of exposure. The Chi-Square result of household exposure and the six selected towns' results indicated a statistically significant variation between the exposure levels of households across the six selected towns in the District.

The results of the analysis of sensitivity level of households across different spatial scales, including the neighbourhood and towns as well as the district revealed a low level of sensitivity. For instance, about four in every five of the district population were found not sensitive. In all six towns except Hoedspruit, the observed sensitivity was generally high. Only Hoedspruit has a considerably low proportion of non-sensitive population. The household sensitivity index is significantly different from town to town and largely a function of frequency of occurrence of climate related hazards and the resultant mortality as well as economic activities engaged in these towns.

However, the level of adaptive capability was relatively high across the district, where the bulk of the respondents had varying levels of capacities to adapt to climate change impacts. Tzaneen town had the highest adaptability rating with an aggregate of more than four out of every five households. Modjadjiskloof of the six towns, however, had the least adaptive capacity, followed by Nkowankowa.

The aggregate households' vulnerability indexes across the selected towns show that vulnerability across the district of Mopani is generally high, with more than three out of five households being highly vulnerable. The situation is similar across the towns except Hoedspruit town that has about one tenth highly vulnerable households and one third moderately vulnerable residents. Other towns had above six in every ten of the residing households highly vulnerable.

From the analysis, exposure as component of vulnerability had the strongest influence on the general HVI in the district as well as the selected towns, where the pull influence of adaptive capacity was not proportional to the capacity they displayed. Despite high households' adaptive capacity (relative though) recorded across these towns, the HVIs were relatively high (varied from towns to town). Generally, higher exposure indicated higher HVI in Mopani. However, adaptive capacity as shown in the results, substantially reduced the impacts of exposure on HVIs in the towns, though may not be equal and proportional to the household adaptive capacities.

On a general note, the role of sensitivity appeared to be weak as indicated in the analysis. This because, despite the low levels of households' sensitivity in the selected towns, except Hoedspruit town, yet, the HVIs was still high in the selected towns.

It is essential to note at this juncture, that the influence of socioeconomic factors on HVI though with low R^2 values in isolation cannot be undermined collectively. As they become stronger when combined. Each town's socioeconomic peculiarities and livelihood Diversification Index may be responsible for some of the anomalies in the HVI and its relationship with the components e.g. Phalaborwa high exposure, high adaptive capacity and yet, high HVI.

. Having analysed the HVI and its relationships with socioeconomic factors, the next section examines the households' and urban planning adaptation strategies that were employed to curtail the effects of climate change in the selected towns.

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CHAPTER SEVEN

HOUSEHOLDS', COMMUNITIES' AND URBAN PLANNING ADAPTATION STRATEGIES ACROSS MOPANI DISTRICT

7.1 Introduction

Following the analysis of the magnitude of HVI and its components across the district of Mopani in the preceding chapter as enunciated in objective two and three, this chapter addresses objective four of the research by examining the strategies that were adopted by households to cope with climate related disasters. Including those related to increased temperature, reduced water level, incidence of floods and other factors. The chapter equally analyses those strategies that were adapted by government through the agencies responsible for urban planning.

7.1.1 Households' Temperature Coping Strategies

The result of the analysis in chapter four of this report established occurrence of heat waves as a result of rise in temperature in different parts of Mopani. According to Hayley and David (2018), households, local communities, and municipal responses to cope with high temperature or heat waves can be undertaken via tree planting and several other strategies. In line with this understanding, the respondents were requested to identify the individual coping strategies against high temperature in the selected towns in Mopani district. The strategies identified were classified into seven types; viz: 1. tree planting, 2. minimizing bush burning, 3. preservation of water bodies, 5. ecofriendly farming practice, 6. flower and grass planting, 7. the use of fans and air conditioners and 8. the creation of parks and gardens. Table 7.1 is a summary of the responses from households on the coping strategies for increasing temperature across the selected towns in Mopani.

7.1.1.1 Tree planting as Temperature Coping Strategy across Selected Towns

According to Henrik *et al.,* (2001), tree planting is one of the coping strategies that was recommended for reducing the impact of high temperature. In the selected towns, as a result we tested the popularity of tree planting as a means of coping with high temperature.

Table 7.1 Temperature coping strategies across Mopani district

	Temperature Coping strategies						
	Tree planting	**Flower and Grass Planting**	**Create Neighbourhood Parks & Garden**	**Minimise Bush Burning**	**preservation of Water Bodies**	**Eco-Friendly farm Practice**	**Use of Fans and Air Condition**
	%	%	%	%	%	%	%
Tzaneen	66.3	45.6	0.0	100	0.0	0.0	100
Nkowankowa	56.6	18.3	0.0	100	0.0	0.6	100
Hoedspruit	88.9	100	0.0	100	83.3	11.1	100
Modjadjiskloof	50	80	0.0	100	60.0	0.0	100
Phalaborwa	95.2	98.8	0.0	98.0	77.4	0.0	100
Giyani	100	51.5	0.0	100	2.3	0.0	100

(Source: Author's Field Data, 2019)

In Tzaneen, the responses reveal that 63.3% and in Nkowankowa 56.6% agreed to the effectiveness of tree planting as a coping strategy for high temperature. Hoedspruit accounted for 88.9%, Modjajiskloof 50%, while Phalaborwa and Giyani both had 95.2% and 100% respectively. Tree planting appears to be a popular and acceptable coping strategy against increases in temperature across the selected towns. Most of the households considered the strategy to be very effective in coping with temperature increases in the selected towns. Plate 7.1 shows an example of planted trees. With the process of photosynthesis by which green plants use sunlight to synthesize nutrients from

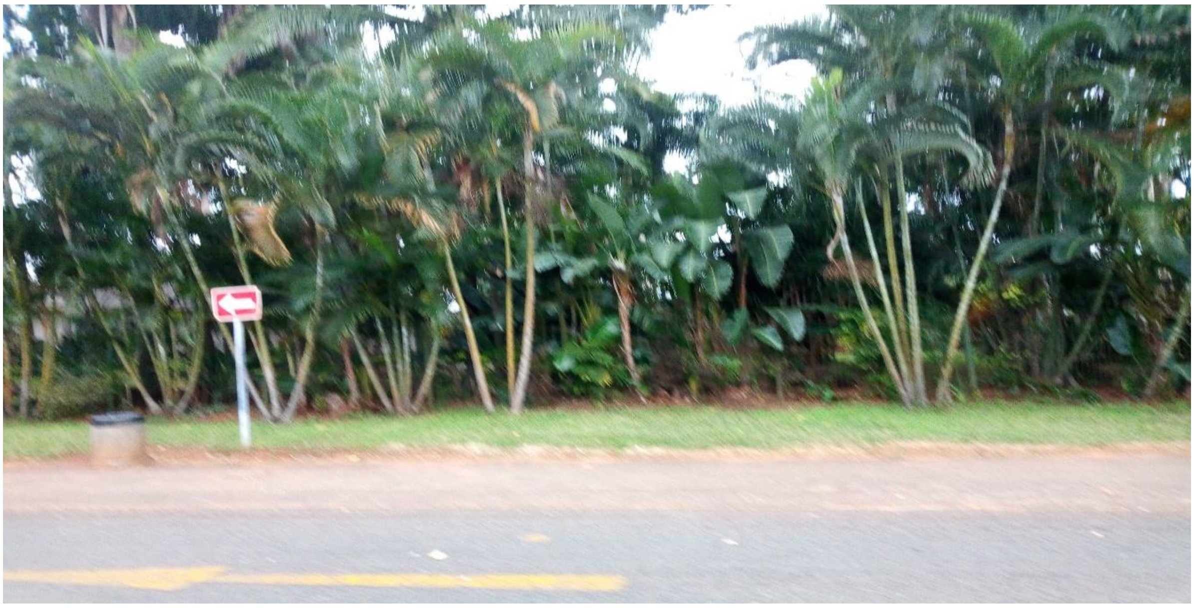

Plate 7.1: Tree planting as a temperature coping strategy in Tzaneen
(Source: Author's Field Photo, 2019)

Carbon dioxide and water. This involves the use of green pigment chlorophyl and release the generated oxygen as by product (Oxford Dictionary cit inen.m.wikipedia.com). the oxygen becomes useful for human consumption as a source of energy and maintain the atmospheric oxygen contents for cooling (as adaptation) as well as carbon sinking as mitigation. Plate 7.1 is a typical example of the tree planting embarked upon by the residents in Tzaneen town. This is believed to sustainably reduce the impact of heatwaves if propagated and sustained.

7.1.1.2 Minimising Bush Burning as Temperature Coping Strategy

An examination of the relevance of reducing bush burning as a strategy for coping with temperature in the selected towns in Mopani district was undertaken and the results of the respondents' answers to minimising bush burning are summarised in Table 7.1. In Nkowankowa, Tzaneen, Hoedspruit and Modjajiskloof, minimising Bush Burning was considered by all households, to be appropriate, while in Phalaborwa, 2% of the entire households surveyed declined the choice of such a strategy. Considering minimising bush burning as one of the strategies by the households; those who were pro-bush burning minimisation were very many. During the field investigation, it wasobserved that most of the respondents in the peri-urban areas would like to continue to burn bush around their towns in order to meet suc domestic energy needs such as cooking and lighting and would only be constrained by law enforcement. The impact of bush burning on the process of photosynthesis, particularly when the green pigment chlorophyll is lost to burning flame, resulting in to the loss of oxygen but increased carbon dioxide, which Invariably exacerbates heat episode and physilogical discomfort.

7.1.1.3 Conservation of Water Bodies as a Temperature Coping Strategy

Table 7.1 shows the respondents' profile on the role of water bodies' conservationas a coping strategy against high temperature. Respondents were requested to indicate yes or no as to whether they would adopt the strategy. The results further show that the bulk of the respondents in Hoedspruit town (83%) were in favour of conserving water bodies. This was followed by Phalaborwa (77.4%), Modjajiskloof (60%) and Giyani with 2.3%. Further results show that the reasons why the respondents in Phalaborwa and Modjajiskloof were more favourable to the conservation of water bodies was because they were more aware (75%) of the benefits than the households from other towns in the district.

7.1.1.4 Households adoption of Eco-friendly Farming Practices as a Means of coping againstHigh Temperature

A probe into the adoption of eco-friendly farm practice as a coping measure was investigated as summarised in Table 7.1. Current literature reviewed on this strategy shows that it is a promising strategy as reported by Katharine *et al.,* (2013). We tested this strategy in the selected towns and the households were expected to respond yes, no, or undicided. The result of the responses of the households shows that in Tzaneen, Modjajiskloof, Phalaborwa and Giyani none of the respondents indicated adopting it as a strategy. In Nkowankowa, less than 1% responded adopting the strategy, thus the idea was not popular with the responding households. The highest percent of households in favour of the strategy was recorded in Hoedspruit (11.1%). This strategy, by implication was not a popular strategy because significant numbers of the households in these towns have their economic activities not directly tied to agriculture. Thus, prescribing it as a strategy for coping with temperature in the district might not be too appropriate.

7.1.1.5 Flower and Grass Planting

According to Pataki *et al.,* 2011, as cited in Matthews *et al.,* (2015) green infrastructure is very useful in contributing to mitigate the effects of hard surfacing by modifying ambient temperatures as well as creating recreational opportunities among other advantages. This strategy was investigated in the selected towns, where the study requested the respondents to indicate if they adopted green landscaping (flower and grass planting) as a coping strategy against temperatures. The responses indicate that all households (100%) in Hoedspruit town adopted the strategy, while 98.8%, 80% and 51.5% households in Phalaborwa, Modjadjiskloof and Giyani towns respectively adopted the green infrastructure strategy. Flower and grass planting seem to be a widespread and suitable temperature coping strategy in the selected towns except in Nkowankowa, where only 18.3% of the households embraced the strategy. This is similar to what is obtainable with respect to tree planting. Vegetation cover do not only protect the top soil against leaching and erosion, it is equally open to the process of photosynthesis, where green plants use sunlight to synthesize nutrients from water and carbon, and releases oxygen that stabilises atmospheric energy and reduces the impacts of heat.

7.1.1.6 Use of Fans and Air Conditioners

The use of Fans and Air conditioners appeared to be a very satisfactory strategy that was favoured by every household traversing the selected towns in Mopani. This was attributed by the respondents to the fact that the former is cheap and affordable, while the latter was enhanced by the stability of electricity. However, it does escalate the energy bills because of the increased loads resulting from cooling, and it equally exacerbates urban heat islands in its own capacity. Thus Kikegawa, *et al.,* 2006 submit that for effective alleviation of urban warming and enhanced cooling, there is, as a necessity the need to reduce air-conditioning as a cause of anthropogenic heat. The use of air-conditioning implies more required energy that will invariably lead to more coal or fuel burning with several attendant consequences like pollution (air and noise) as well as enhanced urban heat island.

7.1.1.7 Create Neighbourhood Parks and Garden

The responses from the probe into the creation of Neighbourhood Parks and Gardens as a temperature coping strategy by the households across the selected towns show a consensus that the siting and development of neighbourhood parks and gardens was the responsibility of the governments at different levels. This reflected in their responses where no households adopted the strategy as a personal temperature coping approach. However, children who desired to recreate use available spaces around them, no matter what the risks involved (see Plate 7.2), because of the failure of the government to adequately provide for and maintain the abandoned existing children parks (see plate 7.3)because of non-availability of official parks and recreation centres for children to play in their neighbourhood.The situation that was common in the selected towns,prompted the option of using the access roads and any available space as alternative. Plate 7.3 shows the abandoned park that could not be used because of its poor state and poor proximity to people.

Plate 7.2: Children playing soccer on a street in Hoedspruit

(Source: Author’s Field Photo, 2019)

Plate 7.3: Abandoned Neighbourhood Parks and Garden in Nkowankowa
(Source: Author's Field Photo, 2019)

7.1.2 The relationship between households' socioeconomic factors and the choice of adaptation strategies against increased temperature

The result of a further probe into the relationship between household socioeconomic attributes and the choices of strategy to cope with increased temperature in the district is summarised in Table 7.2. The Table shows the Spearman correlation between respondents' socioeconomic chraracteristics and their choices of strategies in adapting to increase in temperature in Mopani District.

From the results of Spearman correlation conducted, Age for instance shows a weak and inverse relationship with respect to all the identified temperature coping strategies (implying, the older the age of respondents, the more the adoption of the identified strategies), except the case of minimizing bush burning that shows a unidirectional relationship with age with $r = 0.020$ and $p = 0.65$. Although, the relationships are not only weak but they are equally statistically insignificant.

In a similar development, Marital status and educational qualification both have negative but statistically significant relationship with eco-friendly farming practice with $r = -0.162$, $p = 0.000$ and $r = -0.136$, $p = 0.000$ respectively, indicating that the higher the educational qualification of household head (and status of being married), the lower the acceptability of eco-friendly farming practice as an adaptive strategy for increasing temperature. The negative relationship between educational attainments and eco-friendly farming practice among farmers was explained by the reasons for the adoption of the strategy, being for its economic efficiency and profits maximization, but not really for reducing temperature.

Table 7.2: The relationship between Socioeconomic and other factors on the choice of increase in temperature coping strategy

VARIABLES		Tree planting	Flower and Grass planting	Create Parks & Garden	Minimizing Bush burning	Preservation of Water	Eco-friendly Farming practice	Use of Fan & air conditioner
Towns	Pearson's R	-0.429	-0.321	-	0.035	-0.276	-0.017	-
	Spearman Correlation	-0.406	-0.262	-	0.025	-0.224	-0.075	-
	Sign Level	0.00, (0.00)	0.00, (0.00)	-	0.43, (0.58)	0.00, (0.00)	0.714, (0.94)	-
Age	Pearson's R	-0.060	-0.040	-	0.011	-0.134	-0.027	-
	Spearman Correlation	-0.045	-0.059	-	0.020	-0.150	-0.038	-
	Sign Level	0.18, (0.32)	0.37, (0.19)	-	0.80, (0.65)	0.003, (0.01)	0.55, (0.40)	-
Sex	Pearson's R	0.077	0.054	-	0,033	0.086	0.007	-
	Spearman Correlation	0.077	0.054	-	0.033	0.086	0.008	-
	Sign Level	0.09, (0.09)	0.23, (0.23)	-	0.46, (0.46)	0.06	0.88, (-0.85)	-
Marital Status	Pearson's R	0.099	-0.003	-	-0.029	-0.016	-0.123	-
	Spearman Correlation	0.029	-0.051	-	-0.038	0.003	-0.162	-
	Sign Level	0.027, (0.515)	0.944, (255)	-	0.526,(0.399)	0.728,(0.954)	0.006, (0.000)	-
Highest Educational Qualification	Pearson's R	-0.088	0.031	-	0.036	0.017	-0.125	-
	Spearman Correlation	-0.089	0.016	-	0.043	0.020	-0.136	-
	Sign Level	0.050 (0.048)	0.484 (0.720)	-	0.429 (0.339)	0.703 (0.655)	0.005 (0.002)	-
Disability	Pearson's R	0.045	0.174	-	0.006	0.120	0.018	-
	Spearman Correlation	0.046	0.175	-	0.007	0.120	0.023	-
	Sign Level	0.313 (0.306)	0.000 (0.000)	-	0.886, (0.883)	0.008 (0.008)	0.695 (0.611)	-

(Source: Author's Field Data, 2019)

In addition, however, Flowers and grass planting shows a positive and significant ccrrelation with r = 0.17 and p = 0.000. The result thus suggests that higher tendencies of adopting flowers and grass planting as an adaptation strategy for increasing temperature increases with socioeconomic status. However, the households' responses on creation of parks and gardens as well-as use of Fans and Air conditioners are common to all the selected towns, thus no r- value was estimated for both *strategies.*

7.1.3 Water Scarcity Coping Strategies in Mopani

With respect to water scarcity, the households were required to indicate the strategy they used with respect to coping with water scarcity during climate related drought or long heat waves that reduced the water quantity in their areas. The variables from where their responses were recorded include harvesting water, water embankment, use of storage tanks, water treatment to improve quality and use of water vendor services. The profiles of the towns on this variable are illustrated in Figure 7.1.

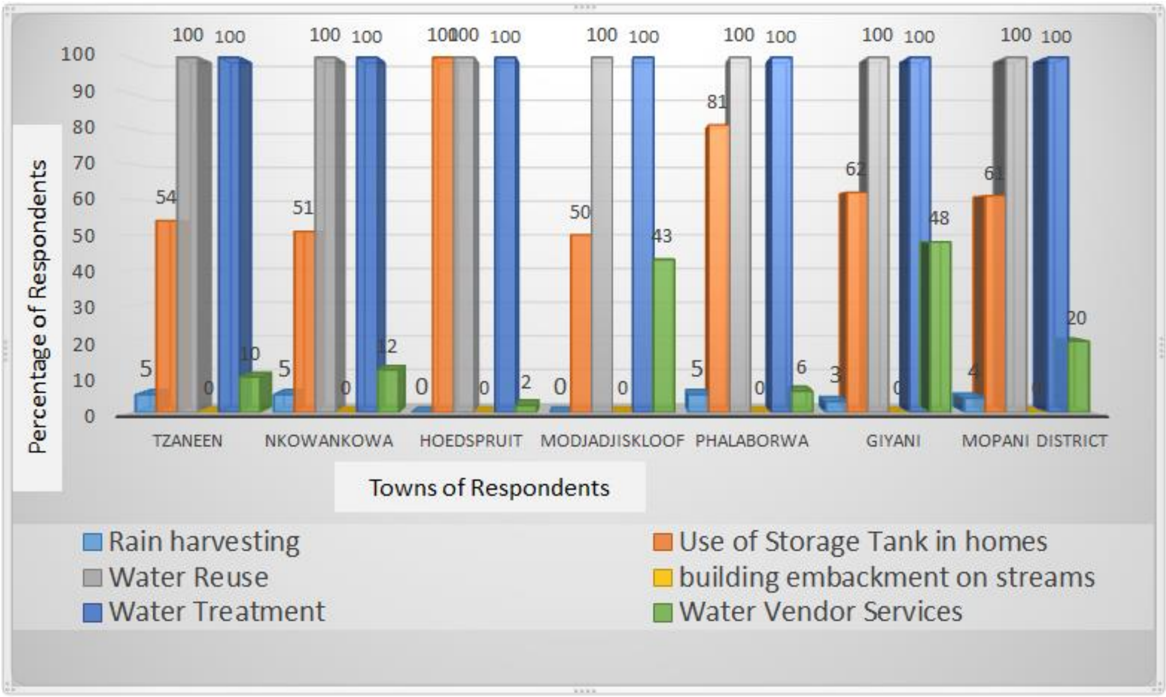

Figure 7.1: Coping strategies for change in water level across towns in Mopani
Source: Author’s Field Data, 2019

7.1.3.1 Rainwater Harvesting (During Drought Period)

Figure 7.1 shows the use of Household coping strategies regarding changes in water level in the selected towns. For example, rainwater harvesting as a strategy used by respondents yielded the following results: The households in Tzaneen that indicated they adopted the strategy was 5.1%. In Nkowankowa about 5% used water harvesting strategy, Phalaborwa 5% and in Giyani 3.1%. However, both Modjajiskloof and Hoedspruit towns did not use such a strategy because according to them, it is time consuming.

7.1.3.2 Households Use of Storage Tanks

Figure 7.1 also shows the use of storage tanks in coping with a drop in water level by the households. It reveals that Hoedspruit and Phalaborwa households overwhelmingly used storage tanks as a backup to forestall the impacts of water provision shortages with 100% and 81% respectively. In Tzaneen and Nkowankowa 54.4% and 51% of the households used storage tanks as a coping strategy. Similarly, in Modjajiskloof and Giyani the households that used storage tanks were respectively 50%

and 61.5%. On the average and in all the six selected towns, 61.1% of the respondents had used storage tanks or were still using it. The study revealed that the storage of water in tanks is a widespread strategy because water provision is not always at RDP level.

7.1.3.3 Water Reuse as a Coping Strategy

According to DeNicola *et al.,* (2015), a significant indicator of health is water supply, which includes both its availability and quality.Water supply is beyond drinking, but is also intimately linked to food security, sanitation and hygiene contributing to health burdens. Poor and vulnerable communities suffer the most from the adverse effects of climate change on water and health related issues; the adaptation strategy which can effectively reduce the strain on water resources includes wastewater recycling and reuse (Ray *et al*., 2012). This was attested to in the selected towns, and it was found that when water became scarce, such as in 2015, 2016 and 2017 during drought periods in Limpopo province, most households turned to the re-use of water for domestic and other uses. Our investigation further showed that 100% of the respondents re-used water, as was advised by the Department of Water Affairs, when Limpopo, was declared a disaster province in 2016 (Maponya and Mpandeli, 2016). The respondents' answers are illustrated in Figure 7.1.

7.1.3.4 Households' treatment of water as a strategy for coping with water scarcity

Water treatment was one of the variables we requested the households to give their response if they used such strategy. Although according to the science of water treatment which involved reverses osmosis etc. This study was more interested in water treatment such as boiling the water, or using aqua active bleaching agents such as hypochlorite to disinfect the water before use. The results in Figure 7.1 show that all of the respondents (100%) use non-complicated methods to treat their water when it becomes very scarce.

7.1.3.5 Water Vendor Services as Water Scarcity Coping Strategy

The general practice particularly in the peri-urban areas of the selected towns is that most people buy water from water vendors who sell water to the households in containers ranging from R5 to R25 depending on the size of container. However, in Modjadjiskloof and Giyani 43% and 48% respectively used water vendor services to cope with water scarcity (Figure 7.1).

7.1.4 The correlation between households' socioeconomic characteristicts and the choice of adaptation strategies for reduced water level.

Varying types and magnitudes of relationship exist between households' socioeconomic factors and the choice of strategies to adapt with reduced water level in Mopani District. Table 7.3 shows the summary of correlation between the socioeconomic factors on the preferred choice of coping strategy for reduced water level in the district.

Table 7.3: The correlations between socioeconomic factors and the choice of adaptation strategies for decreased water level in Mopani District

VARIABLES		**Rain water Harvesting**	**Use of Storage Tank**	**Water reuse**	**Building embankments on streams**	**Water treatment**	**Water Vendor**
Towns	Pearson's R	0.029	-0.132	-	0.011	-	-
	Spearman Correlation	0.033	-0.120	-	0.039	-	-
	Sign Level	0.524 (0.458)	0.003 (0.007)	-	0.806, (0.381)	-	-
Age	Pearson's R	-0.039	-0.035	-	-0.009	-	-
	Spearman Correlation	-0.054	-0.051	-	-0.019	-	-
	Sign Level	0.385 (0.277)	0.436 (0.255)	-	0.850 (0.680)	-	-
Sex	Pearson's R	-0.022	0.041	-	-0.022	-	-
	Spearman Correlation	-0.022	0.041	-	-0.022	-	-
	Sign Level	0.628 (0.628)	0.365 (0.365)	-	0.619 (0.619)	-	-
Marital Status	Pearson's R	-0.004	-0.051	-	-0.113	-	-
	Spearman Correlation	0.019	-0.061	-	-0.096	-	-
	Sign Level	0.923 (0.675)	0.257 (0.177)	-	0.012 (0.033)	-	-
Highest Educational Qualification	Pearson's R	0.078	0102	-	-0.046	-	-
	Spearman Correlation	0.071	0.131	-	-0.042	-	-
	Sign Level	0.081 (0.116)	0.023 **(0.003)**	-	0.304 (0.346)	-	
Primary Occupation	Pearson's R	0.039	0.019	-	0.027	-	-
	Spearman Correlation	0.037	0.014	-	0.019	-	-
	Sign Level	0.380 (0.412)	0.671 (0.759)	-	0.545 (0.676)	-	-
Disability	Pearson's R	-0.029	0.026	-	0.052	-	-
	Spearman Correlation	0.029	0.026	-	0.052	-	
	Sign Level	0.514 (0522)	0.560 (0.566)	-	0.249 (0.249)	-	-

Note: Spearman Correlation significant level is shown in parenthesis
(Source: Author's Field Data, 2019)

Major features of Table 7.3 are that:

(a) The relationships between the socioeconomic factors are generally not strong.

(b) None of the factors, except educational qualifications have statistically significant influence on the use of storage tank.

(c) The higher the educational qualification the higher the adoption of the use of storage tank with $r = 0.131$; $p = 0.003$.

7.1.5 Household Strategy for Flood Control in Mopani

Jongman (2018) noted that with increasing havoc of floods in the urban centres, and its negative impacts particularly on the poorest and the most susceptible, effective coping strategies require the combination of protective infrastructure, nature-based approaches, and risk financing (insurance) schemes to curtail floods and cushion their adversities.

Flash floods have resulted in several degrees of damages in the selected towns in Mopani district Municipality. This occurred at different times, with different frequencies and intensities. This phenomenon has in the past resulted in households losing properties ranging from domestic to farm crops and farm produce. The survey showed that with respect to flood control, the most popular strategies include the construction of embankment to prevent over flow of rivers, the use of Furrow around their houses, building of walls to protect houses during flash floods, growing of lawns, removal of solid waste from the storm water drainages, re-enforcement of dwellings with stones and concretes.

7.1.5.1 Embankment to Prevent Overflow of River

This result suggests that building embankment around houses has a popular strategy particularly for those residing close to rivers and streams, or whose offices were near rivers, along erosion line, or terrain threatening site. Embankments are usually constructed by the community or the local municipality. One aspect of the embankment is to protect dwellings, houses, offices, shops and market areas. Figure 7.2, shows that in Tzaneen a total of 25%, used embankment as a strategy to cope. About 23% was recorded for this strategy in Modjajiskloof and Phalaborwa, Hoedspruit, while Giyani and Nkowankowa both had 27% and 36% accordingly. See also Plates 7.4.

Figure 7.2 and Plates7.4 illustrate the respondents ‘flood coping strategies.

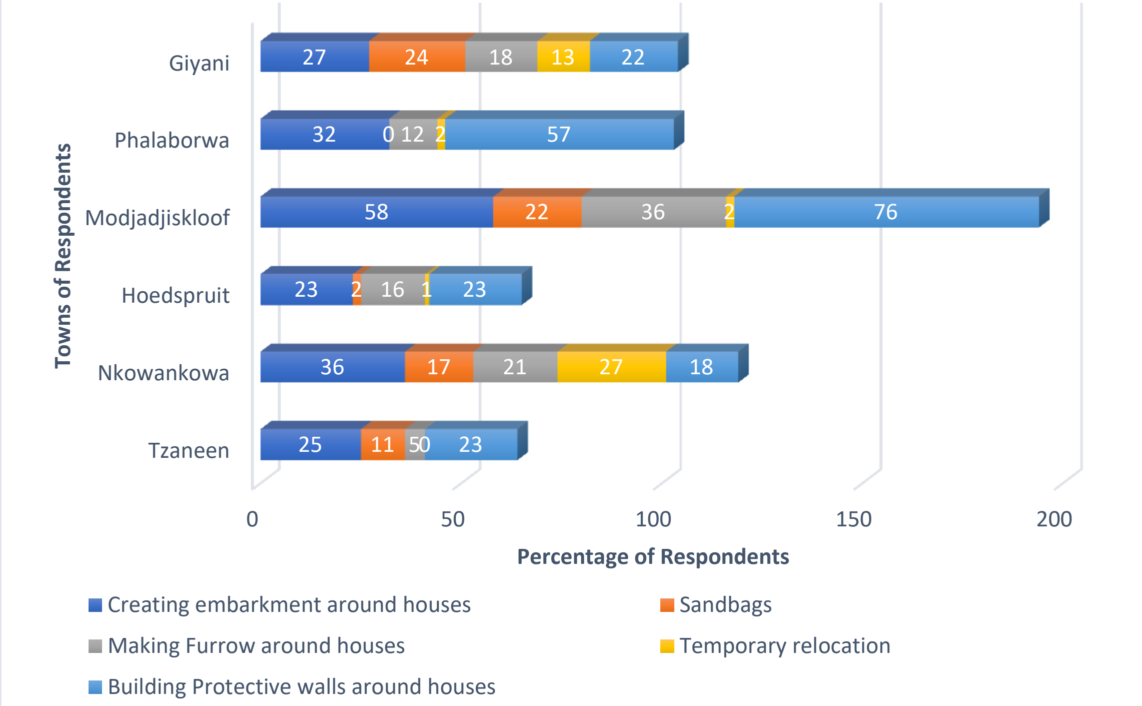

Figure 7.2: Some coping strategies for changes in water level across selected towns (Source: Author's Field Data, 2019)

Plate 7.4 Building embankments on streams as a coping strategy in Tzaneen (Source: Author's Field Photo, 2019)

7.1.5.2 The Use of Sandbags

The result of analysis asillustrated in Figure 7.2 and Plate 7.5 shows that in Giyani, 24% of the households indicated they use sandbags to protect their properties against floods. The proportions were 17%, 11% and 22% respectively in Nkowankowa, Tzaneen and Modjadjiskloof.

Plate 7.5: Use of sandbags to protect properties against flooding (Source: Author's Field Photo, 2019)

Plate 7.6 Construction of Furrows around Houses as a coping strategy around Giyani stadium **(**Source: Author's Field Photo, 2019)

7.1.5.3 Households' use of Furrows to protect their Properties

Figure 7.2 indicates that 5% of Tzaneen residents used furrows around their properties, while about one in every four households in Nkowankowa adopted the same strategy. Hoedspruit and Modjadjskloof accounted respectively for 16% and 36%, and both Phalaborwa and Giyani accounted for 12% and 18%. See figure 7.2 and Plate 7.7.

7.1.5.4 Protective Walls around Buildings

Figure 7.3 presents the proportion of households' which adopted the construction of protective walls around their houses to cope with flooding. The Figure shows that the six

Plate 7.7: Protective walls around Buildings, a coping strategy in Modjadjiskloof (Source: Author's Field Photo, 2019)

selected towns used it as strategy. Residents of Modjadjiskloof used it the most as a strategy, with more than seven in every ten (76%) households in the town. This forms the highest proportion recorded in the district that adopted protective walls as strategy, followed by Phalaborwa town (57%). Households in Nkowankowa using the strategy accounted for just 18%, being the lowest proportion. Plate 7.8 illustrates a typical house with a protective wall in Modjadjiskloof; the photo was taking during the author's visit in 2019.

7.1.5.5 Households' use of Lawn to protect Homes

According to Pataki *et al.,* (2011) and Matthews *et al* (2015), Green infrastructure is very useful in curtailing surface runoff among other benefits). Figure 7.3 presents the households' responses with respect to growing grasses to reduce the effects of floods in the selected towns. The study reveals that one out of every five households in Hoedspruit grows lawn to reduce the flow of surface run off that erodes the soil and as part of the landscaping to decorate the house. The study shows further that 37% of the households in Modjadjiskloof and 36% in Tzaneen grow grasses to reduce erosion, while 2.5% and 20% employed the same strategy in Nkowankowa and Giyani. See plate 7. 9.

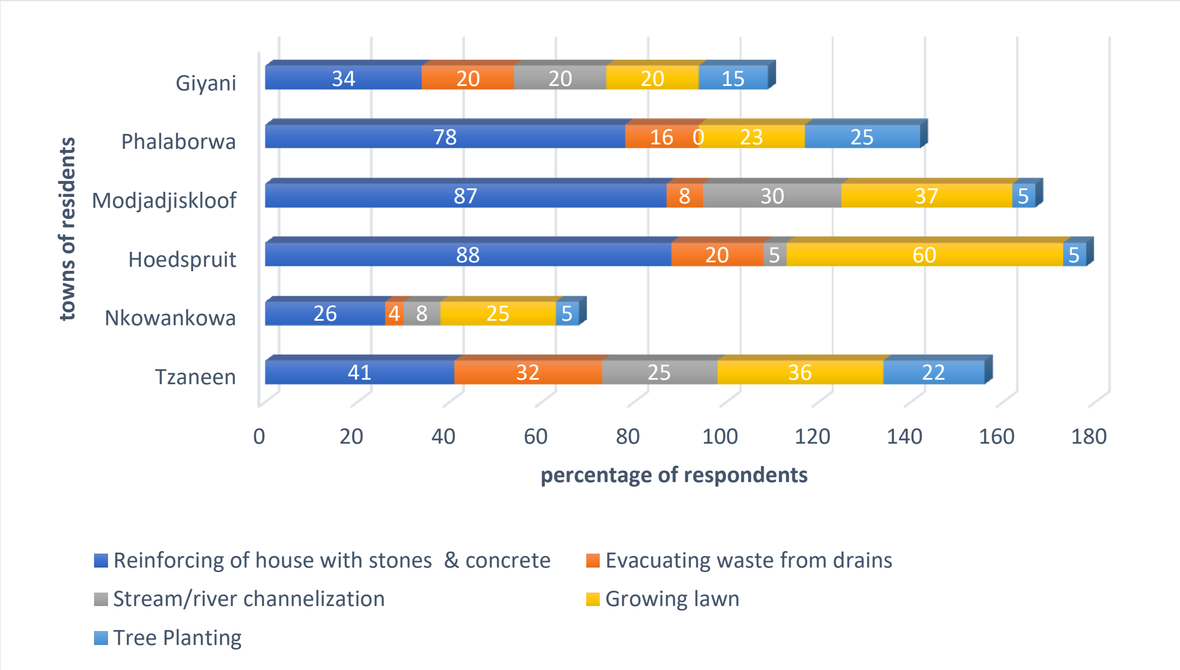

Figure 7.3: Other Coping strategies for change in water level across selected towns (Source: Author's Computation, 2019)

Plate7.8: shows where lawn was used to protect house against surface runoff during downpours. (Source: Author's Computation, 2019)

7.1.5.6 Evacuation of Waste from Drainage Channels

The respondents' answers to the evacuation of waste from drainage channels appeared an acceptable coping strategy across the studied towns in Mopani. A total of 32% of households in Tzaneen did evacuate waste from drainages, while as low as 5% of Nkowankowa households used the strategy to avoid overflow of drainages. However, more than two out of every five Phalaborwa residents engaged in clearing of their drainages to prevent flooding. Figure 7.3 further shows that one tenth of Giyani households embraced it as a coping strategy as well. Further to this, drainage and street channelization was popular, accounting for 25% of Tzaneen households, while one fifth of Hoedspruit households embraced drainage channelization in coping with the incidence of floods. See Figure 7.3.

7.1.5.7 Reinforcement of Houses with Stones and Concrete

Plate 7.10 shows that the households used concrete and stones to reinforce their housing foundations, not only as a way to stabilise the building foundation but also as a means of guarding against any unexpected floods that can erode the building foundation. About 88% of Hoedspruit households endorsed it, while 87% of the households in Modjadjiskloof as well-as 78% of them in Phalaborwa used it as a strategy to cope with floods. Tzaneen accounted for 40% of houses in this category, while Giyani town accounted for 34%, Figure 7.10.

Plate 7.9: A typical house reinforced with stones and concrete in Hoedspruit
(Source: Author's Field Data, 2019)

7.1.6 The adaptation strategies for coping with the Prevailing Climate-Related diseases in Mopani District

The study investigated the households' coping strategies for prevailing climate related diseases in the six selected towns in Mopani District and the summary of the results obtained is presented in Table 7.4.

Table 7.4 Household coping strategies for prevailing diseases across Mopani District

Towns	Consulting Physicians	Consulting native Doctors	Self-Medication	Ensuring good sanitation	Tree and Flower Planting	Not Applicable	No Response	Total
	%	%	%	%	%	%	%	%
Tzaneen	21.5	0.0	0.0	38.0	40.5	0.0	0.0	100
Nkowankowa	12.0	8.6	9.7	36.0	33.7	0.0	0.0	100
Hoedspruit	40.0	0.0	0.0	29.0	11.0	20.0	0.0	100
Modjadjiskloof	40.0	0.0	0.0	0.0	20.0	0.0	40.0	100
Phalaborwa	33.3	0.0	0.0	14.3	10.7	41.7	0.0	100
Giyani	43.1	3.8	0.8	24.6	26.2	1.5	0.0	100
Total	25.4	4.0	3.6	27.6	27.4	11.1	0.8	100

Chi-Square= 556.520, p = 000 (Source: Author's Field Data, 2019)

Table shows that one in every four household consult physicians to cope with the prevailing climate-related diseases across the selected town in Mopani, while about 27.6 and 27.4% of respondents ensured good sanitation and tree/flower planting respectively to cope with the occurrences of climate-prone diseases in Mopani. Other strategies that were employed by the respondents across the selected towns include consulting native (traditional) doctors, while some respondents indulged in self-medication.

7.1.6.1 The relationship between households' socioeconomic characteristics and adaptation strategies for prevailing climate-related diseases

The analysis of the relationship between the socioeconomic factors and choice of adaptation strategies is summarized in Table 7.5. The analysis of factors in Table 7.5 shows that age, has both decreasing (negative) and increasing (positive) relationship with different factors, but only insurance cover has statistically significant correlation with r = -0.109 and p = 0.015. This implies that an increase in the age of respondent will decrease the log odd of insurance cover. This implied, the younger the head of household, the higher the likelihood of having insurance cover.

However, household head's qualification shows negative and significant correlation with ownership of dwellings (r = -0.110, p = 0.014), Stand ownership title (r = -0.222, p = 0.000), insurance cover (r = -0.207, p = 0.000) good condition of building floor (r = -0.108, p = 0.016) and that of the condition of building roofs (r = -0.137, p = 0.002). The results imply that a unit increase in the qualification of household respectively reduce the log odd of the above listed factors.

Table 7.5: The relationship between Socioeconomic and other adaptability factors in Mopani

VARIABLE		Ownership of Dwelling	Stand Ownership Title	Dwelling Accessibility	Insurance Cover	Condition of Building Walls	Condition of Building Floors	Condition of Building Roofs
Age	Pearson's R	-0.021	-0.016	0.102	-0.047	0.035	0.117	0.110
	Spearman Correlation	0.044	0.007	0.081	-0.109	-0.014	0.118	0.095
	Sign. Level	0.648 (0.324)	0.721 (0.882)	0.023 (0.071)	0.292 (0.015)	0.433 (0.755)	0.009 (0.009	0.014 (0.035)
Gender	Pearson's R	-0.082	-0.099	-0.025	0.102	-0.049	-0.131	-0.011
	Spearman Correlation	-0.088	-0.108	-0.026	0.110	-0.014	-0.125	-0.005
	Sign. Level	0.067 (0.050)	0.027 (0.017)	0.576 (0.564)	0.023 (0.014)	0.275 (0.760)	0.003 (0.005	0.805 (0.919)
Marital Status	Pearson's R	0.096	0.064	-0.039	-0.075	-0.114	-0.061	0.002
	Spearman Correlation	0.171	0.046	0.056	-0.040	-0.176	-0.45	-0.065
	Sign. Level	0.033 (0.000)	0.157 (0.304)	0.389 (0.210)	0.096 (0.369)	0.011 (0.000)	0172 (0.001)	0.965 (0.148)
Highest Educational Qualification	Pearson's R	-0.080	-0.171	0.021	-0.164	-0.62	-0.131	-0.128
	Spearman Correlation	-0.110	-0.222	0.031	-0.207	-0.028	-0.108	-0.137
	Sign. Level	0.074 (0.014)	0.000 (0.000)	0.648 (0.493)	0.000 (0.000)	0.170 (0.541)	0.003 (0.016)	0.004 (0.002)
Primary Occupation	Pearson's R	-0.227	-0.096	-0.073	-0.177	0.155	0.176	0.040
	Spearman Correlation	-0.233	-0.096	-0.059	-0.197	0.117	0.155	0.023
	Sign. Level	0.000 (0.000)	0.033 (0.033)	0.102 (0.193)	0.000 '(0.000)	0.001 (0.009)	0.000 (0.001	0.373 (0.603)
Disability	Pearson's R	0.081	-0.080	0.014	0.120	0.048	0.045	0.059
	Spearman Correlation	0.036	-0.079	-0.004	0.129	0.045	0.039	0.062
	Sign. Level	0.071 (0.430)	0.076 (0.080)	0.753 (0.921)	0.008 (0.004)	0.282 (0.319)	0.317 (0.383	0.187 (0.167)

Note: Spearman Correlation significant level is shown in parenthesis
(Source: Author's Field Data, 2019)

The result of the analysis of correlation between disability indicate majorly a positive relationship across the identified adaptation factors only two factors (Stand ownership and Dwelling access) are in negative correlation with disability. However, the relationships are generally weak and statistically insignificant across the district, except for insurance cover.

7.1.7: Other Adaptation Strategies Employed by the Households

The study further probed into other strategies that are adopted by households to adapt to climate change hazards in the selected towns. These strategies are categorised as general but are mentioned in various literature as essential tools in reducing the adverse impacts of climate change among urban dwellers. The data was collated and analysed using frequency distribution and presented in tables, plates and figures.

7.1.7.1: Household Participation in Disaster Management Propagation Training

Disaster management should be everyone's business, because peoples' lives and livelihood as well as infrastructure are not immune to its devastating impacts. The study investigated the households' participation in disaster management adaptation training in order to determine its adoption as an adaptation strategy in the municipalities; Figure 7.4 presented the results of the analysis. With respect to households' participation in disaster management propagation training, 90% of the respondents in Tzaneen indicated they had never participated in any disaster related training. In Nkowankwa 80.69% indicated no training, and in Hoedspruit no household had ever attended any training. Similarly, the proportion of those that had never attended training was 95.2% in Modjadjiskloof and 87.7% in each of Phalaborwa and Giyani 87.7% (Figure 7.4). The low level of participation in disaster management and propagation training may be adduced to the failure of the various municipalities to organise or facilitate such important training programme. As rightly gathered from the oral interview conducted among the professionals in the five municipalities, such training had not been conducted for the members of the public. Though, disaster awareness campaign was aregular sensitisation programme in these municipalitie

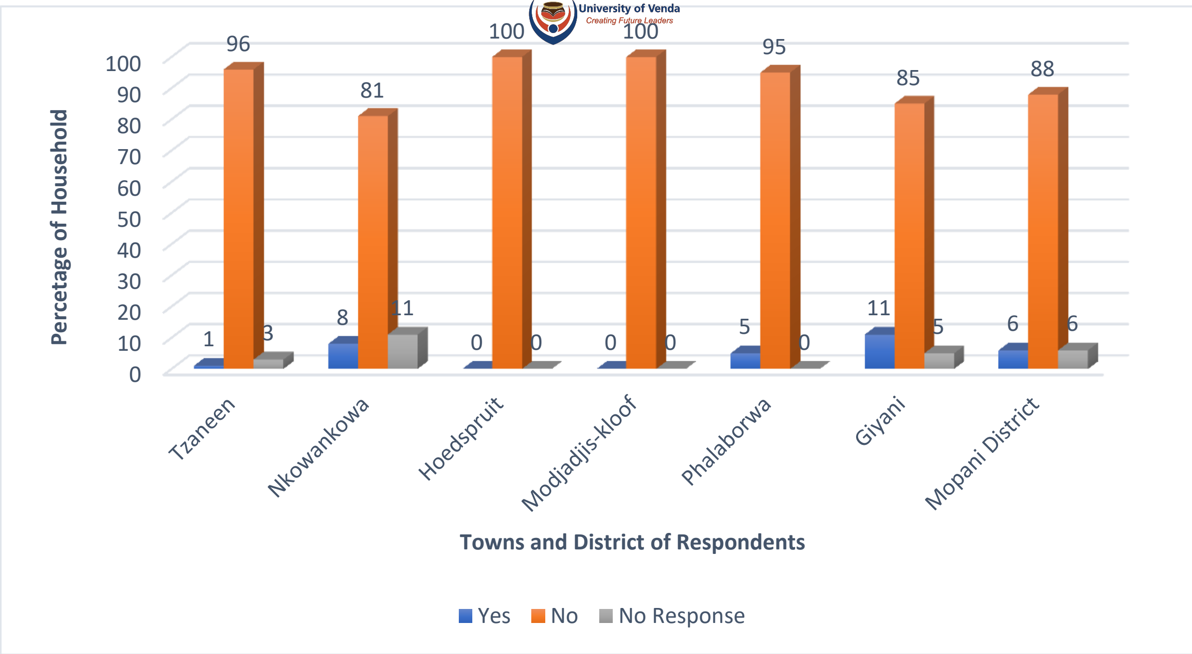

Figure 7.4. Household Participation in Disaster Management Propagation Training (Source: Author's Field Data, 2019)

Similarly, According to Pia-Johanna and Ortwin (2019), disaster mitigation refers to all actions taken before a disaster to reduce its negative impacts, while mitigation rehearsals include several elements of preparedness and long-term risk reduction measures. Examination of the level of households' participation in disaster mitigation rehearsal and knowledge sharing across the selected towns in Mopani is presented in Figure 7.5.

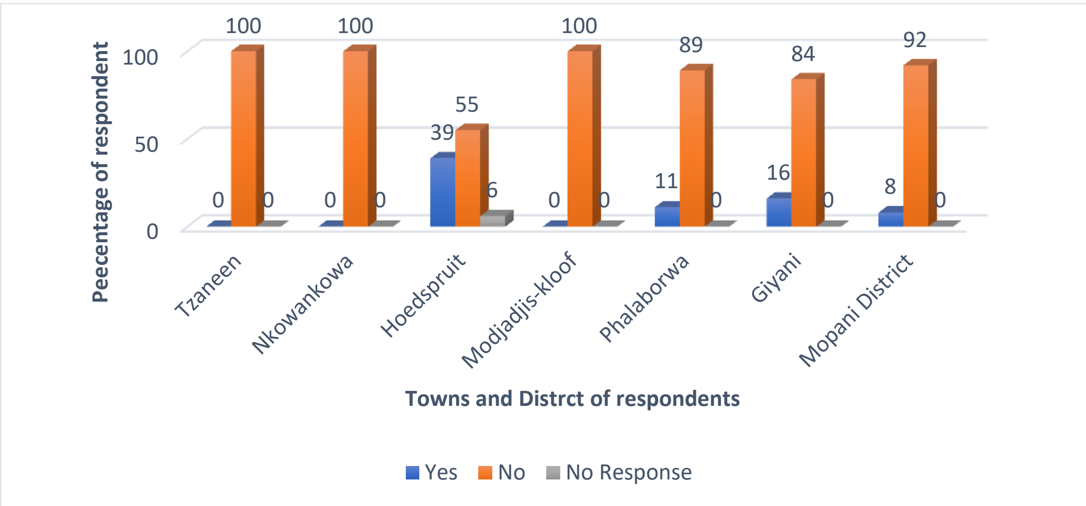

Figure 7.5: Households' Participation in Disaster Mitigation, Rehearsal and Knowledge Sharing **(**Source: Author's Computation, 2019)

The Figure shows that many respondents indicated that they did not participate in any disaster preparedness, mitigation, and adaptation process in Mopani district municipality. The implication is that the non-participation in any of such training, makes the households more susceptible, because of lack of the awareness of the most appropriate method to use and how. According to Eunmi and Haeyoung (2019) the capacity to cope with disaster related problems is related to the level of awareness of the people. These awareness skills are related to how much knowledge one has acquired in the area of preparedness and mitigation responses to climate change.

A significant proportion of households had never participated in disaster mitigation rehearsal and knowledge sharing. For instance, in Tzaneen, Modjadjiskloof and Nkowankowa, all (100%) of the household heads interviewed and 55.6% in Hoedspruit indicated they never participated in disaster mitigation rehearsal and knowledge sharing. In Phalaborwa, it was 89.3% and 83.8% in Giyani respectively. In the six selected towns 92.3% of the respondents indicated no sharing of knowledge or rehearsals. Only 7.5% of the respondents across Mopani district attested to their participation in disaster mitigation rehearsal and knowledge sharing across towns in Mopani district, while only 0.2% of the respondents were indifferent and did not respond at all. This shows that the residents of Mopani district were not mobilised for rehearsal and knowledge sharing to appreciate and understand the impacts of mitigation.

It can be inferred from Figure 7.5 that about 92% on aggregate of the respondents specified that they had not participated in any Disaster Mitigation, Rehearsal and Knowledge Sharingin Mopani district municipality. This shows that the households neither had opportunity to be trained by the municipalities, nor meet with experts or colleagues to share knowledge regarding disaster mitigation rehearsal and knowledge sharing. A probe in to the reason for low participation in these trainings revealed that majority of households were willing to participate in such kind of training but they could not, for lack of opportunity.

This disconnect implies an inability to cope with any climate change disaster because they had no prerequisite knowledge and information of what to do and what not to do before, during and after the occurrence of any disaster. Eunmi and Haeyoung (2019) argue that coping ability with disaster related challenges depends on the ability to know what to do, and when to do it. The lack of basic skills and information signifies the likelihood of high vulnerability.

7.1.7.2 Household Membership of Social Organisation

To understand the adoption of bonds between households in their various communities and neighbourhoods as an adaptation strategy was investigated through household membership of social organisation. The results are summarily presented in Figure 7.6.

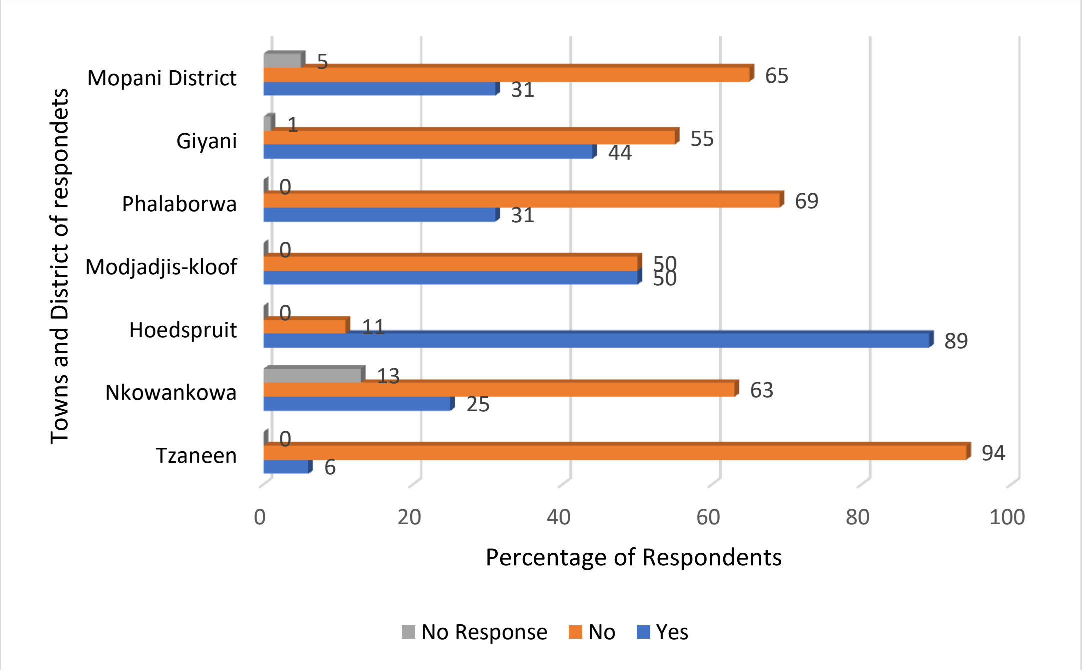

Figure 7.6: Household Membership of Social Organisation
(Source: Author's Computation, 2019)

Figure 7.6 shows that on the aggregate, 65% of households across Mopani had no membership of any social organisation. This is an indication of a weak social bond among households in the towns that further implies a weak social network among the households across the district. This can compromise the benefit of co-existence that can be enjoyed among members at the time of climate change disaster. According to Tierney and Trianor (2003) in Yingxin Chen *et al* (2019), participation in social organisations can "make up for the functional defects of government. Social organisation can make use of its own flexibility advantages to change functions and roles in time, get rid of the bureaucratic dilemma of government institutions…", and improve the people's adaptability to disasters. If this network does not exist, there will be over reliance on government, whose response may either be late or be absent, which implies higher susceptibility to climate related eventualities.

7.1.7.3 Households Access to Refuse Removal in the Selected Towns

Refuse removal across the selected towns in Mopani was examined to determine whether waste handling has compromised the quality of the environment to aggravate the sensitivity level of the households. Figure 7.7 depicts the responses from the households as regards access to refuse removal.

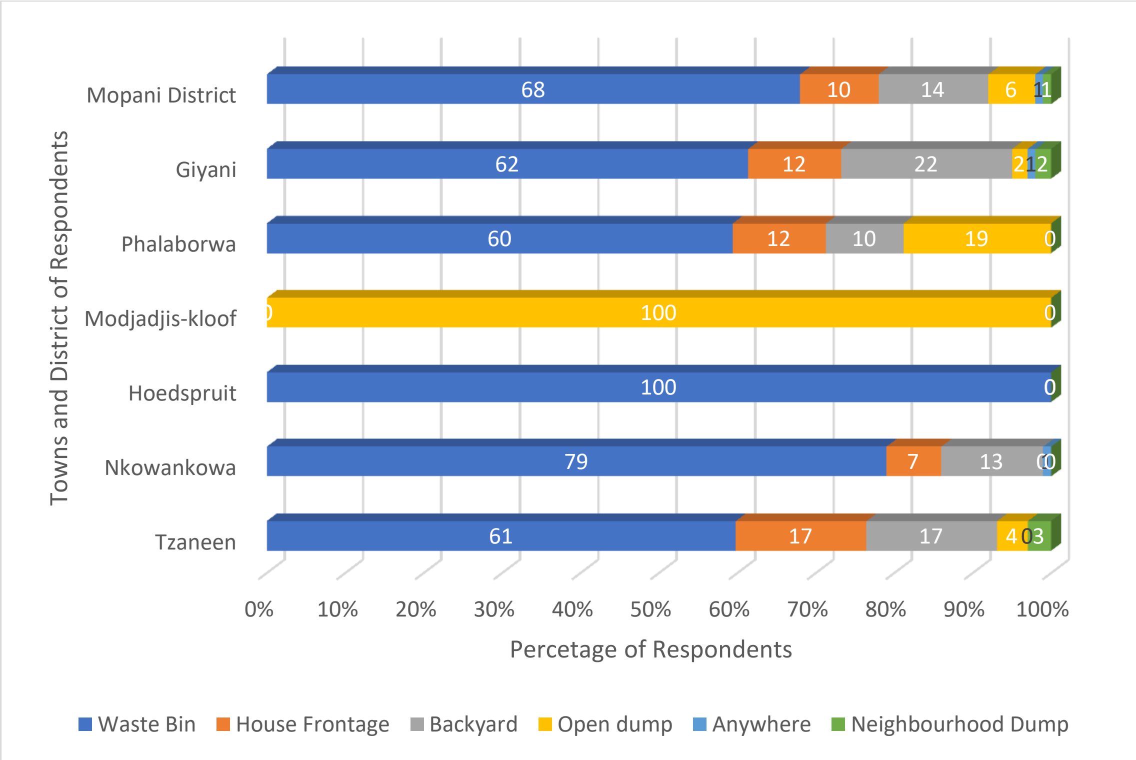

Figure 7:7 Solid Waste Collection Methods across Towns in Mopani
Source: Authors Computation, 2019

The figure shows the use of waste bins, house frontages, backyards, open dumps, or any location and neighbourhood dumps as the main types of waste collection methods in Mopani district. However, the figure depicts further that all the respondents (100.0%) in Hoedspruit, 79% in Nkowankowa, 62.3% in Giyani 61% of respondents in Tzaneenand 59.5% in Phalaborwa made use of waste bins as the most durable and acceptable means of collecting waste in the respective towns. This follows the conventional standard of collecting waste. However, in Modjadjiskloof town, it was observed that the most preferred method of collecting waste was an open dump (100%). Many researchers have identified open dumps as a major source of Methane – an effective greenhouse gas (GHG) – which is found in oxygen free environments. Methane as an extremely effective heat-trapping gas has more than doubled in the atmosphere since 1950 and could double again in the next century (Mastrandrea & Schneider, 2009). It is obvious that Modjadjiskloof and

Giyani towns stand a higher chance exacerbating climate change. A visit to Modjadjiskloof like every other town reveals municipal waste collection practice, yet the town is characterised by indiscriminate dumping of waste in open spaces. See Plate 7.10. It shows the popular waste collection type in Mogkgopa and some parts of Modjadjiskloof.

Plate 7.10: indiscriminate dumping of solid waste in Magopa-Modjadjiskloof **(**Source: Authors Field Photo, 2019)

Plate 7.11: Waste bin just being evacuated by a private company in Nkowankowa (Source: Authors Field Photo, 2019)

Plate 7.12: Solid waste collection method in Tzaneen (Source: Authors Field Photo, 2019)

Plate 7.13: Central solid waste disposal site with individual Scavengers in Giyani(Source: Authors Field Photo, 2019)

Plate 7.12 shows a solid waste bin along a walk way for public use in Tzaneen, Plate 7.13 equally shows the central waste disposal site in Giyani, where scavengers were left to pick without regulation regarding their safety. Wastes were left openly dumped and exposed to all climatic factors such as temperatue, wind and rainfall. The resultant effects are air, soil and water pollution sensitive diseases which are climate-prone ailments aggravating the exposure and sensitivity levels of households to the climate change related hazards.

7.1.7.4 Solid Waste Disposal Methods that Impact on the Environmental Quality

Solid waste disposal by definition is the disposal of normally solid or semisolid materials, resulting from human and animal activities, that are, unwanted or hazardous (Huang, 2009). Careless handling of solid waste can expose households to health risks, and this can be exacerbated by climatic factors such as temperature and runoff from rainfall. While examining the solid waste disposal methods across selected towns in Mopani district, the study as summarised in Fig 7.8 reveals that all the households (100.0%) in Hoedspruit and Modjadjiskloof, about 95% in Tzaneen, 84.6% in Nkowankowa, 78.6% in Phalaborwa and 70.8% in Giyani disposed their waste through the municipal facilities and agencies. This represents 82.5% of total households in the district. This practice is the most significant method of solid waste disposal and management system and the most effective way in which the municipalities dispose of their solid wastes. Recycling was not significant, because there was no organised method in the selected towns except in Greater Tzaneen and Ba-Phalaborwa

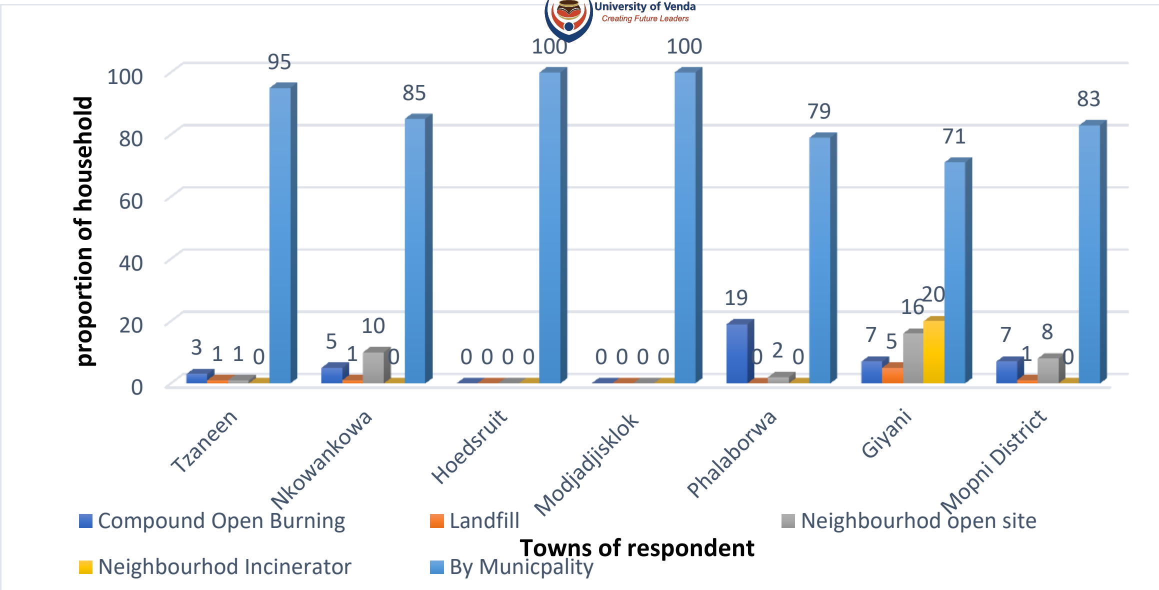

Fig 7.8: Solid Waste Disposal Methods across selected Towns in Mopani
Source: Author's Computation, 2019

Greater Tzaneen amongst other Municipalities had the best organised waste disposal strategy, with designated and well-managed landfill sites. Wastes were disposed off by private companies, sorted by accredited entities, and baled for recycling in a well-regulated environment. A similar strategy was in place at the Greater Giyani Municipal waste Department, but in this case, wastes were left completely in the hands of scavengers who picked and sell to individuals or companies in exchange for cash. Greater Letaba Municipality did occasionally collect, transport and dispose of wastes. Sharing Greater Tzaneen disposal site, Ba-Phalaborwa equally collected and managed the collected wastes. Figure 7.8 shows the various methods of solid waste disposal in selected towns.

Plate 7.14: Solid waste collected, baled and ready for shipment to recycling plant in Tzaneen **(**Source: Author's field photo, 2019)

Figure 7.8 clearly shows that municipalities across the district play very active role in the collection and disposal of waste in the selected towns. Plate 7.14 shows a waste management site in Giyani, where collected wastes are packaged, baled and ready to be transported to a recycling destination outside the district.

7.1.7.5 Sources of Water to the Households in Towns

Livelihood is not only tied to access to, but also the quality of (potable) water, which is largely determined by the sources. The World Health Organisation (WHO, 2003) defines access to water as access to piped water or a public standpipe within 200 meters (219 yards) of a dwelling or housing unit. Table 7.6 shows the respondents access to potable water systems.

Table 7.6: Households Sources of Water across the Selected Towns in Mopani

Sources of Water to the Household	Tzaneen	Nkowankowa	Hoedspruit	Modjadjis-kloof	Phalaborwa	Giyani	Total
	%	%	%	%	%	%	
None	0.0	1.1	0.0	0.0	2.4	2.3	1.4
Well	0.0	11.4	0.0	0.0	4.8	10.	7.9
Borehole	0.0	15.4	0.0	0.0	6.0	3.8	7.5
Pipe borne or Public tap	100	63.4	100	100	82.1	80	78.6
Others	0.0	8.6	0.0	0.0	4.8	3.8	4.8
Total	100	100	100	100	100	100	100

(Source: Author's Field Data, 2019)

From Table 7.6, 78.6% respondents across Mopani district accessed water from pipes or public taps, while 11.1%, 7.5% and 4.8%of households in the district access water from wells, boreholes and other sources like streams, rivers etc. A total of 78.6% of the respondents across the six selected towns' major source of water supply was tap water which complied with the blue drops water quality standard approved by the Department of Water Affairs. In Nkowankowa only 69.4% had access to pipe borne water with significant proportion relying on well (11.3%) and Borehole (15.4%). This scenario was occasioned by the dichotomised land management system in the town. The municipal-serviced area of the town were those having access to pipe borne water from the central municipal water works, while significant proportion of households that occupied land being managed by traditional rulers did not access water from this source, hence they improvised by sinking in boreholes and well.

Our investigation further shows that during the heat waves, a regular supply of water can help households to bath more regularly as an adaptation strategy to reduce body temperature.

7.1.7.6 Households' Participation in Planning Processes and Activities

Traditionally, the concept of public participation in development has been continuously debated in the development domain and political sciences literature (Glucker, *et al*., 2013; Amado, *et al*., 2010 and Masango, 2002). However, the concept is considered to be adjunct to decision making, which is fundamental to development planning (Angus *et al.,* 2015). Table 7.7 shows the households in the selected towns' inclusion in the process which gives the respondents the chance to voice their opinions on matters related to climate change that affects their community.

Table. 7.7: Involvement in Planning Processes and activities

Involvement in Planning Processes and activities	Tzaneen	Nkowa-nkowa	Hoedspruit	Modjadjis-kloof	Phalaborwa	Giyani	Total
Yes	0.0	0.6	0	0	0	3.1	1.0
No	100	99.4	100	100	100	96.2	98.8
No Response	0	0	0	0	0	0.8	0.2
Total	100	100	100	100	100	100	100

(Source: Author's Field Data, 2019)

The participation of the households enables measurement of public exclusion in Mopani with respect to the involvement of the households in planning. Table 7.7 shows that 100.0% of the households in Tzaneen, Hoedspruit, Modjadjiskloof and Phalaborwa indicated they were excluded, while 99.4% in Nkowankowa and 96.2% in Giyani indicated no involvement in the planning process and activities. However, on further investigation into the municipalities' Spatial Development Framework (SDF), and Integrated Development Plan (IDP) which require public participation before their approval, we could not reconcile why such a high number of residents indicated they did not participate.

7.1.7.7: Households' Dwelling Connected by Access Road in MopaniTowns

Good access to dwellings is a facilitator of ease of entry to evacuation and rescue in cases of climate related disasters. The results of the analysis of households' dwellings having access to roads is presented in Table 7.8

Table. 7.8: Dwelling Accessibility across Towns in Mopani

Dwelling Accessibility	Tzaneen %	Nkowankowa %	Hoedspruit %	Modjadjis-kloof %	Phalaborwa %	Giyani %	Total %
No access road	0.0	3.4	0.0	0.0	1.2	2.3	2.0
Footpath	3.9	1.1	0.0	60	1.2	5.4	5.4
Untarred earth road	6.7	42.3	0.0	0.0	3.6	26.2	28.2
Tarred road	89.4	53.1	100	40	92.9	60.8	62.7
Others	0.0	0.0	0.0	0.0	0.0	3.1	0.8
No Response	0.0	0.0	0.0	0.0	1.2	2.3	0.8
Total	100	100	100	100	100	100	100

(Source: Author's Computation, 2019)

The study reveals that 100%, 92.9%, 89.4% and 60.8% of the households' in Hoedspruit, Phalaborwa, Tzaneen and Giyani respectively had houses connected with tarred roads. A total of 42.3% accessed their homes through gravel or untarred roads in Nkowankowa, while about 26.2% homes in Giyani accessed their homes through untarred roads. An aggregate of 60% of the households in Modjadjiskloof and 40% of the houses can only be accessed through footpaths and tarred roads accordingly. However, it can be deduced from this result that most dwellings were accessed through motorable roads, either tarred or untarred. By implication most of the household members have access to their houses that can be used to facilitate entry and exit for rescue and evacuation in case of illustrated of climate related disaster.

7.1.7.8: Household access to Insurance Cover in the selected towns in Mopani

Recent studies on the contribution of insurance cover in cases of disaster emanating from climate change was analysed to determine how many households in the study area locations have access to such cover which can be used to protect their lives and properties when climate change disaster occurs. The responses of the households are presented in Figure 7.9.

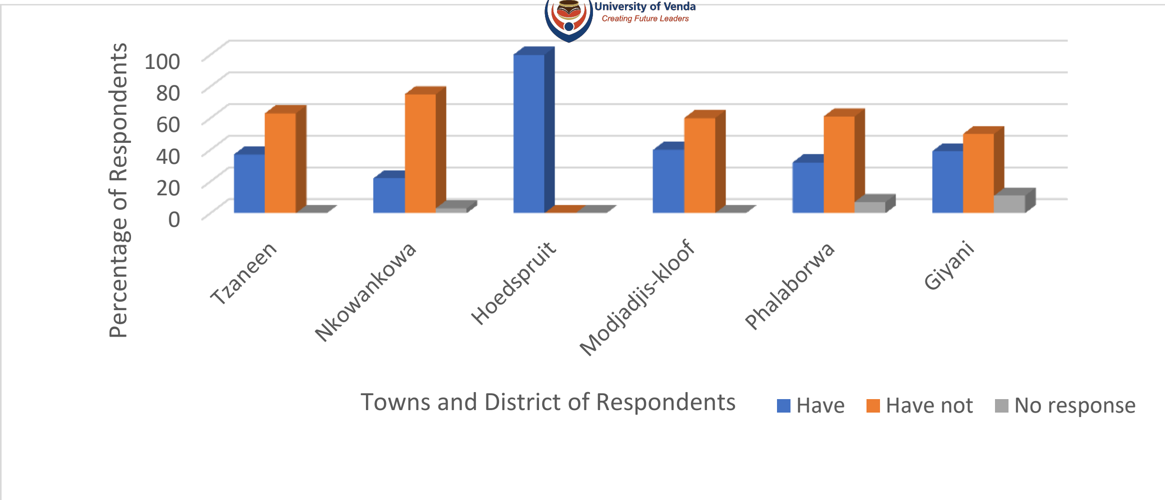

Figure 7.9: Insurance Cover across Towns in Mopani
(Source: Author's Computation, 2019)

The results of the analysis of the data obtained regarding insurance cover to properties among Mopani households reveals that 36.7% of the respondents in Tzaneen had insurance cover, while 63.3% of them did not. In Nkowankowa, only about 19.7% were covered by one form of insurance or the other, while about 80.3% did not have any. Hoedspruit however shows an exceptional result of 98.0% of the respondents having insurance cover. This is because most of the households were headed by mechanized farmers and tourist service providers. About 40% of the respondents in Modjadjiskloof, had insurance cove, 32.1% in Phalaborwa. Giyani on the other hand recorded about 50% of respondents with no insurance cover. From this result, it can be said that a significant percentage of households in the selected towns had no insurance cover, the only exception being Hoedspruit where almost all respondents had cover. The results show that any climate related disaster would affect many households adversely, because a significant proportion of them in the district did not have any form of insurance cover. These will make them highly susceptible to all forms of hardship if climate change disaster strikes the towns.

7.2. Urban Planning Response Strategies to Climate Change in Mopani

To examine the second aspect of objective four, this section deals with the various urban planning response strategies to climate change adaptation in the district of Mopani. This section was based on oral interview that was conducted among the key professionals in the five municipalities and complimented with review of relevant literature. The survey was carried out to appraise some pertinent aspects of adaptation strategies institutionalised by the municipalities to tackle response to climate change hazards.

With the complexity, uncertainties, and scale of possible climate change impacts, Hagen, (2016) argued that urban planning and management has the capacity to reduce the negative impact of climate change among vulnerable households. With informed decision-making tools, government at various levels can assist in responding more appropriately to the negative impacts of climate change (Stephane 2009).

This role has been very central to the national, provincial, and municipal government of South Africa. Accomplishments of government (National, Provincial, district as well-as local municipalities) with recourse to climate change adaptation were reviewed in order to understand specifically, the efforts different levels of government in South Africa have institutionalised to combat the challenges of climate change across the country with particular attention on Mopani. This was examined through the nation's strategies, legislations and policies, programmes, and interventions, with attention to the global commitments. These activities were assessed from two distinct eras: a pre-independence and post independence era. These are discussed as follows:

Attempts by various Government Departments have in different ways addressed the challenges of urban areas since 1994 with significant achievements. However, not many achievements have been recorded in the mainstreaming of climate change to urban sector planning. The National Urban Development Framework seeks to align creative initiatives to strengthen mutual results. Unfortunately, the municipalities within Mopani district still rely on the National Urban Policy without plans (for now) to have a localised policy for the urban sector which embraces their economic, political and social peculiarities.

A national climate change mitigation strategy was adopted by Cabinet in 2008, and the draft Climate change Response Policy amongst others. The policy emphasizes mitigation measures such as the promotion of green building and public transport for coastal cities adaptations to sea level rise, but has less emphasis on adaptation attention to small and medium sized inner cities of the country.

The Succeeding Spatial Planning and Land Use Management (SPLUMA), which deals with the use and development of land in its provision (Sec. 24-31 and (section 25(1)) to determine, harmonise and enhance compatible land use patterns, that is aesthetic, sustainable and friendly with the cultural customs and practices of traditional communities. There is, however, no other provision either reflects or emphasises the mainstreaming of climate change uncertainties in the planning and the management of land.

Mopani District Municipality in 2016 developed Vulnerability Assessment and Climate Change Response Plan to prioritize the development of a Climate Change

Vulnerability Assessment and Climate Change Response. The Plan recognised several ways that climate change will impact on human settlements across the district,as well as the related indicators, sub-projects and actions for inclusion in the Service Delivery and the plans for budget implementation (MDM, 2016). The identified project is reportedly held back because of a paucity of budgetary allocation among the competing priorities.

Another giant stride towards addressing climate change externalities in the republic was the drafting and adoption of the South African National Climate Change Response Strategy. These institutions recognise the level of damages caused by the absence of effective adaptation responses such as threatening and reversing of many development gains made by the Republic, and the need for flexible plans for a wide range of possible responses. Lack of conscious impact-reduction towards climate mitigation and adaptation and poorly serviced towns with paucity of infrastructure and basic services undermines the system. This has made them vulnerable to various environmental hazards including climate change. Unfortunately, the municipalities within Mopani district are still relying on the National Urban Policy without plans to have a localised policy for the urban sector that embraces their economic, political, and social peculiarities.

In 2016, Climate Change Vulnerability Assessment and Climate Change Response Plan was initiated, Mopani District Municipality, in line with the National Disaster Management Act, acknowledged that climate change poses serious threats to both humans and the environment now and in the future development equally. It has recognised the need for actions to mitigate, as well as prepare for the projected changes (adaptation) in the district. The Plan recognises several ways that climate change will impact human settlements across the district. These include amongst others, increase in 1) the severity of storm events and 3) increases in flooding that will damage strategic infrastructure. As laudable as the identified project was, it was reportedly held back because of paucity of budgetary allocation among its competing priorities.

With respect to Planning Regulations for Climate Change Disaster Prevention, Reduction and Response across Municipalities in Mopani district, the investigation reveals that local municipalities across Mopani district have specific planning regulations that were instituted and adopted for the control of development. In general terms, the regulations have no specific provisions for disaster prevention, reduction and adaptation strategies. The Mopani municipalities have equally not reviewed the development control instruments for more than six years. Aside from other factors, there was consensus among the municipalities that traditional institutions were some of the main external factors that hinder the effectiveness of the development control mechanisms in the municipalities, due to a dichotomised system of land administration. Paucity of budgeting was identified on the other hand as the main internal factor. Meanwhile, investigation further reveals that the municipalities never considered conducting surveys to uncover and identify climate change disaster hotspots in the respective municipalities. This was despite the fact that all municipalities have their respective disaster managers, who were though seasoned administrators, but were not climate-related experts.

Notwithstanding these exigencies, the Mopani municipality had never played any specific role during the past incidents of climate change disasters, (especially as regards prevention, reduction, and response) rather than collaborating with both district and provincial Disaster Management Teams in post disaster rescue tasks. Although, Municipalities like Greater Tzaneen and Phalaborwa have in the past donated food parcels, and provided tents for disaster victims during and after disaster incidents.

As regards the municipalities' adaptation strategic plan, the officers charged with climate change responsibility in the municipalities reportedly acknowledged the fact that none of the local municipalities had any plan or policy besides that of the district. This by implication indicates that there exist no proactive action(s) targeted on pre-disaster, disaster, and post disaster by local municipalities. Meanwhile, there exist equally no strategies in place to secure and protect the ecological zones (wetland, flood plain etc) from unjustified invasion across the municipalities under investigation. In a nutshell, the interview revealed an absence of an effective and efficient hazards reporting system at both the local municipalities and the district levels as a serious problem that require urgent attention.

On the other hand, despite that, the municipalities agreed that there was prevalence of slums, risky site occupation (flood plains), squalid life-threatening settlements, and unsecured tenure, across the local municipalities. Yet there was no operational strategy for mainstreaming climate change into planning at Local Municipality level. According to the interview conducted, currently, the municipalities have no interface programmes with Universities or research institutions for information sharing, knowledge and research activities with regard to climate change and urban development.

With respect to initiation and execution of climate related risk prevention, reduction and response/coping projects, the five local municipalities across the district have no specific projects, apart from those identified and articulated in the district plan instituted in 2016. Equally unavailable were projects and programmes targeted towards effecting repairs after disaster incidents, as well as any functional mechanism and structure for recovery in case of disaster occurrence in the local municipalities. The municipalities rather relied on the National, District, and Provincial Framework mechanisms. Mopani

District Municipality currently has full control and responsibility of Rescue Services, and they assist the municipalities in cases of any disaster.

Disaster management is no doubt a costly venture, and the municipal governments in Mopani district essentially finance their disaster management units from the annual budgetary allocation. This made the availability of financial aid to disaster victims very slim because of the competition among other sectors for the scarce resources.

Notwithstanding these policy shortcomings, various local municipalities have at times attempted risk identification, analyses, and responses with relief materials. Some have conducted disaster awareness in communities and schools. Ward committees and Councillors have reportedly been trained on causes, effects and responding strategies to incidents relating to disasters. Communities were sometimes informed of any threat that might cause a disaster (early warning) so that appropriate steps and precautions could be instituted.

7.3 Chapter Summary

The chapter examined both the individual response strategies that were employed to cope with climate change effects. Strategies that were adopted by individual households to cope with the incidents of climate change extreme events were categorised into three, including those related to increased temperature, reduced water level (rainfalls) and incidents of flood. The chapter equally examined those strategies that were adopted by the government at different levels to institutionalise and facilitate the households' and communities adaptive responses to the climate change hazards.

From the obtained results, tree planting was the most popular and most acceptable coping strategy against increasing temperature in the selected towns. Most of the households considered the strategy as the most effective measure to cope with temperature increase in the selected towns, while rainwater harvesting was a strategy that was unpopular among the households across the six selected towns in Mopani.

The use of storage tanks and water reuse across towns were equally very popular as coping strategies for reduction in water levels across the towns. Whereas strategies like the embankments around houses/river, use of Sandbags and Furrows around Houses remained some adopted strategies across towns in the district for coping with floods.

Although attempts by various Government Departments have in different ways addressed the challenges of urban areas since 1994 with significant achievements, not much achievement has been recorded in the mainstreaming of climate change to urban sector planning. The National Urban Development Framework seeks to align creative initiatives to strengthen mutual results. Unfortunately, the municipalities within Mopani district still rely on the National Urban Policy without plans for a localised policy for the urban sector which embraces their economic, political and social peculiarities.

A national climate change mitigation strategy was adopted by Cabinet in 2008, and the draft Climate Response Policy amongst others. The policy emphasizes mitigation measures such as the promotion of green building and public transport for coastal cities adaptations to sea level rise, but has less emphasis on adaptation attention to small and medium sized inner cities of the country.

The provision of Section 24-31 and (section 25(1)) of Spatial Planning and Land Use Management (SPLUMA) determines the use and development of land within its area of jurisdiction, to harmonise land use patterns for sustainability and environmental friendly urban development. There is, however, no other provision that either reflects or emphasise the mainstreaming of climate change uncertainties in the planning and management of land.

Mopani District Municipality in 2016 developed Vulnerability Assessment and Climate Change Response Plan to prioritize the development of a Climate Change Vulnerability Assessment and Climate Change Response. The Plan recognised several ways that climate change will impact on human settlements across the district, as well as the related indicators, sub-projects and actions for inclusion in the plans for budget implementation (MDM, 2016). The identified project is reportedly held back because of a paucity of budgetary allocation among the competing priorities.

The chapter identified gaps related to the current climate change adaptation models, policies, late reporting of climate change events and responses gaps. It equally highlighted gaps relating to incorporating hotspot and monitoring in the models as well-as factors that determine climate change adaptation needs which include but are not restricted to policies, human behavioural factors and climatic and non-climatic factors.

It identified paucity in the provision of up-to-date information on climate change related extreme events, late reporting characterised by lack of precision and transparency. This was compounded by untimely response by the relevant agencies which are considered as some of the fundamental issues that needed to be addressed.

Having examined the strategies that were adopted by households to cope with climate related disasters and those that were employed by government through the agencies responsible for urban planning in the district, as well as the associated gaps, the succeeding chapter first summarises key findings, make recommendations and addresses objective five by proposing the adaptive measures and decision support tools upon which sustainable planning strategies will be built in the district.

CHAPTER EIGHT

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

8.1 Introduction

This research examined the vulnerability and response patterns of households to the climate-related impacts in six towns in Mopani district of South Africa. The discussed issues were based on the context of the objectives of the study. The study accordingly addressed the following issues: the examination of the trends and patterns of temperature and rainfall in the Mopani district South Africa, during 1958-2017; and the magnitude of households' vulnerability in the selected towns. Equally examined were the spatial magnitude and variations in households' vulnerability in the selected towns of the district and how some households' socioeconomic characteristics had influenced the vulnerability. And finally households' and government adopted response strategies to cope with the impacts of climate change in the selected towns were examined.

The study utilized data from both primary and secondary sources. Sets of satellite imageries from USGS (Earth Explorer) for the period of 1987, 1997, 2007 and 2017 were obtained and used for land use and land cover change detection in the towns between 1987 and 2017. The towns boundaries were georeferenced through the use of google map (from www.google/map) to determine the spatial extent of the towns. General information on the households' socioeconomic characteristics, households' vulnerability and response patterns, as well as governments' response strategies were gathered with the aid of structured questionnaires. The secondary data on temperature and rainfall were sourced mainly from the global gridded datasets for the period of 1958-2017. Demographic related data were sourced from Statistics South Africa. Other relevant information was drawn from the Department of Environmental Affairs, Limpopo province, Mopani district and respective municipalities.

The collected data were analysed using methods ranging from descriptive, inferential statistical methods and GIS aided tools. The descriptive statistics were utilised to analyse the spatial distributions and magnitude of household vulnerability. Time series analysis was employed to obtain the trends of temperature and rainfall, and these were regressed to examine the relationship of the trends of the parameters with time. The study further used Chi Square and Analysis of Variance (ANOVA) in testing the components as well as vulnerability variance and level of significance against some households' socioeconomic attributes. The Livelihood Diversification Index (LDI) was calculated adopting the Herfindahl index of diversification and was further subjected to an Ordered Logit Regression Model (OLRM), to examine the influence of LDI on the HVI. While both the Ordered Logistic Regression and Pearson correlation Coefficients were employed to examine the relationships between the variables, Geospatial analysis was carried out with the use of ArcGIS 10.3 software for graphical representation of the results. The study, in response to disaster reporting and response challenges in the district develop a mobile application and web for Disaster Reporting and Hotspot Monitoring System using PreHypertext Preprocessor (PHP); Java Programming Language; MYSQL**;** Android operating system based on Linux with a Java programming interface and the use of Google Map API to allow communication on Google platforms and services. The analyses were presented with graphical interpretation of the vulnerability and response pattern, upon which conclusions and recommendations were based.

8.2 Summary of Findings

In line with the objectives of the study, this sub-section centres on the summary of its findings.

8.2.1 The trend in temperature and rainfall occurrence in Mopani (1958 – 2017)

This section deals with the trends in temperature and rainfall in Mopani, Limpopo, South Africa for the period 1958 to 2017. The period was informed by the study focus to cover two climate cycles (60 years) periods.

The analysis of the inter-annual trend of temperatures (minimum and maximum) exhibited an increase tendency during the sixty years of examination with high and positive correlation coefficients with soil moisture evaporation tendencies and significant impacts on rain-fed livelihood that are urban related in the district. The situation occurred with anomalies of extremes (cold weather and heat episode) in different years that had resulted in droughts and wildfires. The temperature trend was a pointer to an increase in what the residents of these towns have been subjected (exposed) to, annually during 1958-2017. The concern is particularly on the health of children, women and the Aged populations of these towns.

The phenomenon reflected the regional climate and was complemented by the peculiarities of the individual town landscapes. The prominence of impervious land cover at the core of these towns, deforestation resulting from the invasion by built up sector, wood energy sourcing, and tree consumption by timber industry as well as mining were some of the factors exacerbating the heat episode.

The trend in mean precipitation across Mopani district was low with varying inter annual intensities. There was equally high variability between extremes of both wet and dry seasons resulting in both water scarcity and occasional floods across the district. The scenarios of the precipitation implied potential for high exposure and vulnerability among residents of the district to climate change extreme events. This is equally critical to influence most socioeconomic activities, upon which urban households consistently depend for their wellbeing.

8.2.2 Locational and other characteristics of the selected towns

The analyses of the physical characteristics of the six towns (topography) that may influence exposure and aggravate vulnerability were examined. The section explored the possibility of the influence of land use and land cover changes in Mopani district. The study revealed that most selected towns are characterised by gentle relief which were largely attributed to the relative slow flow of rivers and general runoff in some of the selected towns. Specifically, towns like Tzaneen, Nkowankowa and Giyani were identified to be generally faced with blockages of drainage channels by weeds.

The wet nature of the southern part of Nkowankowa suggests its susceptibility to mild and regular flash floods, worsened by the paucity of drainage channels on roads and the invasion of wetland by residential land use. The gentle sloping terrain of Hoedspruit town coupled with the strategic role of being a host to several private game reserves as well as mechanised farms contributed to the local economy and the growth and expansion of the small town. Similarly, Phalaborwa, being a mining town has the lowest elevation, relatively flat terrain that ranges from 442m (asl) being the highest point on the north-western area and 433.5m (asl) being the lowest elevation to the north eastern edge of the town with some roads lacking drainages. In the case of Modjadjiskloof, the study uncovered a town with dichotomised neighbourhoods with opposing types of topography, with the main town facing terrain-related challenges because of the steep sloping nature of its landscape.

However, land transformation in the six selected towns in Mopani revealed a steady increase in the built-up areas throughout the three decades under examination (1987-2017). Vegetation cover was found on the other hand to have depleted consistently. Athough the extent of the transformation in land use varied from town to town and equally from decade to decade. The Pearson correlation coefficient results in the built-up areas show an increasing (positive) relationship between the built-up areas in the six selected towns in Mopani district with increasing years, throughout the three decades. These results implied an increasing loss of vegetation, through continuous urbanization that was characterized by impervious cover and wood energy sourcing among other factors. These phenomena may not be unconnected with development witnessed in these towns being the administrative headquarters of local municipalities, (except Nkowankowa) such as attraction of businesses, industries, major Shopping Malls and commercial hubs, and various multinational entities. These have resulted in population growth and consequently leading to land concretisation resulting in heat trapping and general warming in the towns.

The demographic analysis uncovered a higher proportion of female headed households in the selected towns of the district, with varying proportions from town to town. The cases of Hoedspruit and Modjadjiskloof towns presented a contrary result, with household-headship higher in males than the female counterpart.

The households age structure shows that the household heads that were in their prime ages (20-50) dominated in the selected towns across the district. This category accounted for about 80% of the total sampled population, though varied in proportion across the towns. The scenario suggests that any developmental and empowerment intervention targeting this population category will significantly be impactful across the selected towns, including climate change adaptation and early warning propagation programmes.

The results of the analysis further shows that a significant proportion of Mopani district households were engaged in non-climate fed economic activities, while the unemployed households accounted for less than one in every four households (23%) in the district. The findings equally reveals that self-employed, professionals and civil servants dominated the work force in the district. However, timber industry played a major role in Modjadjiskloof town like minning in Phalaborwa.

Household heads that were married accounted for more than one in every two of Mopani residents, while 29.8% were single, and 5.2% were widows/widowers. Across the selected towns, the study found that Nkowankowa and Phalaborwa towns had about three in every five of their residents married, while Hoedspruit and Giyani accounted for 38.9% and 37.7% respectively of single household heads. However,household heads with higher education attainment were 16.5% in Tzaneen, 37.7%% in Giyani.

Further results show that majority of households in the selected towns were poorly served with the basic infrastructure and service. Backlogs of services were observed in the district which was partly a reflection of factors that included, but not limited to population increase (due to birth and migration), and a shortage of budgetary allocation, due to competing needs of the people of the district. However, by implication, households that were short-served with basic services were more prone to being vulnerable to climate change extreme events, because the paucity of services would limit the households' capacities to buffer the impacts of climatic factors, with potential consequences of enhancing households exposure and compromising their adaptability.

8.2.3 Magnitude of household vulnerability to climate change with respect to its components in Mopani district

The study found the exposure to climate change among households to be generally high in Mopani district. With respect to towns, Hoedspruit, Modjadjiskloof, Phalaborwa respectively had more than half of their households exposed, while Nkowankowa and Tzaneen accordingly had half of their population and Giyani town with the least exposed households (36.1%). The variation according to the Analysis of Variance (ANOVA) of Households' level of exposure across selected towns in Mopani district revealed an insignificant variation.

In the six towns, except for Hoedspruit, a very low household sensitivity index was observed. Only Hoedspruit town had a significant proportion of its population (about one in every five household heads) sensitive, while Phalaborwa recorded the highest, with more than nine in every ten households not being sensitive. Average sensitivity scores across the five-local municipalities in the district, indicated that Maruleng has the lowest recorded average sensitivity level among others. Giyani town followed as the second highest on the average, while Tzaneen and Nkowankowa recorded the closest to the average sensitivity score. A positive relationship between primary income and household sensitivity to climate change illustrated a positive but insignificant relationship between income andhouseholds' sensitivity. By implication, income did not explain level of sensitivity, perhaps a combination of other factors such as ownership of assets were fundermental.

In the selected towns, there were observed differences in the adaptive capacity across densities. For example, the low and medium-density areas across the respective towns varied in aggregate capability between 41.67% and 67.51% while the high density neighbouhoods had the highest proportion of households that were not capable with about 58.33%.

8.2.4 Households' Aggregate Vulnerability Index across Towns

In compliance with the established threshold in chapter six, the results of the analysis of the aggregate vulnerability reveal a generally high vulnerability level, with about three in every five household heads vulnerable in Mopani district. However, the situation is similar across the towns, except in Hoedspruit town, with the highest proportion of households that were lowly vulnerable. On the other hand, every other town had more than three in every five of their household heads highly vulnerable across the district.

8.2.5. Households' Adaptation strategies across Mopani district

This section examined the individual response strategies that were employed to cope with climate change effects. The strategies were categorised into three types, including those related to increased temperature, reduced water level (rainfalls), and incidents of flooding.

Tree planting, minimising bush burning, and the use of fans and air conditioners were the most popular and acceptable coping strategies against increasing temperature across the selected towns. With respect to coping with reduced water level, preservation of water bodies and rainwater harvesting were unpopular strategies among the households across the six selected towns of the district. The use of storage tanks in homes, water reuse and water treatment were the most embraced strategies for changes in water level.

However, the building of embankments on streams was popular amidst those residing close to or whose offices were near rivers or along erosion lines, as flood coping strategy. Others, such as growing of lawns, evacuation of waste from drainage channels, drainage and stream channelization, planting of trees among other strategies remained most prevalentas they were considered the cheapest and most effective among residents across the district.

The participation of households in planning was inadequate, with non-participation in Tzaneen, Hoedspruit, Modjadjiskloof and Phalaborwa and almost none in Nkowankowa and Giyani as signified by households when probed on their involvement in spatial planning decision making process.

The study also shows that a low proportion (42%) of the households across the selected towns in Mopani had insurance cover of either life or properties, implying potentialties for increased households' vulnerability in case disaster strikes.

8.2.6 Urban Planning Response strategies across Mopani district

Various attempts by government departments to address the challenges of urban subsectors since 1994 have produced significant achievements in areas such as service extensions, municipal reforms, urban renewal and economic infrastructural delivery. The municipalities within Mopani district still largely rely on the National Urban Policy with no clear plans for locality-specific policies, particularly the mainstreaming of climate change inurban climate governance. Also, the National Urban Policy emphasized mitigation measures such as the promotion of green building and public transport with less attention on adaptation. Although, there was attention on coastal cities adaptations to sea level rise, but less emphasis was placed on adaptation of small and medium sized inner cities of the Republic.

Despite this strategic initiative by the parliament to have adopted the National Climate Change Response Strategy, in its efforts to fulfil the expected obligations as a signatory to the UNFCCC, there existed no clear channels of information sharing with broader stakeholders about the engagement with climate change programmes that were implemented at the Provisional, District and Local levels.

The Spatial Planning and Land Use Management Act provisions, apart from Sections 24 to 31that mandated the municipality, to,in accordance with the provisions of land use scheme (section 25(1))determine the use and development of land within its area of jurisdiction, there was no other provision that either reflected or emphasized the mainstreaming of climate change uncertainties in the planning and tmanagement of land in the Municiplities.

The National Disaster Management Framework Policy of the Republicgave birth to the establishment of Mopani District Disaster Management Centre. Consequent upon this, Mopani district Municipality in 2016 developed a Vulnerability Assessment and Climate Change Response Plan.

The local municipalities across Mopani district had specific planning regulations that were instituted and adopted for the control of development. Despite this, in general terms, the regulations have no specific provisions for disaster prevention, reduction and adaptation strategies.

Aside from other factors, there was consensus among the municipalities that the dichotomised system of land administration as well as paucity of budgetwere the main factors that hindered the effectiveness of the development control mechanism in the municipalities. The investigation further reveals that the municipalities had no interface programme with Universities, research institutions and the like for information sharing, knowledge and research activities as well as collaboration on climate change and urban related matters.

Notwithstanding the identified policy shortcomings, various local municipalities had at some times attempted risk identification analyses and response with relief materials. Others had conducted disaster awareness campagn in some communities, schools and other public places. In addition, ward committees and councillors were reportedly being sensitized on causes, effects and response strategies to climate change related events as early warning strategies, for appropriate steps and precautions to be instituted.

As rightly gathered from the interview among the key stakeholders, the Challenges that reportedly hindered effective urban adaptation/responses to climate change related hazards across the municipalities in the district included but were not restricted to: communities' proximity to the stations of agencies that were charged with rescue responsibility andunder-staffing of these agencies. These factors had led to ageneral delay in the reporting (before) and responding todisaster (during) emergencies.

8.3. Contributions to Knowledge

This study has conducted empirical analysis of urban households' vulnerability and adaptation to climate change in the Mopani district, Limpopo Province, South Africa. It has been able to address the salient issues relating urban households' vulnerability and adaptation in small and medium-sized towns in semi-arid areas of South Africa with a paucity of empirical data. It has similarly assisted in gaining a better insight into drawing inferences on the issues being investigated.

This work has enabled the corroboration of existing research knowledge work, providing richer details and initiating new lines of thinking, through attention to paradoxes, "turning ideas around" and providing fresh insights. It has provided the households' vulnerability levels at different spatial scales with attention on the levels of exposure, sensitivity as well as adaptive capacity. The study has adequately provided answers to the research questions.

The study had unpacked that climate is changing and the trend as well as the extent as influenced by temperature and rainfall reveals its variability in Mopani district during (1958-2017). The mean average temperature had been consistently on the increase; while the mean average precipitation had consistently decreased with inter-annual variation and anomalies, throughout the period of examination. The study equally provided answer to the revealed generally high but varied households' vulnerability to climate change hazards in the selected towns, influenced by several factors that ranged from physical, environmental, socioeconomic as well as system failure etc. The vulnerability levels of households were further established across spatial scales i.e the neighbourhoods, towns and District. Socioeconomic factors such as age, gender, marital status, income and educational qualifications out of others were found to be fundermental in explaining households'vulnerability to climate change in the District.

With regards to the individual households and urban planning response strategies that were employed to cope with the impacts of climate change in the selected towns and the District, the study unpacked the prominence of independent and self-improvised adaptation and response strategies being employed among the households across the District. These included but not limited to tree planting, growing of lawn and flowers, use of fans and Air conditioners, insurance, and water reuse etc. The adoption of these strategies was similar in all the towns selected but varied in magnitude.

On the parts of governments, the study uncovered the several attempts that have been institutionalised at various levels of governance in the Republic of South Africa to combat the scourge of climate change, particularly in the urban areas.There were for instance several policies, legislations and strategies instituted at national levels which were yet to be implemented at local government level. Meanwhile,the Spatial Planning and Land Use Management Act (SPLUMA) provided an agenda and mandates for the municipalities through its provision (section 25(1)) on the use, development and management of land within their area of jurisdictions. The Act however, neither provided for, nor emphasized the mainstreaming of climate change uncertainties in the planning and land management tools.

These findings will enrich the data availability and enhance the solution to data paucity problem regarding urban households' vulnerability and adaptation to climate hazards in the district, province as well as national levels. Findings here will equally enhance planners', academia, and policy makers' awareness and understanding about the critical interactions between climate change and the social, economic, physical and ecological indices as well as governance, particularly as it affects the households in small and medium sized non-coastal African towns. It will further justify the desirability or otherwise and the integration of, a comprehensive adaptation strategy, while mainstreaming them into urban planning to reshape our towns and promote healthy and safe urban households against climate related hazards

Finally, the study proposed an adaptation conceptual framework and developed an events (hazard/disaster) hotspot reporting and early warning system that will focus on combining anticipatory and reactive responses that will be based on an informed, inclusive and transparent process. This will address the location peculiarities of situations while promoting an integrated methodology. The system is though peculiar to the study area (Mopani), but operationally expandable and can be replicated in other districts and provinces.

8.4 Limitations

The study was unavoidably hindered by several issues, such as the challenge of non-availability of adequate number of desired satelilite imageries, and where available such as for 2009, they are low quality resolution. The satellite imageries for the years that preceded 1999 were not available and data for those periods could not be captured. However, there was no serious adverse effect on data quality as there were enough imageries used for the analysis.

The efforts to conduct town specific climatic analysis were limited due to the absence of town-based data stations and data inadequacies in some cases, hence we resolved to use regional (District) scale data.

Furthermore, swamps, wetlands, and water bodies in some cases could not be distinctly identified because of the seasons/periods when the data were captured (dry season). Due to the unavailability of Satellite imageries for the years before 1970, the study was constrained to a 40 years analysis of changes in land use and land cover. Landsat 7 was launched in 1999, so it only captured data for 1999 to the current date, while Landsat 8 was launched in 2013, and it equally covers only 2013 till date. Landsat legacy data includes Landsat satellites that were launched before 1999. Therefore, we could only retrieve data for 1987 and 1997 from Landsat legacy and 2007 from Landsat 7 and 2017 data from Landsat 8.

Because of inadequate knowledge of GIS application and the technology for tools employed to design and develop the mobile application and web for Disaster Hotspot Reporting and Monitoring System, experts were drawn to oversee this aspect of the work.

The study unpacked the paucity of research work on small and medium-sized towns and non-coastal towns in the District. With the population of Mopani District becoming more prone to the growing occurrences of extreme events of climate change e.g. floods, drought, heat waves, and the spread of climate-related diseases, aggravated by increasing poverty and unemployment, limited access to resources, and high infrastructure deficit, the need for empirical examination of household vulnerability in other towns is imperative.

The study did not include the analysis of local cultural practices of the residents that may induce climate change in the study areas, likewise other salient factors that govern the behavioural component of the choices of household’s adaptation strategies to climate change among options that require further investigation and could not be covered in this study.

This study observed the influence of domestic group's reorganisation, which is currently resulting in the increasing number of female-headed households and because of its envisaged implications on households' adaptive capacities and vulnerability; it is recommended for further studies.

The study was limited to six towns chosen as the cse studies from Mopani District Municipality due to limitation of time and resources. The study was limited to the boundaries and the areal extents of the towns' neighbourhoods which are refered to as Sections in most cases. For instance Tzaneen was limited to neighbourhoods such as Hippo Roch Tzangen, Matumi Park, Aqua Park, River Side Estate, Santra Park, Valencia Estate, Macadamia Village and Arbor Park, others are Avis Park, Golden Acre, Valencia Estate, Adams Park, Santra Park, Flora Park, Medi Park, Fauna Park and Premier Park, Golden Arce neigbourhoods and Talana hostel. Modjadjiskloof included Modjadjiskloof main neighbourhood and Magkopa hostel, while Maruleng was restricted to its mono neighbourhood. Phalaborwa covered Extention 1 - 8 and Giyani was limited to Sections A-F, while Nkowankowa covered Sections A-E.

8.5 Recommendations

Based on the findings of the study, two sets of recommendations are suggested; these are described as general and specific recommendations. They are presented as follows:

8.5.1 General Recommendations

1. A fundamental requirement is the need to stem the rapid transition in land use/cover changes with the attendant environmental adversities in the selected towns as well-as in Mopani as a District: This calls for the need to adopt an aggressive afforestation (tree planting) policy and programme as a matter of urgency. This is to be facilitated by governments (Local, District and Provincial), private sector, NGOs, and residence owners through active public participation. Also, Land Use Planning Policies and other relevant laws should be overhauled to regulate and encourage vertical development patterns as well-as enforcing appropriate planning and ecological protection laws.
2. Environmental infrastructure provision and maintenance must be continued and it must encompass provision of drainages on roads and regular clearance and

evacuation of drainages and drain channels, particularly in Tzaneen, Nkowankowa, Giyani and Modjadjiskloof. Prompt attention must be given to fixing of broken infrastructure, public utilities and services particularly the sewer lines and sewerage systems in Nkowankowa town and leaking drainage in Phalaborwa. Adequate attention must be paid to the protection of wetlands. These are essential to stem the occurrences, intensities and frequencies of flood in the district. Promotion of soft landscapes must be prioritised and enforced for any proposed residential development submitted for approval. This is because house premises are still significantly landscaped with impermeable materials despite the rising temperature and reducing precipitation. These steps will significantly reduce the rising and unbearable heat across seasons in the towns and the district.

3. Retraction of the dichotomized land management system is considered necessary to abolish the current bi-camera land management system to promote a unified system, where all land within the jurisdiction of any local municipality is left in the custody and control of such municipality, while traditional rulers serve as facilitators to ensure the payment and remittance of necessary levies in respect of the land. This will curtail the current system to continuously promote incompatible land development and to equally endorse illegal development on and along unsafe terrains such as flood plains, wetlands and other disaster-prone landscapes. It will also discontinue undermining environmental quality and prevent the enforcement of planning rules and standards. Thus, compromising safety, hindered services provision, and heightened service-prone violence through disturbances will be resolved.
4. Establishment of the Mopani Geographical Information System (MoGIS): at district level and the establishment of a Geographical Information Centre where Spatial Data infrastructures will be deployed as a hub within the district is imperative. This will regularly and continuously collate, process and disseminate spatial information of all kinds (physical, economic, social, ecological, political, and infrastructural services etc.) for purposes of a proper environmental monitoring system, budgeting, ease of governance and policy making. MoGIS will complement and facilitate the proposed Disaster Hotspot Reporting and Early Warning System and the climate change mainstreaming policy proposal.
5. A private sector-driven and government facilitated livelihood diversification strategy in non-climate-fed economic activities (green jobs) among the youths and women in form of entrepreneurship and skills acquisition programmes at local Municipality levels should be promoted. As a livelihood diversification strategy,

skills acquisition programme has the potential to create entrepreneurs among the teeming youth population across gender, enhance climate change mitigation as well-as facilitate adaptation among households. The advantages of the current green infrastructure are becoming more embraced globally so there is the need to take advantage of the increasing trend in the demand for green related skills. The demand for the initial design skills and installation of green infrastructure practices as well-as for long term operation and maintenance will soon be on the rise in South Africa, going by the several green policies of government. It will equally broaden the multiplier potential for several green projects and enhance green infrastructure training, retraining and certification programmes. This idea can better be facilitated through huge investment in renewable energy, to be anchored by the Reserve Bank of South Africa by offering single-digit loan youth and women, and financial markets interfaces, and appropriate policy formulation and development.

6. Policies for mainstreaming climate change into spatial planning are considered essential at this time in history of the District. This policy at macro level on one hand must promote urban climate mapping to provide information about the urban meteorological conditions and city requirements that planners, architects, urban designers and other allied professionals need to attend to. This map will provide urban climate analysis with urban climate planning recommendations. It will also provide the structure for location-specific climates in relation to land use characteristics (to identify and cluster areas with the same urban climatological characteristics). This will provide appropriate policy formulation and implementation guides for coping with local climate influence on urban comforts and the impacts of the configuration of the built environment on the local climate. While at micro level, on the other hand, for planning approval purposes, climate-friendly guidelines will be developed by the respective local municipalities. Mainstreaming will be facilitated by the proposed Disaster Hotspot Reporting and Early Warning System to promote climate-prone urban analysis that will provide the needed data for sustainable spatial planning.
7. Urban Greening as a matter of necessity should be promoted and enforced: this is proposed to form greening of the urban cores. Urban agriculture as a win-win strategy, through home-grown fruit and vegetable farming is strongly proposed among household with government and NGOs providing free high yielding seedlings. This should be promoted to serve multiple purposes and advantages, i.e. provides shield, reduces urban heat island, ensure food supply as well-as

providing economic returns, while mitigation through carbon sinking will be equally achieved.

8. The promotion of households' diversified livelihoods particularly into non-climate-fed activities is capable of boosting incomes, risks reduction, curbing poverty, facilitating more productive investments, and significantly enhancing households' adaptive capacity.

8.5.2 Specific Recommendations

1. Establishment of more centralised parks and playing grounds across towns which lack such amenities and other communities for relaxation purposes. The abandoned children's' park at Nkowankowa Section 'A' should be resuscitated and regularly maintained and the leaking sewer in its proximity should be mended.
2. The review of existing land-use planning and control laws to mitigate the occupation of high-hazard areas, improve disaster resistance of structures by enforcing building codes, and adequately ensure the enforcement of application of proper methods in post disaster rebuilding of infrastructures.
3. Instituting and enforcing a disaster insurance retail plan to reduce disasters' financial impacts and enhance preparedness.
4. Acquiring and stockpiling necessary items, vehicles and equipment, emergency supplies with regular maintenance, at the local municipalities' level. This will bring the response time to bear with coordinated communications systems (as proposed).
5. Establishment of community volunteer groups, from which to recruit personnel for emergency services and with regular training (for both response personnel and concerned citizens) on germane topical issues that border on early warning, mitigation, responses as well-as rescue strategies.
6. The Mopani Disaster Management Centre should engage in regular disaster management training exercise for communities (stakeholders)and carry out routine response capabilities tests and equally activate emergency operations centres/units to draw-up emergency operations plans at local municipality level.
7. Research collaboration with relevant tertiary institutions, research centres and disaster related exploration and donor entities for a continuous investigation into the dynamics of climate and response situations across the district and province to be financially facilitated by donors' grants to research students and the likes to complement statutory annual budgets.

8. Inter-municipal collaboration should be instituted to focus on climate change knowledge sharing, skills acquisition and other benefiting twinning programmes that will guarantee a facilitated and sustainable adaptation policy, programme, and projects.
9. Institutionalising the proposed Disaster Hotspot Reporting and Early Warning System to provide for instant (eyewitness) accounts of events (hazards/disasters). This will facilitate transparent data collection, for planning urban adaptation strategies and policies in the district. The concept is detailed in 8.5.3.

8.5.3 Proposed Climate Change Adaptation Model

As a system, the proposed conceptual framework is based on observations from the identified analysis in this work. Major shortcomings to be addressed at the Municipality level include but not limited to the following

a. Climate change hazards occurred at varying frequencies and intensities at different locations in the selected towns, with varying degrees of impacts. Yet, little evidence was available to indicate the efforts of municipal governments in the district to incorporate regular climate change disaster hotspot identification and monitor their response operations.
b. The five municipalities still relied on the national framework for attending to climate related disaster, which was largely reactionary. No evidence of deliberate adaptation policy, strategy and interventions, particularly that are proactive; and
c. Late responses during climate change emergencies were a major challenge identified by both professionals and the communities during the field survey that hindering effective and timely urban adaptation/responses to climate change related hazards in the selected towns.

However, the proposed model is in line with the provision of the National Disaster Management Framework (NDMF) that allows for an integrated and uniform approach to disaster management at all government levels. NDMF equally empowers governments at all levels to put in place a framework that reflects coherence, transparency and inclusivity within the disaster management policy. Emphasis is placed on private and public sector participation, partnerships and capacity building, research, and information gathering. Figure 8.1 presents the proposed Hotspot reporting system and its components

8.5.4 The Focus of the Proposed Conceptual Framework

The proposed conceptual framework model is flexible participatory and applicable at all levels of policy making and it is focused on the:

i. Provision of up-to-date information on climate change and variability and extreme events (in collaboration with related agencies);
ii. Timely, precise, transparent, flexible and verifiable climate extremes and hazard related information from the community;
iii. Promotes synergy between government policies and the citizens, through enhanced public participation;
iv. Regular consultations with all stakeholders on adaptation problem identification, programme and project development, prioritization and selection;
v. Inclusive adaptation project evaluation, budgeting and financing processes;
vi. Private sectors' engagement at climate change adaptation planning and intervention levels;
vii. Municipal linkages that are facilitated by a central monitoring and coordinating system.

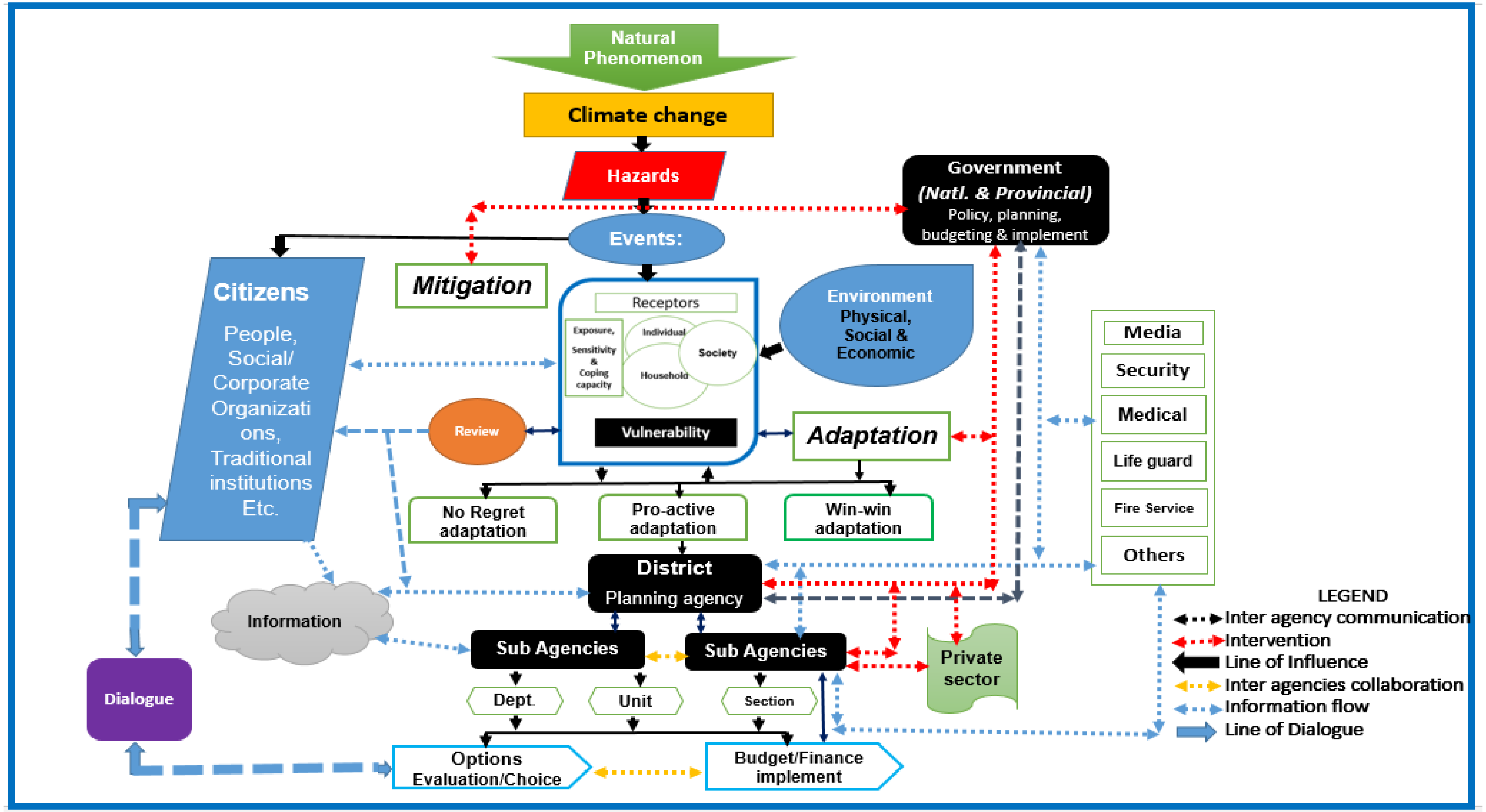

Figure 8.1: Proposed systemic model of climate change adaptation and hotspot reporting and monitoring

(Source: Authors, 2019) The framework is an improvement on the current disaster management framework, because it is a dialogue model that incorporates the household socioeconomic peculiarities and human behavioural components via citizens' participation. It gathers on-the-spot and traceable climate change disaster related information for analysis by experts, with stakeholders' inputs at both district and local municipalities levels.

8.5.5. Conceptual model applicability at the municipality level

This section highlights the applicability of the proposed model at the municipality level in Mopani district being the centre of coordination. Figure 8.1 depicts the working of the proposed adaptation model.

The proposed model will exist and operate within the context of the prevailing administrative structure of the district and local municipalities as regards adaptation processes and municipal management systems with some initiatives for operational improvement. The model notes that, tackling climate change issues is a cyclical process. Between the two broad approaches (*Mitigation and Adaptation),* this research has biased concerns for the latter (adaptation).

The basis for the proposed model, apart from the earlier identified shortcomings is further rooted in the call from the National Disaster Management Framework that empowers the municipalities (district and local) to institutionalize an integrated and uniform framework that reflects a coherent, transparent and inclusive disaster management framework. The White Paper on Local Government equally expects that municipalities should be “working with citizens and groups within communities to find sustainable ways to meet their social, economic and material needs and improve the quality of their lives” (MDMIDP 208/19). The proposed municipalities’ model of climate change adaptation (conceptual framework) is an improved South Africa Framework for climate change adaptation. It is a concept that incorporates a system that promotes climate change hazard (early warning) reporting and monitoring for both preventive and curative strategies.

It is on this note that the proposed model is designed to be coupled with the current operational system of the Municipalities (District and Local) Table 8.1 shows the ctivities required to implement the climate change adaptation model.

8.5.5.1 System User and Architecture

Require Internet Speed (Downloading and Uploading) is 64 Kilobyte/Sec (0.64 Megabyte/Sec), With the appliication’s estimated life span of 50 years and a minimum user or report cases of 10,000/month (0.0038580247/Sec).

Total report for 50 years is

10,000x12x 50 = 6,000,000

Storage size

With 500 byte/report x 6,000,000 = 3,000,000,000 Megabyte

(3,000 Terabyte)

Table 8.1 Required activities for the applicability of the proposed climate change adaptation model

Phase	Activities and purpose	Action by	Time bound
Preparatory	Technology deployment and staff training	District planning and disaster management unit	At the onset
Performance	Create linkages with relevant Agencies, Departments, Organisations and citizen registration.	District planning and disaster management unit	Continuous (all year round)
Data capturing	Field survey, Citizens audiovisual reporting via mobile phones, Data to be sourced from other organisations, data collation, sorting and dissemination	District planning and disaster management unit, local municipalities, emergency response, citizens, NGOs,	Continuous
Analysis and Strategy options	Data sorting by sectors, data analysis, adaptation options consideration and prioritization	Municipalities, experts, citizens, NGOs, Private sectors and other relevant stakeholders	Continuous
Project/policy selection, evaluation and recommendati on	Adaptation Project/policy selection, evaluation (costing) and recommendation for approval.	Municipalities, experts, citizens, NGOs, Private sectors and other relevant stakeholders	Continuous but Sequels to analysis of data
Approval/ budgeting	Municipal legislative and administrative approval and budgeting	Legislatures and the executives	Sequels to eva-luation (Continuous)
Implementatio n, monitoring and review	Adaptation project execution, performance monitoring and review	Community-based (indigenous expert)	Periodical

(Source: Author, 2020)

8.5.6 Basic steps of the proposed conceptual framework

The section highlights the basic steps that are involved in the operations of the proposed framework.

a) Preparation and Linkages:

This activity is expected to be facilitated by enabling legislations at both district and local municipalities' levels. These legislations should be linked with the relevant national and provisional legislations.The stage involves the deployment of required technologies, recruitment of required staff and training.The initial installations and the implementation of the whole process may require the engagement of both System developer and GIS expert. These experts will do the installations, networking and the linkages of all the parts of the whole to a complete working system.

b) Capturing and reporting of the incidence of Climate Extreme events or Hazards

This stage marks the starting point for inclusiveness in the proposed system, where climate extreme events (hazards) information is collected through a survey or/and citizens monitoring, capturing, and reporting system (Figure 8.2). The prevailing climate change related extreme events in their localities are captured and reported to the relevant authority. There are available in-built media options of capturing events, they can opt for any combination as well as choose all the available media, which include: writing, audio, video, and imagery. These options are to make the reporting detailed, authentic, and flexible.

The integrity of the reports that may be generated by and from the citizens are ensured through an inbuilt '*location coordinate capturing system*' that provides location details (geo-referenced coordinate) alongside the ID (name of the reporting citizen, the mobile number, and picture) while reporting. However, depending on the nature of the incident, this could either be a calm (not immediately life threatening) or emergency. The report is communicated to the district municipal office (control central) proposed to be at Mopani District Disaster Management Centre, with an advance copy sent to the local municipality, where the event is happening. The district, through the web, collates, archives, and communicates the appropriate agency of government for prompt and appropriate action. In case it is an emergency, the emergency organ of the system such as the media, police, ambulance, lifeguard, fire service etc are instantly notified. If it is otherwise a calm situation, the district communicates with the concerned local municipality, where relevant departments, sections, units will act upon it accordingly.

c) Report sorting and analysis and identification of adaptation options and selection

Upon receipt of information, preliminary sorting of the data takes place, which will then be sent to sectors to inform and invite relevant stakeholders. This phase is characterized by input gathering from the residents for goal setting. Adequate public engagement will be through the launch of events, focus groups and other interest groups. As many citizens from diverse interest groups in the community will participate in the event and as many as required relevant priority goals will be identified from feedback, these goals will facilitate envisioning the future.

d) Adaptation options evaluation

This is a collaborative responsibility of the relevant Departments, Units and sections of the municipality, representatives of the citizens, NGOs, traditional institutions, experts, researchers, youths and women organisations and other social groups etc. Understanding the options will be ensured by taking into account the chain of available options from the focused workshops to advance strategies that can achieve the outlined goals in section (b) above.

d) Situation analysis

This will be undertaken through brainstorming, discussion and prioritization sessions, and participants will envision and identify alternative set of goals for the future. These scenarios will be anchored on two major sources of uncertainties both external and internal. Subsequently, 'Strategy' discourse will follow, where plans to guide the process of goals achievement will be developed based on the thematic priorities. The overall process will take the form of: Identifying and summarizing relevant local goals, classifying the obstacles that can hinder the achievement of the goals; and Develop strategies capable of preventing the identified barriers.

At this point, local leaders, municipal staff with relevant expertise will be part of this focused discourse. At a final stage of this phase, 'Technical review' dialogue will be put in place for outcome assessment of all previous discussions, put them in perspectives, prioritize actions, identify projects and programmes, predict implementation, as well-as benchmark performance measuring indicators.

e) Project identification and planning

Appropriate adaptation options are highlighted, projects are derived and prioritized according to the focus, desirability, urgency, and coverage. At these stage strategies to mobilize people, monetary, equipment and infrastructure will be identified and selected. The management composition will be agreed upon cutting across all relevant stakeholders, plans are drafted (entailing seeing through to the future, drafting, and review to finalize plan). This will involve experts, researchers, and specialized stakeholders' participation to do a thorough review of the plan and supply feedback that forms the basis for final adaptation plans.

f) Choice of plan:

Focusing on the goals and strategies generated in a-d, plans are evaluated regarding the social, economic, cultural, and environmental costs as well-as the benefits. Therefore, the project option with the minimum cost (not only finance) and highest benefits will be selected for implementation. At this point, policy templates are prepared and agreed on, focusing on long-term adaptation policies and interventions by the planning department on different themes. The templates will in detail, spell out how and why each stakeholder must be included in the process. These evaluations will facilitate budgeting, approval, implementation and review processes. The input from experts will be required in the process of evaluation and review.

g) Policy/Budgeting

The reports of the evaluated option(s), the process of making workable policy will be instituted within the municipal arrangement, subsequent upon which budgetary allocation is made for the proper implementation of the adaptation solutions.

h) Implementation/appraisal

Execution upon approval will be through municipal collaboration with the community and stakeholders (private sectors). Adaptation solutions will be implemented using the concept of local content; except when necessary, the executor of the project must be from the locality where the project will be sited. The project will be monitored by a constituted ad-hoc community-based steering committee, whose responsibility would be, amongst others, to ensure that the terms and conditions of the project are adhered to and upheld by the contractor. While ensuring quality delivery of the project, unless where unavailable, the required workers for the execution of such a project must equally be locally sourced (community-based). This will serve as a form of job creation for the enhancement of households' adaptive capacity.

i) Training and retraining

Capacity development through continuous training and retraining of those municipal staff who will oversee the system is one of the pivotal elements of the effectiveness, efficiency as well-as sustainability of the entire system. The deployment of the system must be done with the involvement of the designated officers that will take charge of the system operations.

8.6 Incorporation and the workings of Climate Change Hazard Hotspot Reporting System (Mobile Application and Website based)

This section describes the integrated reporting component of the proposed conceptual framework with the view to highlight its operation to compliment the other processes involved in the operations of the model. The Mopani Hotspot reporting system Figure 8.2, is proposed to be a '3-tier architecture', which comprises of the client, business intelligence, and the back end. It will be a web and native mobile application which will assist Mopani residents to effectively report an on-going climate change hazard in the various towns and localities of their local municipalities.The application was designed by the author under a close supervision and guide by application development expert.

Fig. 8.2 illustrates the Mopani Disaster *"Hotspot reporting and monitoring system" to solve* the problems of lack of facilitated information flow, lack of reliable and verifiable data, while promoting accountability, promptness, and participatory adaptation governance in the district.

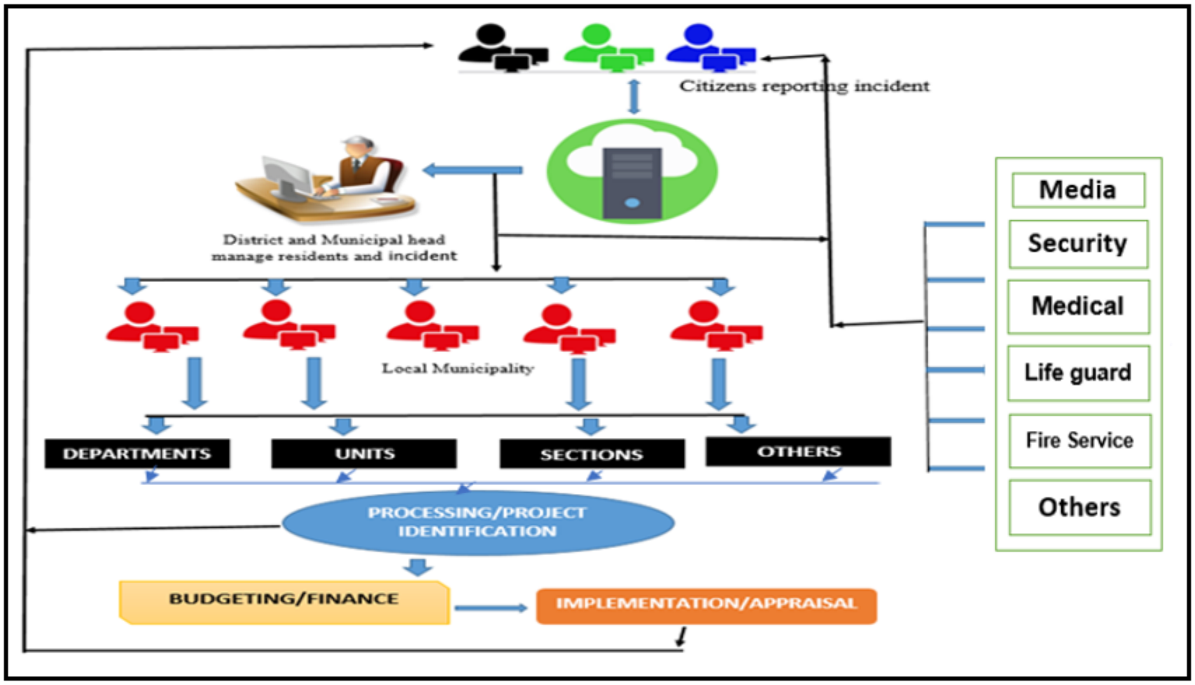

Figure 8.2 Mopani Disaster Hotspot Reporting and Monitoring System*, a* Mobile Application and web-based system (Source: author, 2019)

8.6.1 System Operations

The system, with the client serving as the 'front-end' which provides an interface that a resident can interact with, using a native android application to report an incident in various locations on one hand (see 3.11). The web application on the other hand is configured to be used by the district municipality and connected to relevant agencies and organs of government (police, fire fighters, ambulances, press etc.). This system is designed to be under the office of the municipal manager to coordinate the activities of the system. Figures 8.3 to 8.10 depict the details of operations of the hotspot reporting and monitoring system.

The business intelligence provides information based on resident's request. It allows the citizen report in whatever format they choose (written, audio, visual or combinations). It serves as an intermediary between the 'front-end' and the 'back-end'. (See Appendix 15 for coding)

The 'back-end' serves as the database and information reservoir, which holds or stores all information (reports) in its entirety. This component of the system saves the reported incidents including the details as regards the specific (georeferenced) location of the report and the reporter, the picture and other relevant details that make the system flexible and transparent. It equally proves the integrity of the report. The component equally keeps a comprehensive report of all data which are already analyzed for future references and planning.

8.6.2 System design

The System is designed to have several activities or screens built using XML and HTML. These screen and web interfaces tend to create interaction between the residents, agencies and districts and local municipalities. The screen has been simplified to have various objects representing certain identity (such as reporting location) that enable residents to report an incident in their local municipal to the corresponding agency that is best suited to respond to the incident appropriately. (See Appendix 15 for coding).

8.6.3 System Implementation

The system was by a consultant under a close author's supervision using Android Studio Integrated Development Environment (IDE). This platform is enriched with many programming languages such as Kotlin, Python, Node.js, Ruby etc. It helps the developer to create a rapid application development with a friendly and good-looking interface. Figures 8.3 to 8.12 depict the results obtained by the general procedure of the Hotspot Reporter System as proposed in the previous chapter to validate the applicability. These are results that were obtained during validation (test running) of the application.

Registration is free though, but any resident who is not registered on the application will not be allowed to report an incident or view all reported incidents to ensure the integrity of the information generated through the reporting system. The Municipal Manager will thoroughly check to validate the resident's report, then forward it to the appropriate agency for swift action. This could be the local municipality concerned, Police Services, Press, or Fire service) or a combination of them as may be required.

8.6.4 Log in Screen

This activity enables a user to provide valid phone numbers and passwords for seamless authentication so residents can have access to unlimited activities on the platform.

8.6.5 Registration Screen

This activity allows a resident to create an account by providing necessary biodata as shown on the screen. This data will be used in subsequent actions on the system

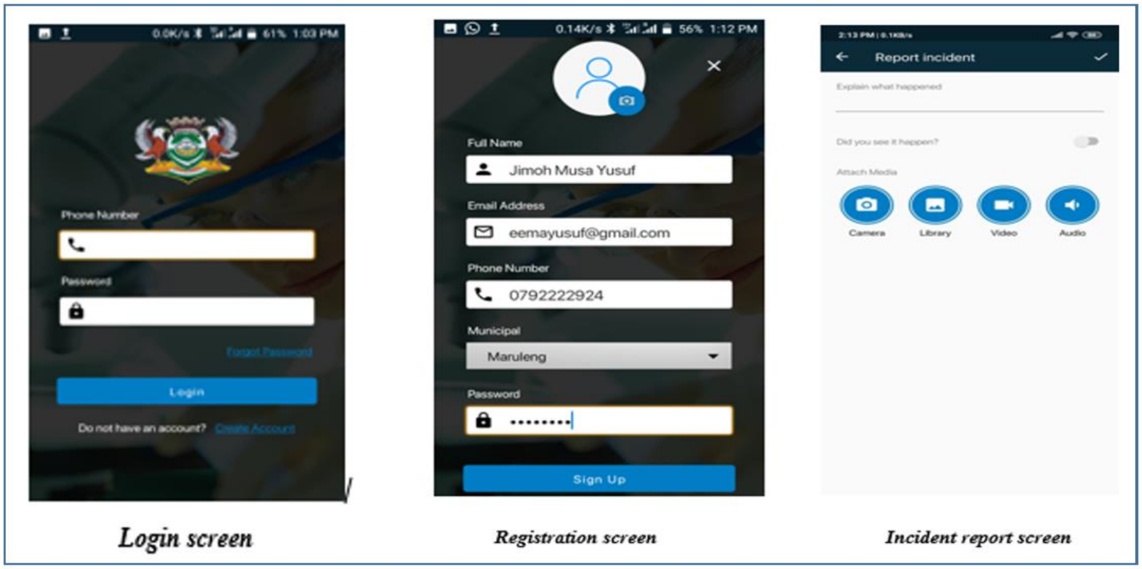

Figure 8.3: Residents' registration screen

8.6.6 Incident report Screen

a) This activity allows a resident to report a hotspot incident going on in their environment at a given period. These are the interfaces that will be seen by other residents within the municipality. This activity will automatically be displayed when a resident has successfully logged on; it allows a resident to see his report and all other incidents which have been reported by other residents in their respective municipalities.

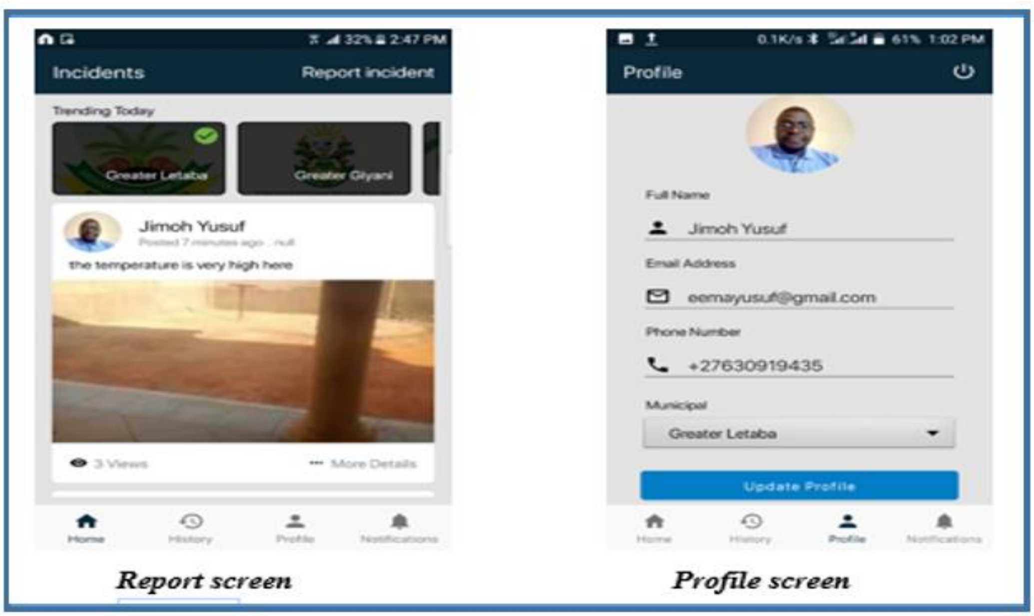

Figure 8.4: Residents' report screen

8.6.7 Profile Screen

This interface shows the information on activities of a particular resident, and which is subject to update or edit by that resident at a given period of time.

8.6.8 Forget Password Screen

Perhaps a resident forgot his password; this activity allows a user to reset the forgotten password by supplying his email address for processing.

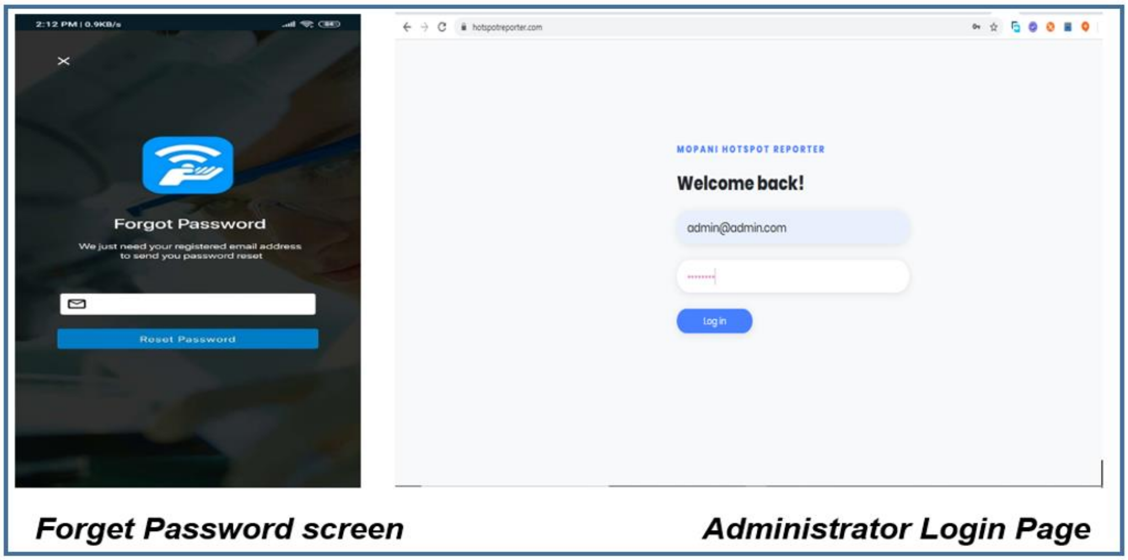

Figure 8.5 Forget Password screen and Administrator Login Page

8.6.9 Administrator's Login Page[https://hotspotreporter.com]

This page authenticates an administrator (District Mayor, Municipal Manager or Agency head), it prompts them to provide a valid email and password in order to explore system functionalities.

a) Dashboard

This page is automatically displayed when an administrator successfully logged on to the system. It presents to the administrator the overall function of the system, a statistical report and an analysis of the incident across the local municipalities, management of residents and agencies

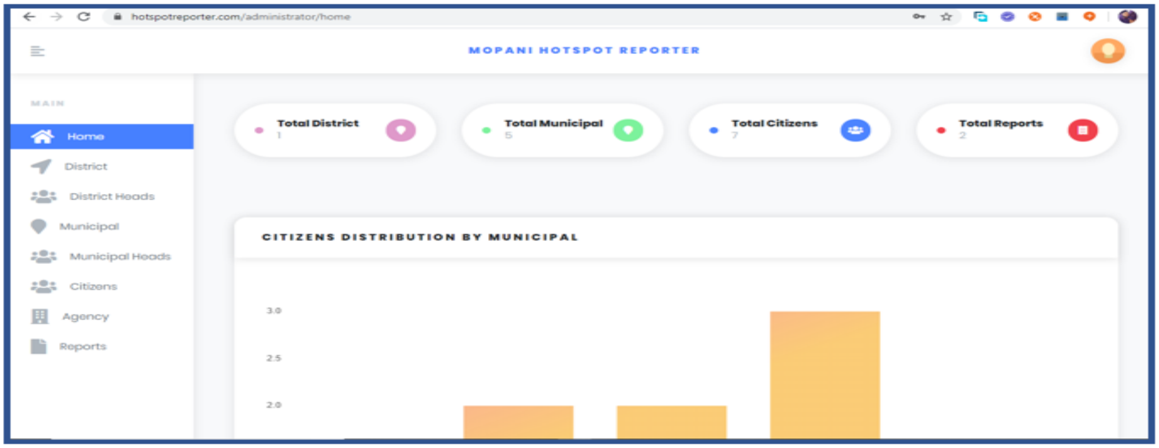

Figure 8.6: Web Dashboard

b) District Head Page

This web page shows the overall information management of a district; here an administrator can create, update, view and process data for usage.

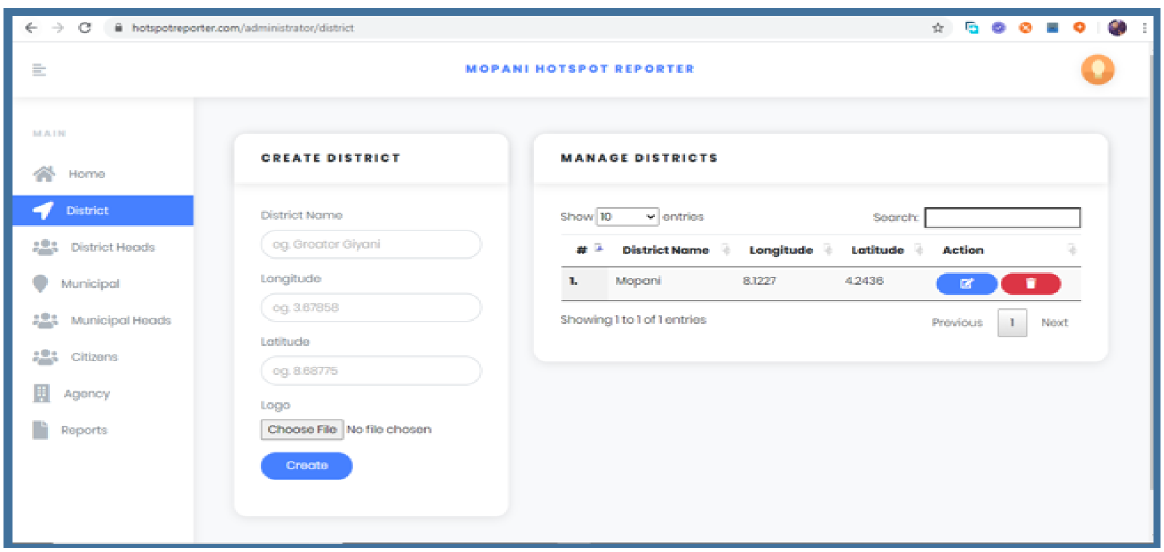

Figure 8.7 Web District Page

This web page allows an administrator to assign or appoint a district head, the district head will serve as an overseer of the system, thus monitoring all inflow of resident’s reports and prompt relevant or immediate action.

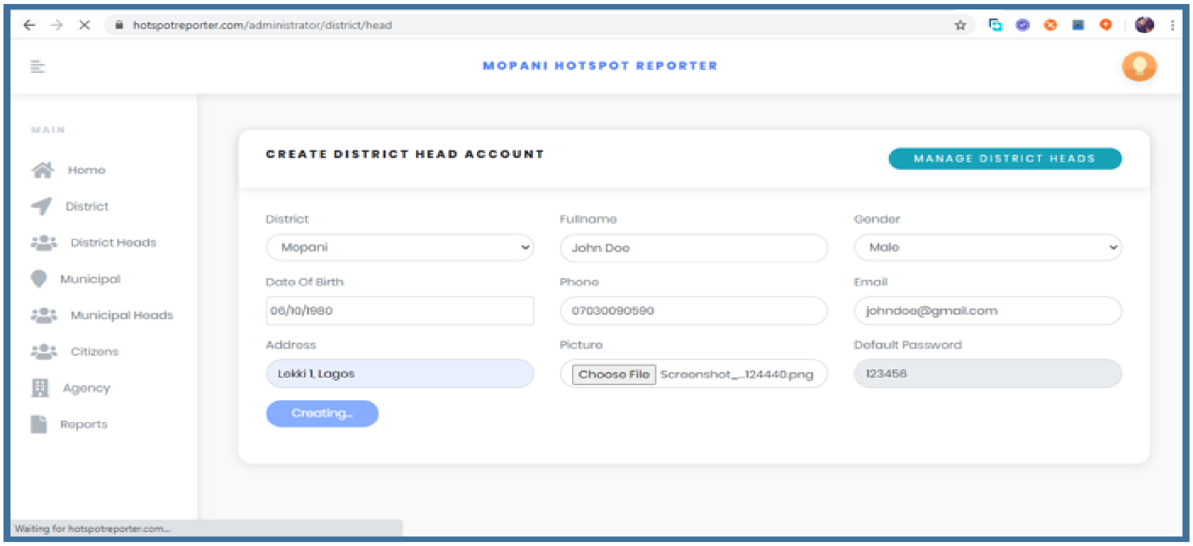

Figure 8.8: Web district head Page

8.6.10 District head Information page

This web page is shown when an administrator completes the appointment process of a district head. The table on the web page shows the information of the appointed district head.

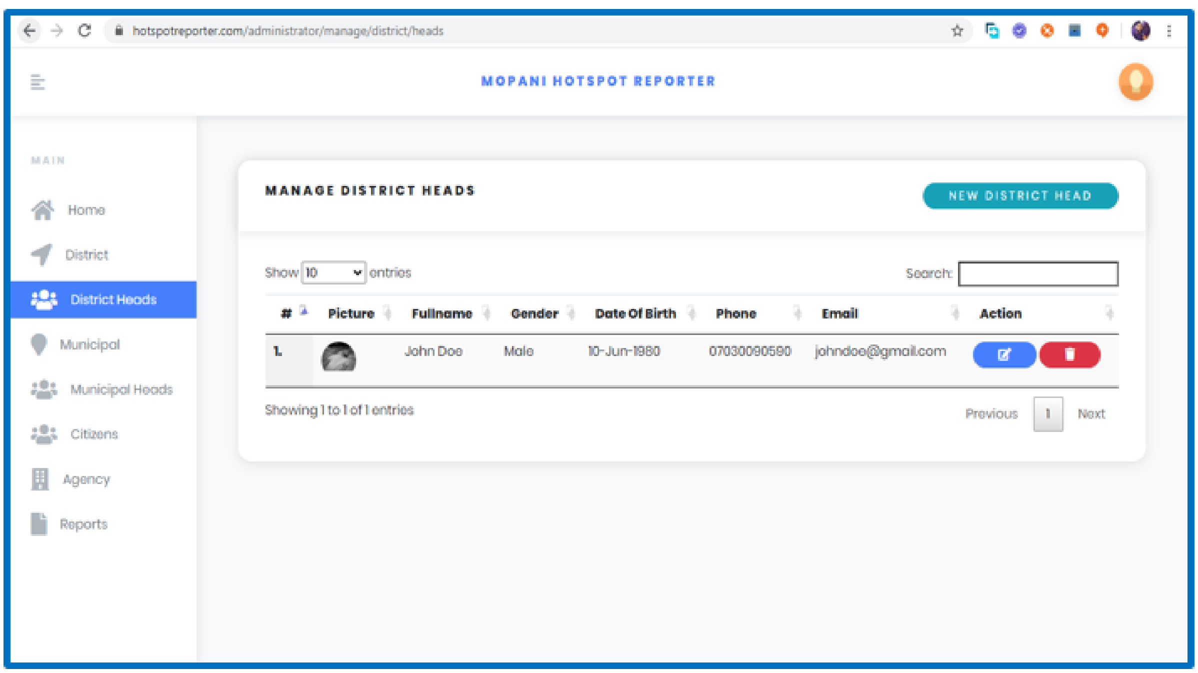

Figure 8.9: District head Information page

8.6.11 Residents/Citizen Information page

This web page allows an administrator to manage all resident's information. You can choose to edit, suspend, delete and search for a particular resident.

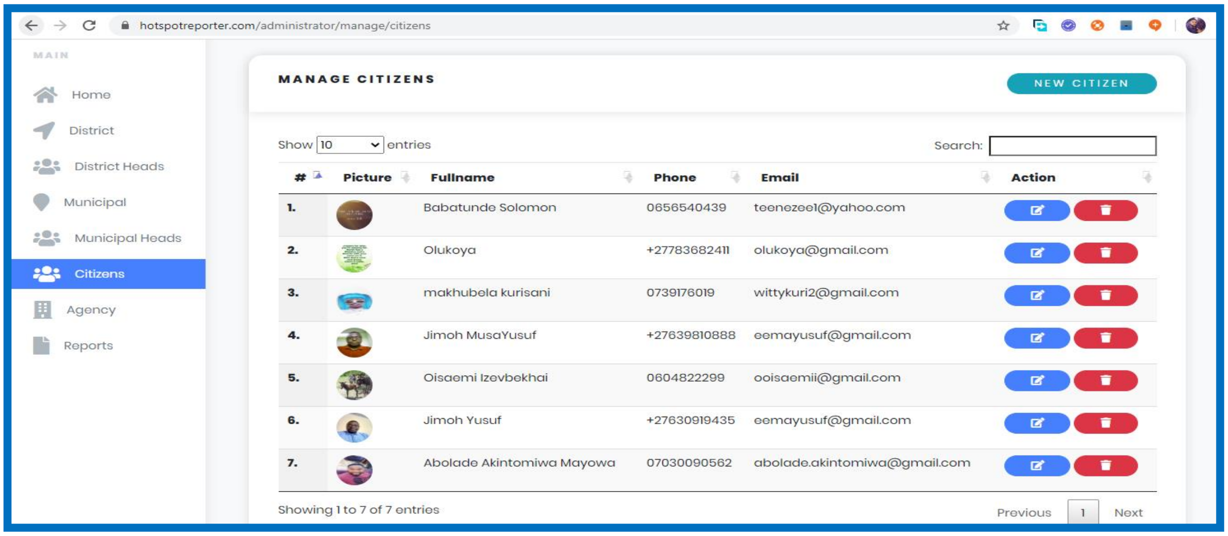

Figure 8.10: Residents or Citizen Information page

8.6.12 Residents Report page

This page shows all the incidents which have been reported by residents throughout a given period. Here, the report can be managed, processed and screened before pushing to an agency. The administrator can click on the view button to know more about the incident.

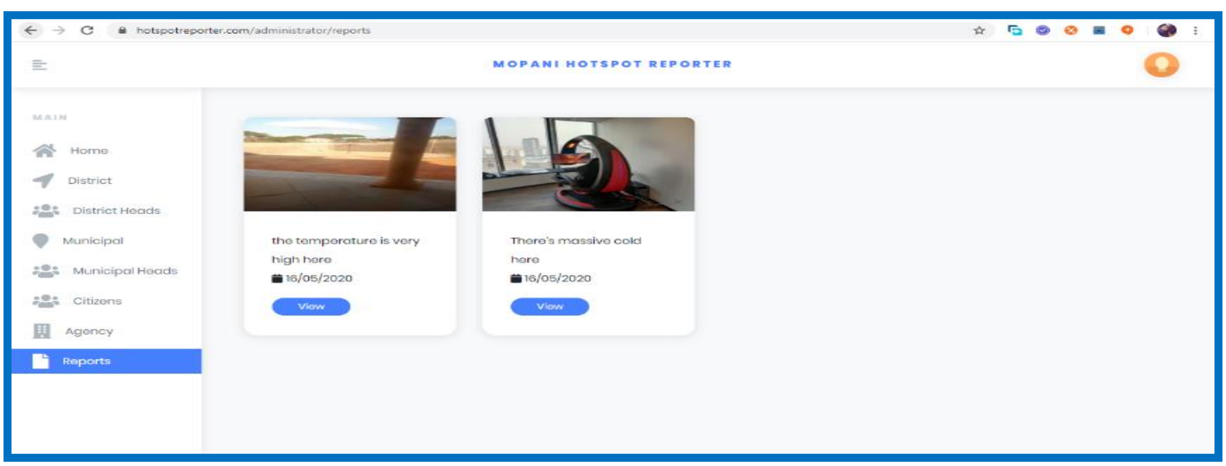

Figure 8.11: Web report page

8.6.13 Report Details page

This web page presents to an administrator a full detailed report of the incident(s). Here, the administrator can see a clearer view of incident images, location map, reporter, and date when the report was made. At the upper right corner, the administrator can choose to logout when he is done with the operation.

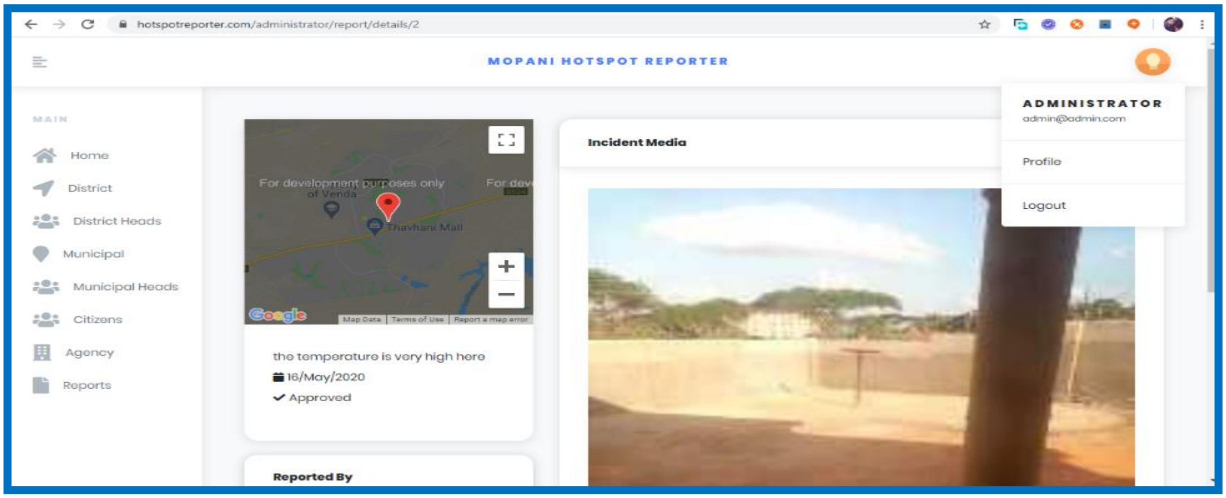

Figure 8.12: Report details page

8.6.14 The usage of data (reports) generated

The reports that are received from the platform will be forwarded to the appropriate channel for further action, which is either the local municipality or relevant emergency (response) management agencies. This will then be fed into the main proposed climate change adaptation conceptual framework model for sector consideration, agent-based analysis, adaptation option consideration and prioritization and evaluation with adequate consultation (dialogues) with the citizens at grass root level. The choice of the most appropriate adaptation policy or project option(s) will be recommended, budgeted for, approved and implemented. However, because of the dynamism involved in the whole system, the implemented project and policy will be subjected to routine review and performance check to ascertain whether or not the set goal is achieved.

8.6.15 Validation

The validation of the system was done by sharing the application to citizens to register on the platform in their respective municipalities. This enabled them to make report on various environmental related activities and submitted for further processing at the hub of the application. This was being tested in the concerned municipalities, facilitated by the municipal advisory committee (as control) at the Mopani Disaster Management Centre. The response from the populace was 70%.

8.7 Areas for Further Study

This study examined the vulnerability and adaptation of households in selected small and medium towns to climate change in Mopani district, Limpopo Province of South Africa. It measured the magnitude of the vulnerability, through its components (exposure, sensitivity and adaptive tendencies) in the selected towns, their neighbourhoods and densities as well-as the entire district, through the local municipalities. It equally established the trend in climatic factors (temperature from 1958 – 2017 and rainfall from 1958 – 2016. The study further appraised the variability of households' exposure, sensitivity, adaptive capacity as well as the households' aggregate vulnerability across local municipalities, towns, density, neighbourhoods and across communities. Furthermore, the relationship between the socioeconomic attributes of households and vulnerability were established. The variability in household socioeconomic attributes and factors influencing vulnerability was equally unpacked, while adaptation strategies among the households and the government at several levels were examined.

Further research therefore should focus on other non-coastal inner cities and small and medium sized towns alike in other districts and other climatic belt with socioeconomic peculiarities in South Africa as well-as in the Southern African sub-regions, to ascertain peculiarity-based variations. The study equally underscores town-specific pragmatic research attention on the factors that govern the behavioural component of the choices of household's adaptation to climate change among options. It further emphasises the need for proper understanding through investigation of the influence of the domestic group's reorganisation, which is currently resulting in the increasing number of female-headed households with regards to its implications on households' adaptive capacities and vulnerability to climate change strategies, particularly in Mopani District, South Africa and Africa in general. And finally, urban adaptation models that take care of African culture, technology, and socioeconomic limitations should be developed to cater for African idiosyncrasies.

8.8 Conclusion

This study set out to examine urban household vulnerability and adaptation to climate change in the Mopani district of Limpopo Province of South Africa. It discovered that the climate is changing and has come to stay for decades to come in a business-as-usual scenario. Living and livelihood will continue to be threatened by the changing climate in the Mopani District, with upward (increasing) trends found in both minimum and maximum temperatures, and reducing trend in rainfall reflecting a negative relationship, indicating reduction in trends throughout the cycles examined in the district. The occurrence of floods across the selected towns varied in frequency, intensities as well as the associated impacts. Reasons for these are not wholly attributable to climate, though it may be one of the underlying factors. Others include low-lying topography, system failure, and human habits.

Land use and land cover have transformed during the three decades examined (1987-2017), with the built-up land use constantly in unidirectional relationship with time, implying an increase over time, while vegetation suffered depletion consistently during the same period. The findings confirmed a direct connection to climate factors, but they appear less important than factors such as urbanisation, wood energy sourcing, and infrastructure development.

While households' exposure across the selected towns are very high, the households' sensitivity levels as well-as their coping capacity with climate related hazards varied in the selected towns across the district. Overall, household vulnerability was found to be generally high across Mopani district. However, Hoedspruit of all the selected towns appeared to host the least vulnerable households, while Tzaneen was the highest. However, the variation regarding households' vulnerability across the three residential densities decreased towards a low-density residential zone. The study further revealed that Modjadjiskloof was the highest vulnerable, while Phalaborwa was the lowest vulnerable out of the other communities.

A strong but negative relationship respectively exists between both primary income and the Livelihood Diversification Index, and with the Vulnerability Index across the district of Mopani, but Vulnerability increased with female-headed households with positive significant coefficients across the district.

Consequently, it can be concluded that climate has changed under the two climatic cycles under study. This has significantly increased heat which may have intensified meteorological related ailments and partly responsible for the flash floods recorded in the district. These have resultantly rendered urban households significantly vulnerable across the district. Multiple factors have been identified to have complimented to be responsibility for the magnitude of the vulnerability, ranging from the physical, economic, and statutory, at local, regional, national, and global scales.

Private adaptation to climate change was very popular among the residents of the selected towns across the district, despite the lack of synergy between the community and the municipality in intervention provision. There is equally the failure of inter-municipal collaboration for sustainable adaptation programmes.

The varying nature in the households' adaptation strategies which are commonly based on individual peculiarities (needs and capacity) is a strong signal for policymakers to painstakingly understand before initiating the priorities, projects and policies for adaptation.

These peculiarities include the local and regional climate change scenarios, and the local population's adaptive capability and behaviour.

Because the urban heat island remains a major climate related source of discomfort occasioned by impervious surfaces in urban communities in the region, adaptation is hence imperative to enhance and sustain the greening of the core areas of the towns. At higher levels it will require huge investment in greening policies and interventions. Threats occasioned by climate change may compromise the achievement of the Sustainable Development Goals by the 2030; hence urban household vulnerability should thus be aggressively curtailed through hazards reduction and enhanced response strategies. These should be complimented with comprehensive sustainable empowerment programmes that are protected and facilitated with guidelines and legislations. If left unabated, as towns become more urbanised, this could risk more severe disasters capable of undermining the sustainable development with possibilities of lives and livelihood being wiped out seriously threatened.

There is the need to strengthen the weak inter-municipal collaboration and synergy among agencies of government as well-as the private sector. Effective urban adaptation actions between neighbouring urban metropolitan authorities can close the gaps between local municipalities in terms of knowledge sharing and collaborations.

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Appendix

Appendix.1: HOUSEHOLD SURVEYQuestionnaires

University of Venda

School of Environmental Sciences
Department of Urban and Regional Planning

URBAN HOUSEHOLDS' VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN MOPANI DISTRICT

Dear Respondent, HOUSEHOLD SURVEY

GENERAL INFORMATION **A**

Introduction

The researcher is a PhD candidate at the University of Venda, in Urban and Regional Planning Department, School of Environmental Sciences. He is carrying out research, entitled Urban Households' Vulnerability and Adaptation to Climate Change in Mopani District, Limpopo Province, South Africa.

You are kindly requested for participation in this research by expressing your views on the topic. The purpose of this study is to examine the vulnerability and response pattern to the nature and frequency of climate-related impacts among households in Mopani District, during the period of 1958-2017, with the view to suggest practicable and sustainable strategies capable of enhancing households' adaptive capacity and resilience.

Your participation is voluntary, hence you may choose not to answer any of the questions, should you feel that such question(s) is /are not proper. You equally have the right to withdraw from the study, even after you have started completing the questions. The questionnaire will take about 10-15 minutes to complete. It does not require you to provide your name and contact details, thus, your confidentiality will be protected from third parties. Therefore, you are kindly requested to give honest opinion on every issue in the questionnaire, to allow for an assessment that will inform appropriate policies and strategies.

Thank you for your time from your busy schedule. Please do not hesitate to contact me if you have any questions.

Jimoh M. Y.
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RESEARCH QUESTIONNAIRE

Section A Part 1: GENERAL INFORMATION

1 Neighbourhood ________________________________

2 Ward ____

3 Town:_______________ Local Municipality______________

4 Residential Density: (1) High☐ (2) Medium☐ (3) Low ☐

Part 2

(RESIDENT'S SOCIO-ECONOMIC CHARACTERISTICS)

Respondent's **(Household Head)** Bio-data

1. Age of Respondents: 1) 1 – 12, ☐ (2) 13 – 19, ☐ (3) 20 – 35,☐ (4) 36 – 50,☐ (5) 51 -65,☐ (6) 66 and above☐

2. Sex of Respondents (1) Male ☐ (2) Female ☐

3. Marital Status? (1) Married ☐(2) Single ☐ (3) Divorced (4) Widow ☐ (5) Widower ☐ (6) Widower ☐ (7) Others (specify) ☐ ____________________

4. (a) How many male children do you have? (1) 1☐ (2) 2☐ (3) 3 and above☐

5. (b) How many female children? (1) 1☐ (2) 2 ☐ (3) 3 and above☐

6. What is your Ethnicity (1) Tsonga ☐ (2) Sepedi ☐ (3) Tshivenda☐ (4)Afrikaans ☐ (5) Indians☐ (6) Others (specify)___________________

7. What is your highest educational qualification? (1) No formal education☐ (2) Quranic Education☐ (3) Primary☐ (4) JSSCE☐ (5) SSSCE☐ (6) NCE/OND☐ (7) HND/B. Sc. ☐(8) Higher Degrees☐ (9) Others (specify) ___________________________________

8. What is your Primary Occupation? (1) Not Employed ☐ (2) Farming ☐ (3) Mining ☐ (4) Artisan (5) Self Employed ☐ (5) Trading/Business☐ (6) Professionals ☐ (7) Civil Servant ☐ (8) Others (specify) ☐ ____

9. What other source do you have that supplements your income? (1) Farming☐ (2) Artisan☐ (3) Self Employed☐ (4) Trading/Business☐ (5) Professionals☐ (6) Civil Servant☐ (7) Social grants ☐ (8)Others (specify)_______________________________________

10. What is your Total Monthly Income (from primary occupation)? R____________________

11. What is your Total Monthly Income (from the other source or sources)? R_____________

12. Do you have any form of disability? (1) Yes ☐ (2) No ☐

____

Part I: Causes and Effects of Climate Change

S/N	Causes of Climate Change	Awareness		Levels of Significance				
		Yes	No	VS	S	NS	NSA	DK
6	Increased tarred & roof surfaces							
7	Transportation & Communication							
8	Urban encroachment on farmlands							
9	Fuel wood consumption							
10	Industrial emission							
11	Heat trapping gases accumulation							
12	Livestock Farming							

1) How long have you been living in this community? 1) 1-3 years☐ (2) 4-6years ☐(3) 7-10 years☐ (4) more than 10 years☐ (5) since birth☐.

2) Are you aware that the climate is changing? (1) Yes ☐ (2) No ☐

Note: Using the following Likert Scale ratings, answer questions 3 and 4. VS: Very Significant; S: Significant; NS: Not Significant; NSA: Not Significant At All; DK: Don't Know.

3) Are the following human activities synonymous as causes of climate change in your locality? Then rate their level of significance.

KEY: VS= Very Significant; S= Significant; NS= Not Significant; NSA= Not Significant at all; DK= Don't Know

4) Are the following evidences synonymous as effects of climate change incidence in your locality? Then rate their level of significance.

S/N	Causes of Climate Change	Awareness		Levels of Significance				
		Yes	No	VS	S	NS	NSA	DK
1.	Deforestation							
2.	Bush Burning							
3.	Population Increase							
4.	Poor Sanitation							
5.	Overgrazing							
6	Increased tarred & roof surfaces							
7	Transportation & Communication							

4. Are the following evidences synonymous as effects of climate change incidence in your locality? Then rate their level of significance.

13	Use of other fuel							
14	Others (Specify)_______________							

KEY: VS= Very Significant; S= Significant; NS= Not Significant; NSA= Not Significant at all; DK= Don't Know

S/N	Effects of Climate Change	Awareness		Level of Significance				
		Yes	No	VS	S	NS	NSA	DK
1	Disease Prevalence							
2	Unemployment							
3	Forced Migration (displacement)							
4	Loss of land and Soil fertility							
5	Indebtedness							
6	Landlessness							
7	High Price of Food Items							
8	Infrastructural destruction							
9	High Evapo-transpiration							
10	Water Scarcity							
11	Occurrence of wind storms							
12	Occurrence of Heat Episode							
13	Incidence of flood							
14	Loss of Life/Disability							
15	Loss of Property							
16	Crop Failure							
17	Shrinking water bodies size							
18	Others (Specify) _____________							

KEY: VS= Very Significant; S= Significant; NS= Not Significant; NSA= Not Significant at all; DK= Don't Know

SECTION C: (VULNERABILITY AND RESPONSE PATTERNS TO CLIMATE CHANGE)

Part I: Vulnerability (Exposure)

Exposure (Occurrence of Heat Episode/Changing Temperature)

1) Do you notice that the temperature of your locality is changing? (1) Yes ☐ (2) No ☐ (3) Don't know ☐
2) If yes, what is the direction of change?(1) Increasing☐ (2) Decreasing☐ (3) Insignificant ☐
3) If yes, since when have you started noticing the persistent change in temperature (year)? ______________________
4) How many times in a year do you notice the change in temperature? (1) Once☐ (2) 2-5 times☐ (3) 6-10 times☐ (4) 11-15 times☐ (5) more than 15 times☐ (6) Don't know☐.

5) What are the vulnerability factors to changes in temperature in this locality? (1) cutting of trees (2) increased tarred, concreted and roof surfaces☐ (3) high evapo-transpiration ☐

(4) increased population☐ (5) accumulation of heat trapping gases☐ (6) bush burning☐ (7) shrinking of water bodies☐ (8) others specify)_______________________________

5) What steps are taken in your locality to cope with changing temperature?(1) tree planting ☐ (2) planting of flowers and grasses in homes☐ (3) Creation of neighbourhood parks and gardens ☐ (4) creation of new forest reserves☐ (5) minimising bush burning ☐ (6) preservation of water bodies ☐ (7) eco-friendly farm practices☐ (8) use of fans and air-conditioners☐ (9) others (specify) ____

Change in Level (Quantity) of Water Available

6) Do you notice any change in the level of water available (supply) in your locality?

(1) Yes☐ (2) No☐ (3) Don't know☐.

7) What is the direction of change in the level? (1) Increasing☐ (2) Reducing ☐ (3) Insignificant☐ (4) Don't know☐.

8) When did you start noticing the change in water supply level here? (1) 1-3 years☐ (2) 4-6years ☐ (3) 7-10 years☐ (4) more than 10 years☐ (5) Don't know☐.

9) How many times a year do you notice that there is change in water supply level?(1) Once☐ (2) 2-5 times☐ (3) 6-10 times☐ (4) 11-15 times☐ (5) > 15 times☐ (6) Don't know ☐.

10) What are the vulnerability factors to changes in quantity of water supply in this locality? (1) reduced rainfall☐ (2) reduced water percolation/increased surface run-off☐ (3) high evapo-transpiration☐ (4) increased population☐ (5) lack of storage facilities☐ (6) lack of water reservoir☐ (7) shrinking of water bodies☐ (8) contamination of water point sources☐ (9) Others (specify) ____

11) What steps are taken in your locality to cope with change in the level of water supply? (1) rain harvesting☐ (2) use of storage tanks in homes☐ (3) water re-use☐ (4) building embankments on streams☐ (5) water treatment☐ (6) require water vendor services☐ (7) Others (specify) ____

Part II: Vulnerability *(Sensitivity)*

1. Have you lost a family member due to climate change disaster? 1) Yes ☐ (2) No☐

2. If yes, how many death of members have you recorded due to climate related disasters? (1) 1 ☐ (2) 2☐ (3) 3 & above☐

3. What are the years of occurrence of the incidences? (1) Last year☐ (2) the last 2-4 years☐ (3) 5-7 years☐ (4) 8-10 years☐ (5) above 10 years☐ (6) Don't know☐

4. What form of properties have you ever lost to or damaged by flood/landslides (1) Land ☐ (2) farmland☐ (3) House(s) ☐ (4) car ☐ (5) others (specify) ______________________

5. Have you lost your household source of income to flood/ landslides/ drought before? (1) Yes☐ (2) No☐

6. If Yes, what was the total worth loss in Rands? R________________________________

7. How many times has any of your family members been treated for any of the following 5 climate change related diseases in 5 years (1) None☐ (2) 1-5 times☐ (3) 6-10 times ☐ (4) 11-15 times ☐ (5) more than 15 times☐

Part III: ***Vulnerability*** *(Adaptive capacity)*

1) Which of the following screened items do you or your community have? (Tick as appropriate).

LIST OF SCREENED ITEMS

Personal Possessed Assets	**Responses**			**Community Possessed Assets**	**Responses**		
	Have	**Don't Have**	**Don't want**		**Have**	**Don't Have**	**Don't want**
House				Electricity			
Parcel of Land							
Farmland				Library			
Gas Cooker							
Television Set				Daily Open Market			
Car				Shopping Mall/Centres			
Blender				Postal Agency			
Kerosene Stove				Town Hall			
Coal Pot/Fire wood				Event Centre			
Generating Set				Neighbourhood Park			
Fan				Games Reserve/ Tourist Centre			
Air Conditioner				Well			
Radio Set				Borehole			
Decoder				Pipe borne water			
Refrigerator				Water Reservoir/Dam			
Deep Freezer				Drainage System/Culverts			
Inverter				Public Toilet			
Water Heater				Incinerator			
Computer				Waste Dump Site			
Radio				Waste Contractors			
Decoder				Waste Compactor Vehicles			
Mobile Phone				Primary School			
Laptop				Secondary School			
Fax Machine				Tertiary Institution			
Internet Access				Religious/Informal			

Personal Possessed Assets	Responses			Community Possessed Assets	Responses		
	Have	**Don't Have**	**Don't want**		**Have**	**Don't Have**	**Don't want**
				Schools			
Land Phone				Dispensary			
Well				Primary Health Centre			
Spring/Stream				Maternity Centre			
Borehole				Patent Medicine Store			
Pipe borne water				Pharmacy Store			
Waste Bin				General Hospital			
Toilet				Teaching Hospital			
Bathroom				Specialist Hospital			
Drainage				Banks			
Social grant				Cooperative and Thrift Societies			
				Donor Agencies			
Landscaped compound				All Season Roads (Tarred)			
Vehicles				Earth Roads			
Motorcycle/Tricycle				Rail roads			
Bicycle				Pedestrian pathway			
First Aid Box				Formidable transport system			
Store of Balanced Diet (food)				Kinship system			
3 Square meal per day				Local organisations (CDAs, and CBOs)			
Access to medical care				Other organisations (NGOs)			
Weighing scale				Mineral & Water Resources			
Thermometer				Forest Reserves			
Sfig (BP instrument)				Agricultural Land			
Shares and Bonds				Community Development Fund			
Savings in Bank				Land for future development			

Personal Possessed Assets	Responses			Community Possessed Assets	Responses		
	Have	Don't Have	Don't want		Have	Don't Have	Don't want
Small amount to settle bills				Philanthropists/Politician			
Regular monthly income				Business Tycoons			
Access to insurance				Police post/Station			
Small amount to maintain household needs							

1. Type Housing (1) Flat ☐ (2) Compound form☐ (3) Duplex☐ (4) Terrace ☐ (5) Others (specify)____

2. Ownership type (1) Self-Built ☐ (2) Rented ☐ (3) Inherited ☐ (4) Mortgage ☐ (5) Others (specify) ____

2b What type of Title do you hold on the property? (1) Title Deed ☐ (2) Deed of Grant ☐ (3) PTO ☐ (4) None ☐ (5) Others (specify) _______________________________

3. Construction material (1)Sand Crete block☐ (2) mud/bricks☐ (3)Corrugated iron sheet ☐ (4) temporary structure (5) Others (specify) ________________________________

4. Accessibility to the house (1) no access road☐ (2) footpath☐ (3) untarred (earth) road ☐ (4) tarred road ☐ (5) Others (specify) ____________________________________

6. How many toilet do you have in the house? (1) none☐ (2) one☐ (3) two☐ (4) three and above ☐

7. Type and location of toilet (1) Bush ☐ (2) Latrine within ☐ (3) Bucket within ☐ (4) Water Closet within☐ (5)Latrine outside☐ (6) Water Closet within☐ (7) Others (specify) ____

8. Do you have any insurance coverage? (1) Yes☐ (2) No☐

9. If yes, what does it cover? (1) Life☐ (2) House☐ (3) Farm☐ (4) Car☐ (5) Others (specify)__________________

10. What is the condition of the House in respect of the following?

Building /Condition	*Good	**Fair	***Bad

Wall			
Floor			
Roof			
Total			

Key:
Wall: **un/cemented with no crack* ***cemented/uncemented with minor cracks* ****major crack*
Floor: **cemented/tilled with no crack* ***cemented/tilled with cracks* ****uncemented & untilled*
Roof: **intact corrugated/aluminium/brick* ***partly removed corrugated/aluminium/brick* ****thatch/carton/other temporary materials*

11. How many members of the family graduated above secondary level? (1) none☐ (2) one ☐(3) two☐ (4) three and above ☐

12. Have you participated in disaster mitigation & CC adaptation training courses before? (1) Yes ☐ (2) No☐

13. Have you participated in disaster mitigation propagation training before?(1) Yes☐ (2) No ☐

14. Have you participated in rehearsal for disaster mitigation and knowledge sharing before? (1) Yes☐ (2) No☐

15. Are you a member of any social organisation in the community? (1) Yes☐ (2) No☐

16. Are you participating in community funds raising/cooperative/thrift program? (1) Yes☐ (2) No☐

17. Do you normally have supports from communities and relatives when in need? (1) Yes☐ (2) No☐

18. What is your source of water? (1) None (2) Well (3) Borehole (4) Public Tap (5) Stream/ River (6) Others (specify) ______________________________

19. Is the water contaminated? (1) Yes☐ (2) No☐

20. If yes what is/ the sources of the contamination? (1) Domestic waste☐ (2) Industrial Waste ☐ (3) Commercial waste☐ (4) Others (Specify) ______________________________

21. Plot/ building coverage? (1) 1-10%☐ (2) 11-20%☐ (3)21-30%☐ (4) 31-40%☐ (5) more than 40%☐

22. Soft (green) landscape coverage? (1) No green landscape ☐ (2) 1-10% ☐ (3) 11-20% ☐ (4)21-30%☐ (5) 31-40%☐ (6) more than 40%☐

23. How do you collect your wastes? (1) Waste bin☐ (2) house frontage☐ (3) back yard☐ (4) open dump☐ (5) anywhere☐ (6) neighbourhood dump☐ (7) others (specify)______________________________

24. How do you transport your waste? (1) By hand☐ (2) own vehicle☐ (3) public vehicle ☐ (4) private collector☐ (5) others (Specify)______________________________

25. How do you dispose your disposal? (1) Compound open burning☐ (2) land fill☐ (3) neighbourhood open site☐ (4) Neighbourhood incinerator☐ (5) others (Specify)_______________________________

26. What type of access do you have to your house (1) None☐ (2) Tarred road☐ (3) untarred road☐ (4) footpath ☐ (5) Others (specify)___________________________________

27. Is electricity available? (1) Yes☐ (2) No☐

27 b If yes how frequent? (1) Uninterrupted☐ (2)Occasional interruption ☐ (3) Once a week ☐ (4) twice a month☐ (5) Once a month ☐ (6) Others (specify) ________________________

28. If no, what is your source of energy (1) Lantern☐ (2) Candle☐ (3) Generator☐ (4) Solar/wind☐ (5) others (specify) ____

29. Are you involved in the process of planning and planning decision making in your local municipality? (1) Yes ☐ (2) No☐

30. If yes, at what stage of the process? (1) Data gathering ☐ (2) Proposal making☐ (3) Decision making☐ (4) Review ☐ (5) Others (Specify)_________________________

Diseases Prevalence

(1) Have you noticed the prevalence of climate change related diseases (malaria, measles, typhoid fever, cholera, diarrhoea) in your locality? Yes☐ (2) No☐ (3) Don't know☐.

2) If yes, from which of the diseases are you or any member of your locality being treated? (1) malaria (2) measles (3) typhoid fever (4) cholera (5) diarrhoea (6) others (specify) ____ _

3) How many members of your household ever being treated of any of these diseases listed in the above? (1) None ☐(2) one☐ (3) two ☐ (4) three (5) more than three☐

4) fill in the details of the climate change related diseases in the spaces provided in the table.

Disease Type	**Year of Occurrence**	**Frequency of occurrence in a year**					
		None	**Once**	**2-5 times**	**6-10 times**	**11-15 times**	**More than 15 times**
Malaria							
Measles							
Typhoid Fever							
Cholera							
Diarrhoea							
Others ________							

5) What are the vulnerability factors to this prevalence of diseases in your locality?

(1) Poor sanitation☐ (2) contamination of water point sources☐ (3) inadequate income to seek medical care☐ (4) inadequate health facilities☐ (5) poor nutrition☐ (6) others (specify) ____

6) What steps are taken in your locality to cope with the prevalence of diseases in your locality? (1) consulting physicians☐ (2) consulting native doctors☐ (3) self-medication☐ (4) ensuring good sanitation ☐ (5) building community health facility☐ (6) embracing vaccination programmes☐ (7) tree and flowers planting around homes☐ (8) others (specify) ____

Incidence of Flood

1) Have you ever experienced any incidence of flood in your locality in ten years? (1) Yes☐ (2) No☐ (3) Don't know.
2) If yes, is it a recurrent incidence? (1) Yes (2) No (3) Don't know.
3) If yes, when do you start having flood incidence in your area (year)? ____________________
4) How many times a year do you experience recurrent flood incidence in your locality? None☐ (2) once☐ (3) 2-5 times☐ (4) 6-10 times☐ (5) 11-15 times☐ (6) more than 15 time ☐ (7) Don't know☐.
5) What are the vulnerability factors to the incidence of flood in your area? (1) Hard/impervious surfacing☐ (2) poor drainage system☐ (3) dumping of wastes on drainage channels☐ (4) heavy rainfall☐ (5) building on flood plains☐ (6) others (specify) ___________________________
6) What steps are taken in your locality to cope with flood incidence? (1) growing of lawn in homes ☐ (2) evacuating waste rather than dumping in drainage channels☐ (3) channelizing drainage and stream channels☐ (4) planting of trees as flood embankment☐ (5) cover cropping☐ (6) ban buildings on flood plains☐ (7) others (specify) ____________________________________
7) What other general suggestion can you offer for a sustainable adaptation strategy in the Municipality
____
____
____
____
____

Thank you so much for your time.

Appendix 2 : Questionnaires (Agencies Responsible for Planning and Development Control/Regulations)

University of Venda

School of Environmental Sciences

Department of Urban and Regional Planning **B1**

Topic: **URBAN HOUSEHOLDS' VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN MOPANI DISTRICT**

Dear Respondent (**Agencies Responsible for Planning and Development Control/Regulations)**

GENERAL INFORMATION

Introduction

The researcher is a PhD candidate at the University of Venda, in Urban and Regional Planning Department, School of Environmental Sciences. He is carrying out research, entitled Urban Households' Vulnerability and Adaptation to Climate Change in Mopani District, Limpopo Province South Africa.

You are kindly requested for participation in this research as an official representative of your organisation especially as the topic relates with and concern your organisation. The purpose of this study is to examine the vulnerability and response pattern to the nature and frequency of climate-related impacts among households in Mopani District, during the period of 1958-2017, with the view to suggest practicable and sustainable strategies capable of enhancing households' adaptive capacity and resilience.

Your participation is voluntary, hence you may choose not to answer any of the questions, should you feel that such question(s) is /are not proper. You equally have the right to withdraw from the study, even after you have started completing the questions. The questionnaire will take about 10 minutes to complete. The questions do not require you to provide your name and contact details, thus, your confidentiality will be protected from third parties. Therefore, you are kindly requested to give honest opinions on every issue in the questionnaire, to allow for an assessment to inform appropriate policies and strategies.

Thank you for your time from your busy schedule. Please do not hesitate to contact me if you have any questions.

Jimoh M. Y.

Cell: 0630919435
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RESEARCH QUESTIONNAIRE

FOR PROFESSIONERS (PLANNER, ARCHITECT, ENGINEER, BUILDER & DISASTER MANAGER)

Section A Part 1: GENERAL INFORMATION

1) Institution (1) Local Municipality☐ (2) District Office☐ (3) Provincial☐ (4) District Disaster Management office☐ (5) NGO ☐
2) Location____________________________ Officer's Designation ……………………………..
3) How long have worked in this office? ____

Part II: Development Control Regulations

1. Are there specific Planning Regulations available for development control and guidelines in the municipality? (1) Yes ☐ (2) No☐
2. If yes, when was these regulations instituted? (1) within one year☐ (2) 1-5 years ago☐ (3) 6-10 years ago☐ (4) 11-15 years ago☐ (5) above 15 years☐

3) Does it make specific provision for:

   a) Disaster Prevention? (1) Yes☐ (2) No☐

   b) Disaster Reduction? (1) Yes☐ (2) No☐

   c) Adaptation/ Response? (1) Yes ☐ (2) No☐

4) Has the regulation been reviewed since inception? (1) Yes ☐ (2) No☐

5) If Yes, when last was the regulation reviewed? (1) within one year ☐(2) 1-5 years ago ☐ (3) 6-10 years ago☐ (4) 11-15 years ago☐ (5) above 15 years ☐

6) What are the adaptation or response strategies in the review? ____ ____

7) How successful will you rate the implementation of the strategy so far? (1) Very successful ☐ (2) Successful ☐ (3) not very successful ☐ (4) not successful ☐

8) If not successful, what strategic restructuring will you recommend? ____ ____

9) What are those external factors that hinders the authority's development control unsuccessful? (1) inter-agency law conflicts☐ (2) Traditional Institution ☐ (3) lack of community cooperation ☐ (4) Others (specify)___________________________

10) What are those internal factors that hinders the authority's development control unsuccessful especially as regards on flood plains? (1) Paucity of funds☐ (2)

Lack of adequate tools ☐ (3) corruption among officers☐ (4) lack of adequate staff ☐ (5) absence of regular staff training ☐ (6) Others (specify)__________________

Part III: Risk Prevention, Reduction, and Response approach

1) When last has the authority conducted survey to identify climate change disaster hot spot in the area? (1) within one year☐ (2) 1-5 years ago☐ (3) 6-10 years ago☐ (4) 11-15 years ago☐ (5) above 15 years☐ (6) Never☐
2) Does the organisation has climate change expert? 1) Yes☐ 2) No☐
3) What are the specific arrangement the authority has in anticipation of the incidence of climate change disaster, especially as regards :
   a) Prevention of Risk? ____ ____
   b) Risk Reduction? ____ ____
   c) Response to Disaster incidence? ____ ____
4) Does the office has Adaptation Strategic Plan? (1) Yes☐ (2) No☐
5) How successful will you rate the implementation of the strategy so far? (1) Very successful ☐ (2) Successful ☐ (3) not very successful ☐ (4) not successful ☐
6) Has climate change disaster struck in this town before 1) Tes 2) No
7) If yes, what are the specific actions that was taken
   a) Before the disaster? ____
   b) During the Disaster? ____
   c) After the Disaster? ____
8) What are the strategies in place to secure and protect occupation of ecological zones (flood plains)? a) ____________________ b) ____________________ c) ______________
9) What are the aspects that the authority have identified crucial to risk reduction in this area?
   a) ____
   b) ____
   c) ____

Part IV: Project on Vulnerability and Adaptation

Are the following activities considered paramount vulnerability problems in your area of jurisdiction? Then rate their level of significance (Linkert Scale of ranking)

s/n	Problems/Ranking	Awareness		Level of Significance				
		Yes	No	VS	S	NS	NSA	DK
1	Over crowding							
2	Slum emergence							

3	ill serviced building							
4	Risky site occupation							
5	Poor construction							
6	Squalid life threatening settlement							
7	Unsecured tenure							
8	Others(specify)							

1) Do you agree there is a link between urban form and climate change risk? (a) Yes☐ (2) No☐
2) Is there any need to integrate adaptation into urban planning? (1) Yes ☐ (2) No☐
3) If yes, What will you suggest as operational strategy for mainstreaming climate change for sustainability?
____
____
____
4) What local program will you suggest for sustainable climate change-urban planning strategy?
____
____
____
5) What organisational function will you suggest for the authority for a sustainable adaptation program?
____
____
____
6) Do you consider the strategy of promoting a more distributed risk governance system? (a) Yes ☐ (b) No☐
7) Was there an interface between the authority and University, researchers and the likes for information sharing? (a) Yes ☐ (b) No ☐
8) In what way(s) is your authority empowering the population to cope and deal with natural threats and climate change disaster:
   a) Before disaster____
   b) During disaster____
   c) After Disaster ____
10) Will you recommend changing or developing the existing regulation(s) (a) Yes☐ (b) No ☐
11) If yes, do you agree to change of any of these? The rate them

Rules	Agree to change		Strength of agreement				
	Yes	No	Strongly agree	Agree	Dis agree	Strongly disagree	Indifferent
Building Codes							
Plan							
Policy							
Program							
Internal reorganisation							

Staff capacity building							

12) What project have you initiated and executed in last 10 years on
    a) Risk Prevention ____
    b) Response ____
    c) Coping ____

12) What are the programs and project the authority has to effect repairs after the previous incidence of disaster:

    a) ____
    b) ____
    c) ____
    d) ____

1) Is (are) there informal settlement(s) in the town? i. Yes ii. No

2) If yes, how are the tenure of inhabitants of this informal settlement(s) enhanced, does the municipality provide the following services to them?

Topic	Programmes for managers	
	Yes	No
School		
Electricity		
Pipe Borne water		
Drainages		
Roads & Road maintenance		
Cleaning and sanitation		
Security		
Others (specify)		

____

3 What are planning and management policies that prevent the development of slum /flood plain/ wetland?
____
____

4 What are the policies in place to promote and support autonomous adaptation efforts by poor urban population? ____
____

5 What are the management strategies and policies on:
    i. Disaster preparedness? ____
    ____
    ii. Disaster response? ____
    ____
    iii Prevention of new development in disaster prone areas?______________
____

6 What other general suggestion can you offer for a sustainable adaptation strategy in the Municipality? ____
____

7 What are your functional mechanism and structure for recovery in case of disaster occurrence?____

____

SECTION 2: Part 1 administration

3) What are the source of income for this establishment? (a) Allocation form government☐ (b) Charges and levies☐ (c) community contribution☐ (d) Donor Agencies☐ (e) Others (specify) ____________________________
4) If its government allocation, how much is the budget for the following sectors in the following years:

S/N	Sector	YEAR					
		2017 – 2018	2015 – 2006	2013 – 2014	2011 – 2012	2009 – 2010	2007 – 2008
In (000) Rands							
1	Water supply						
2	Health						
3	Environmental Sanitation						
4	Drainages and Sewer						
5	Roads						
6	Waste management						

5) What other source of finance are available to your establishment aside the above mentioned?

____

6) Is there available financial Aids to people for disaster safe housing? (a) Yes☐ (b) No☐
7) Is there any functional relationship between your unit and other units in mitigating climate change? i Yes ii No
8) If yes, state the unit(s) an the specific activity

S/N	Name of the collaborating unit	The specific activity
1		
2		
3		
4		

Appendix 3: Land cover change in Tzaneen Town (1987-2017) at ten-year Interval

Classification	1987-1997		1997-2007		2007-2017	
	Area(Ha)	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Bare lands – Built-up	36,81	0,61	364,32	5,99	221,31	3,64
Vegetation – Built-up	232,56	3,82	-	-	132,75	2,18
Vegetation – Bare lands	253,08	4,16	546,12	8,98	449,64	7,39
Bare lands - Vegetation	196,74	3,23	203,31	3,34	393,21	6,46
No Change	5363,82	88,18	4969,26	81,69	4886,1	80,32
	6083,01	100	6083,01	100	6083,01	100

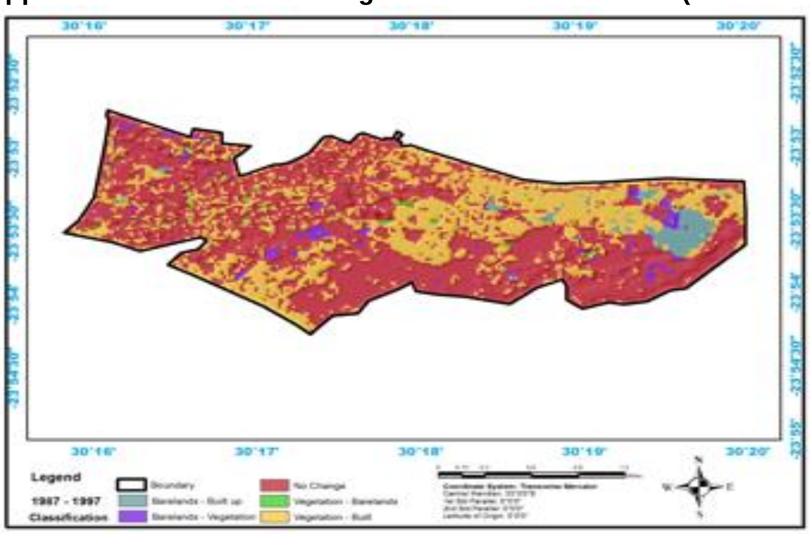
Source: Author's Field Data, 2019

Appendix 4: Land use and land cover change in Nkowankowa town (1987-1997, 1997-2007 and2007-2017)

Classification	1987-1997		1997-2007		2007-2017	
	Area(Ha)	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Bare lands – Built-up	33.93	2.73	14.13	1.14	69.48	5.58
Vegetation – Built-up	445.14	35.75	370.08	29.72	24.39	1.96
Bare lands – Vegetation	25.02	2.01	-	-	64.17	5.15
Vegetation - Bare lands	10.08	0.81	110.61	8.88	-	-
No Change	730.89	58.70	750.24	60.26	1087.02	87.31
	1245.06	100	1245.06	100	1245.06	100

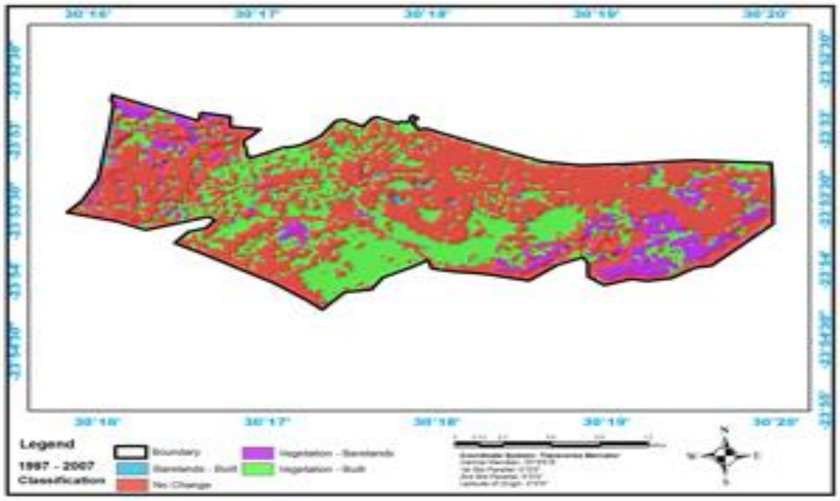
Source: Author's Field Data, 2019

Appendix 5: Land cover change in Nkowankowa Town (1987-1997)



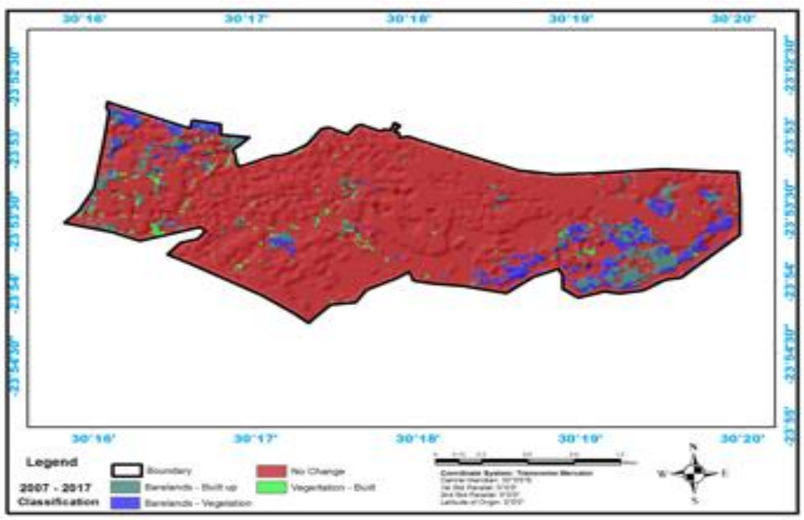
Source: Author's Field Data, 2019

Appendix 6: Land cover change in Nkowankowa Town (1997-2007)



Source: Author's Field Data, 2019

Appendix 7: Land cover change in Nkowankowa Town between 2007-2017



Source: Author's Field Data, 2019

Appendix 8: The Land use and land cover change in Hoedspruit town (1987-1997, 1997-2007 and2007-2017)

Classification	1987-1997		1997-2007		2007-2017	
	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
Bare lands- Built up	80.82	8.36	78.66	8.14	0	0.0
Vegetation - Built	15.84	1.64	194.49	20.13	30.42	3.15
Bare lands - Vegetation	6.75	0.70	10.53	1.09	0	0.0
Vegetation - Bare lands	121.14	12.54	386.64	40.02	107.82	11.16
No Change	741.69	76.76	295.92	30.62	828	85.69
Total	966.24	100	966.24	100	966.24	100

Source: Author's Field Data, 2019

Appendix 9A: Kappa Coefficient for accuracy test (Nkowankowa)

	Builtup	Vegetation	Waterbody	Bareland	Total	UA
Builtup	6621	336	37	5003	11997	55.2%
Vegetation	4	128	11	40	183	69.9%
Waterbody	0	4	0	0	4	0.00%
Bare land	144	580	60	953	1737	54.7%
Total	6769	1048	108	5996	13921	
PA	97.8%	12.2%	0%	15.9%		0.139690
UA(User's Accuracy), PA(Producer's Accuracy), Kappa Coefficient = 0.709755						
Like Modjajiloskoof and Giyani, a high Kappa coefficient of 0.709755 was obtained, though with a total accuracy of 55.3%. In Nkowankowa, the accuracy of land cover classes differed when compare with each other (2017 actual LULC and predicted 2017 LULC). Built up was found to have 55.2% UA, vegetation possessed 69.9% UA, waterbody was observed to possess 0.00% UA and bare land had 54.7% UA. There was huge disparity in the PAs of the classes. Built-up possessed 97.8% PA, vegetation possessed 12.2% PA, Waterbody possessed 0% PA and Bare land possessed 15.9% PA. The high Kappa coefficient showed that the prediction is highly reliable and can be employed for the 2047 prediction.						

Appendix 9B: Kappa Coefficient for accuracy test (Modjadjiskloof)

Builtup	1596	2412	52	152	4212	37.9%
Vegetation	169	8643	33	39	8884	97.3%
Waterbody	1	220	59	0	280	21.1%
Bareland	593	3970	19	61	4643	1.3%
Total	2359	15245	163	252	18019	
PA	67.7%	56.7%	36.2%	24.2%		57.5%
Kappa coefficient = 0.710715						
The comparison between the classified 2017 LULC for Modjadjiskloof and the predicted 2017 land cover gave way to an effective method of measuring its accuracy. The result from the error matrix showed how reliable the LULC prediction was. The total accuracy between the two imageries was 57.5%. Built-up land cover had 37.9% UA. Vegetation possessed higher UA at 97.3%. Like built-up, Waterbody and bare land possessed lower UA of 21.1% UA and 1.3% UA respectively. PA's for the classes have less deviations as built-up has 67.7% PA, vegetation possessed 56.7% PA, waterbody possessed 36.2% PA and bare land recorded 24.2% PA. However, a Kappa coefficient of 0.710715 shows the reliability of the 2017 Modjadjiskloof LULC prediction as proof for a near accurate prediction of 2047 Modjadjiskloof LULC.						

Appendix 10A: Kappa Coefficient for accuracy test (Giyani)

	Builtup	Vegetation	Waterbody	Bareland	Total	UA
Builtup	1288	5	1	541	1835	70.2%
Vegetation	133	577	329	3370	4409	13.1%
Waterbody	0	3	0	2	5	0%
Bareland	2575	92	59	10623	13349	79.6%
Total	3996	677	389	14536	19598	
PA	32.2%	85.2%	0%	73.1%		63.7%
UA (User's Accuracy), PA (Producer's Accuracy), Kappa Coefficient = 0.754018						
The comparison of LULC of classified Giyani features and its predicted LULC returned results differing across classes. While built-up areas representing buildings, roads and other man-made features showed 70.2% UV, vegetation showed 13.1% UA. Waterbody showed 0% UA while bare land showed 79.6% UA. Built-up, vegetation, waterbody and bare land showed 32.2% PA, 85.2% PA, 0% PA and 73.1% PA respectively. The total accuracy was 63.7% and overall Kappa was 0.754018 showing the level of reliability of LULC prediction.						

Appendix 11 A: Tzaneen Landuse and land cover projection

Error Matrix Analysis of TZANEEN_CLASS_17_CLIP
(columns: truth) against TZANEENPREDICT_2017_CLIP
(rows: mapped)

	1	2	3	4	255	Total	ErrorC
1	1617	228	3	3069	0	4917	0.756720
2	74	363	165	1723	0	2324	0.624149
3	0	1	0	12	0	13	1
4	1345	360	29	6081	7	7813	0.265038
255	0	0	0	0	5055	5055	0
Total	3036	952	197	10878	23846	38909	0
Error0	0.036072	0.778467	1	0.877396	0		0.332445

Error0 = Errors of Omission (expressed as proportions)
ErrorC = Errors of Commission (expressed as proportions)

90% Confidence Interval = +/- 0.004501 (0.238538 - 0.339566)
95% Confidence Interval = +/- 0.004636 (0.237818 - 0.240690)
99% Confidence Interval = +/- 0.004871 (0.235782 - 0.242725)

KAPPA INDEX OF AGREMENT (KIA)
Using TZANEENPREDICT_2017_CLIP as reference image…

Category	KIA
1	0.518162
2	0.695889
3	0.209080
4	0.4788897
255	1.000000

TZANEEN_CLASS_2017_CLIP

Category	KIA
1	0.790090
2	0.241790
3	0.851141
4	0.294712
255	1.000000

Overall Kappa = 0.710755

Appendix 11 B Hoedspruit Landuse and land cover projection

Error Matrix Analysis of HOEDSPRUIT_CLASS_17_CLIP
(columns: truth) against HOEDSPRUITPREDICT_2017_CLIP
(rows: mapped)

	1	2	3	4	255	Total	ErrorC
1	1771	1431	29	2874	0	6105	0.688901
2	92	4396	16	58	0	141	0.762159
3	1	110	28	0	0	141	0.762159
4	297	1984	21	40	0	2361	0.297576
255	0	0	0	0	34431	34431	0
Total	2160	7921	94	2972	34431	47600	
Error0	0.232442	0.344070	0.386037	0.775937	0		0.166359

Error0 = Errors of Omission (expressed as proportions)
ErrorC = Errors of Commission (expressed as proportions)

90% Confidence Interval = +/- 0.002477 (0.137381 - 0.142336)
95% Confidence Interval = +/- 0.002951 (0.136907 - 0.142801)
99% Confidence Interval = +/- 0.003884 (0.135974 - 0.143743)

KAPPA INDEX OF AGREMENT (KIA)
Using HOEDSPRUIT PREDICT_2017_CLIP as reference image…

Category	KIA
1	0.513607
2	0.706299
3	0.820906
4	0.483797
255	1.000000

HOEDSPRUIT_CLASS_2017_CLIP

Category	KIA
1	0.463644
2	0.741752
3	0.385319
4	0.132646
255	1.000000

Overall Kappa = 0.732366

Appendix 12: Distribution of respondents according to socio-economic characteristics

Variable	Percentage	Variables	Percentage
Age		**Monthly Income**	
≤13-19	2.2	No income	24
20-35	37.7	≤R500	5
36-50	44.4	R501-5000	2
51-65	12.5	R5,001-10,000	3
66 and above	2.2	R10,001-15,000	3
Marital Status		R15,001-20,000	6
Married	56.7	R20,001-25,000	11
Single	29.8	R25,001-30,000	16
Divorced	4.6	R30,001-35,000	17
Widow	5.2	R35,001-40,000	11
Widower	0.6	>R40,000	1
Separated	2.8	**Qualification**	
Others	0.2	No formal education	3.2
Duration of stay		Quranic education	0.2
1-3 years	10.1	Grade 0-7	8.5
4-6	11.1	Grade 8-12	11.3
7-10 years	5.8	Matric	32.9
above 10 years	51.0	Certificate/Diploma	14.7
Since birth	22.0	Higher Diploma/	12.5
Gender		Bachelor/Honour	11.7
Male	35.1	Masters/PhD	3.2
Female	64.9	Others	

Source: Author's Field Data, 2019

Appendix: 13: Distribution of Gender and Marital status of respondents across Mopani

	Marital Status						
	Married	Single	Divorced	Widow/ Widower	Separated	Others	Total
	%	%	%	%	%	%	%
Male	38.8	27.0	56.5	19.2	35.7	0.0	35.1
Females	61.2	73.0	43.5	80.8	64.3	100.0	64.9
Total	100	100	100.0	100.0	100.0	100.0	100.0

Source: Author's Field Data, 2019

Appendix 14: INDIGENT HOUSEHOLDS AS PER INCOME CRITERION IN MOPANI

Local Municipality	Municipal determination of indigent household (2011)	Total H/H	Total Indigents		Indigents benefitting		Indigents NOT benefitting	
			No.	%	No	%	No	%
Greater Tzaneen	0≤(h/h income)≤ R3 000 pm	108926	86 343	79,3	32 573	37,7	53 770	62,3
Greater Giyani	0≤ (h/h income)≤ R1 400 pm	63548	40 873	64,3	336	0,8	40 537	99,2
Greater Letaba	0≤ (h/h income)≤ R3 000 pm	58261	49 935	85,7	898	1,8	49 037	98,2
Maruleng	0≤ (h/h income)≤ R1 500 pm	24470	15 333	62,7	1 365	8,9	13 968	91,1
Ba-Phalaborwa	0≤ (h/h income)≤ R3 000 pm	41115	27 221	66,2	2 275	8,4	24 946	91,6
Total/ Mopani DM		**296320**	**219 705**	**74,1**	**37 447**	**17,0**	**182 258**	**83,0**

Source: Mopani District IDP 2019/20 version

Appendix 14a: blockage of drainage influencing exposure in Tzaneen town

Source: Author's Field Survey, 2019

Appendix 15: SYSTEM IMPLEMENTATION [Codes]

//Login Activity

```
package com.hotspot.reporter.ui.activities;
import android.app.Activity;
import android.content.Intent;
import android.os.Bundle;
import android.widget.EditText;
import android.widget.TextView;
import androidx.annotation.Nullable;
import com.hotspot.reporter.R;import com.hotspot.reporter.db.MemoryManager;
import com.hotspot.reporter.db.entities.UserEntity;
import com.hotspot.reporter.ui.bases.BaseActivity;
import com.hotspot.reporter.ui.presenter.LoginPresenter;
import com.hotspot.reporter.ui.view.LoginView;
import com.hotspot.reporter.util.Util;
import butterknife.BindView;
```

```
import butterknife.OnClick;
public class LoginActivity extends BaseActivity implements LoginView {
    private static final int REGISTER = 100;
    @BindView(R.id.txtForgotPass)
    TextView txtLeft;
    @BindView(R.id.txtRegister)
    TextView txtRight;
    @BindView(R.id.txtPhone)
    EditText txtPhone;
    @BindView(R.id.txtPassword)
    EditText txtPassword;
    private LoginPresenter presenter;
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        if(MemoryManager.getInstance().getUser() != null)
            loadingSuccessful(null);
        else{
            setContentView(R.layout.activity_login);
            presenter = new LoginPresenter(this);
        }
}
    @OnClick(R.id.txtForgotPass)
    public void leftClicked(){
        startActivity(new Intent(this, ForgotPasswordActivity.class));
    }

    @OnClick(R.id.txtRegister)
    public void rightClicked(){
        startActivityForResult(new Intent(this, RegistrationActivity.class), REGISTER);
    }
    @Override
    public void loadingStart() {
        Util.hideKeyboard(this);
        startLoading();
    }
    @Override
    public void loadingFailed(String msg) {
        Util.showKeyboard(this);
        super.loadingFailed(msg);
    }
    @Override
    public void loadingSuccessful(String msg) {
        Intent intent = new Intent(this, DashboardActivity.class);
        startActivity(intent);
        finish();
    }
    @Override
    public void invalidEmail(String msg) {
        Util.showKeyboard(this);
        txtPhone.setError(msg);
```

```
    }
    @Override
    public void invalidPass(String msg) {
        Util.showKeyboard(this);
        txtPassword.setError(msg);
    }
    @Override
    public void loginSuccessful(UserEntity data) {
        MemoryManager.getInstance().putUser(data);
        super.loadingSuccessful("Login Successfully!");
        loadingSuccessful(null);
    }
    @OnClick(R.id.btn_login)
    void loginClick() {
        presenter.validateInput(Util.text(txtPhone), Util.text(txtPassword));
    }
    @Override
    protected void onActivityResult(int requestCode, int resultCode, @Nullable Intent data) {
        super.onActivityResult(requestCode, resultCode, data);
        if(resultCode == Activity.RESULT_OK && requestCode == REGISTER)
            loadingSuccessful(null);
    }
}
// Create Post Activity
package com.hotspot.reporter.ui.activities;
import android.Manifest;
import android.app.Activity;
import android.content.Intent;
import android.content.pm.PackageManager;
import android.location.Location;
import android.net.Uri;
import android.os.Bundle;
import com.elkanahtech.widerpay.myutils.activities.ImagePickerActivity;
import com.elkanahtech.widerpay.myutils.activities.VideoPickerActivity;
import com.google.android.gms.location.FusedLocationProviderClient;
import com.google.android.gms.location.LocationServices;
import com.google.android.material.floatingactionbutton.FloatingActionButton;
import com.google.android.material.snackbar.Snackbar;
import androidx.annotation.Nullable;
import androidx.appcompat.app.AppCompatActivity;
import androidx.appcompat.widget.Toolbar;
import androidx.core.app.ActivityCompat;
import androidx.core.content.ContextCompat;

import android.view.Menu;
import android.view.MenuItem;
import android.view.View;
import android.widget.EditText;
import android.widget.FrameLayout;
import android.widget.ImageView;
import android.widget.Switch;
```

```
import android.widget.VideoView;
import com.hotspot.reporter.R;
import com.hotspot.reporter.ui.bases.BaseActivity;
import com.hotspot.reporter.ui.presenter.CreateReportPresenter;
import com.hotspot.reporter.ui.view.BaseView;
import com.hotspot.reporter.util.MediaType;
import com.hotspot.reporter.util.Repository;
import com.hotspot.reporter.util.Util;
import butterknife.BindView;
import butterknife.OnClick;
public class CreatePostActivity extends BaseActivity implements BaseView {
    private static final int IMAGE_PICKER = 100;
    private static final int VIDEO_PICKER = 200;
    @BindView(R.id.imageView)
    ImageView imageView;
    @BindView(R.id.mediaLayout)
    FrameLayout mediaLayout;
    @BindView(R.id.txtIncident)
    EditText txtIncident;
    @BindView(R.id.swSeeItHappen)
    Switch swSeeItHappen;
    private String media;
    private MediaType mediaType = MediaType.TEXT;
    private CreateReportPresenter presenter;
    private FusedLocationProviderClient fusedLocationClient;
    private Location location;
    @BindView(R.id.videoView)
    VideoView videoView;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_create_post);
        Toolbar toolbar = findViewById(R.id.toolbar);
        setToolbar(toolbar, getString(R.string.title_activity_create_post));
        presenter = new CreateReportPresenter(this);

        if (ContextCompat.checkSelfPermission(this,
android.Manifest.permission.ACCESS_FINE_LOCATION) ==
                PackageManager.PERMISSION_GRANTED &&
                ContextCompat.checkSelfPermission(this,
android.Manifest.permission.ACCESS_COARSE_LOCATION) ==
                        PackageManager.PERMISSION_GRANTED) {
            fusedLocationClient = LocationServices.getFusedLocationProviderClient(this);
            fusedLocationClient.getLastLocation().addOnSuccessListener(this, this::lastLocation);
        } else {
            ActivityCompat.requestPermissions(this, new String[] {
                            Manifest.permission.ACCESS_FINE_LOCATION,
                            Manifest.permission.ACCESS_COARSE_LOCATION },
                    100);
    }
```

```
    }
    private void lastLocation(Location location) {
        this.location = location;
    }
    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        getMenuInflater().inflate(R.menu.create_post_menu, menu);
        return super.onCreateOptionsMenu(menu);
    }
    @Override
    public boolean onOptionsItemSelected(MenuItem item) {
        if(item.getItemId() == R.id.content_save){
            presenter.validateInput(Util.text(txtIncident),  media, mediaType,  swSeeItHappen,
location);
            return true;
        }
        else
            return super.onOptionsItemSelected(item);
    }
    @OnClick({R.id.camera, R.id.library})
    public void imageClicked(){
        startActivityForResult(new Intent(this, ImagePickerActivity.class), IMAGE_PICKER);
    }
    @OnClick(R.id.video)
    public void videoClicked(){
        startActivityForResult(new Intent(this, VideoPickerActivity.class), VIDEO_PICKER);
    }
    @OnClick(R.id.close)
    public void closeClicked(){
        mediaLayout.setVisibility(View.GONE);
        imageView.setVisibility(View.GONE);
        videoView.setVisibility(View.GONE);
        if(videoView.isPlaying())
            videoView.pause();
        media = null;
    }
    @Override
    protected void onActivityResult(int requestCode, int resultCode, @Nullable Intent data) {
        super.onActivityResult(requestCode, resultCode, data);
        if(resultCode == Activity.RESULT_OK && data != null &&
data.hasExtra(getString(R.string.data))){
            closeClicked();
            mediaLayout.setVisibility(View.VISIBLE);
            String dataReturned = data.getStringExtra(getString(R.string.data));
            switch (requestCode){
                case IMAGE_PICKER:
                    this.mediaType = MediaType.IMAGE;
                    media = Repository.loadPixFromLocal(imageView, dataReturned,
getContentResolver());
                    videoView.setVisibility(View.GONE);
                    imageView.setVisibility(View.VISIBLE);
```

```
                break;
            case VIDEO_PICKER:
                this.mediaType = MediaType.VIDEO;
                videoView.setVisibility(View.VISIBLE);
                imageView.setVisibility(View.GONE);
                media = Repository.loadVideoFromLocal(videoView, dataReturned,
getContentResolver());
                break;
        }
    }
}

@Override
public void loadingStart() {
    super.startLoading();
}

@Override
public void loadingFailed(String msg) {
    super.loadingFailed(msg);
}
@Override
public void loadingSuccessful(String msg) {
    super.loadingSuccessful(msg);
    finish();
}
}
```

(Source: Abolade et al., 2019)

```
// Report Details Activity
package com.hotspot.reporter.ui.activities;
import android.content.Intent;
import android.net.Uri;
import android.os.Bundle;
import android.view.View;
import android.widget.ImageView;
import android.widget.TextView;
import android.widget.VideoView;
import androidx.appcompat.widget.Toolbar;
import com.hotspot.reporter.R;
import com.hotspot.reporter.db.entities.ReportEntity;
import com.hotspot.reporter.ui.bases.BaseActivity;
import com.hotspot.reporter.ui.presenter.ReportDetailPresenter;
import com.hotspot.reporter.ui.view.BaseView;
import com.hotspot.reporter.util.MediaType;
import com.hotspot.reporter.util.Repository;
import butterknife.BindView;
import butterknife.OnClick;
public class ReportDetailActivity extends BaseActivity implements BaseView {
```

```
    @BindView(R.id.reportImage)
    ImageView reportImage;
    @BindView(R.id.imageView)
    ImageView imageView;
    @BindView(R.id.txtFullName)
    TextView txtFullName;
    @BindView(R.id.txtTime)
    TextView txtTime;
    @BindView(R.id.txtAddress)
    TextView txtAddress;
    @BindView(R.id.txtTitle)
    TextView txtTitle;
    @BindView(R.id.toolbar)
    Toolbar toolbar;
    @BindView(R.id.videoView)
    VideoView videoView;
    private ReportDetailPresenter presenter;
    private ReportEntity reportEntity;
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_report_detail);
        setToolbar(toolbar, getString(R.string.title_activity_report_detail));
        reportEntity = (ReportEntity) getIntent().getSerializableExtra(getString(R.string.data));
        presenter = new ReportDetailPresenter(this);
        presenter.postViewed(reportEntity.id);
        loadInformation();
    }

    private void loadInformation() {
        Repository.loadPixFromString(reportEntity.picture, imageView);
        txtFullName.setText(reportEntity.fullname);
        txtTime.setText(reportEntity.created_at);
        txtAddress.setText(Repository.getFullAddress(reportEntity.latitude, reportEntity.longitude,
this));
        txtTitle.setText(reportEntity.incident);
        switch (MediaType.valueOf(reportEntity.media_type)){
            case IMAGE:
                reportImage.setVisibility(View.VISIBLE);
                Repository.loadPixFromString(reportEntity.media_url, reportImage);
                break;
            case VIDEO:
                Repository.loadVideoFromString(videoView, reportEntity.media_url);
                break;
        }
    }
    @Override
    public void loadingStart() {
        super.startLoading();
    }
    @Override
```

```
    public void loadingFailed(String msg) {
        super.loadingFailed(msg);
    }
    @Override
    public void loadingSuccessful(String msg) {
        super.loadingSuccessful(msg);
    }
    @OnClick(R.id.fab)
    public void fabClicked(){
        String loc = String.format("geo:%.4f,%.4f", reportEntity.latitude, reportEntity.longitude);
        Uri gmmIntentUri = Uri.parse(loc);
        Intent mapIntent = new Intent(Intent.ACTION_VIEW, gmmIntentUri);
        mapIntent.setPackage("com.google.android.apps.maps");
        if (mapIntent.resolveActivity(getPackageManager()) != null) {
            startActivity(mapIntent);
        }
    }
}
```

Login Screen XML

```
<?xml version="1.0" encoding="utf-8"?>
<FrameLayout xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    app:layout_behavior="@string/appbar_scrolling_view_behavior"
    tools:context=".ui.activities.LoginActivity"
    tools:showIn="@layout/activity_login">
<ImageView
        android:scaleType="centerCrop"
        android:layout_width="match_parent"
        android:layout_height="match_parent"
        android:src="@drawable/bg"/>
<View
        android:layout_width="match_parent"
        android:layout_height="match_parent"
        android:background="@color/overlay_color"/>
<ScrollView
        android:scrollbars="none"
        android:id="@+id/loginLayout"
        android:layout_width="match_parent"
        android:layout_height="match_parent"
        app:layout_behavior="@string/appbar_scrolling_view_behavior"
        tools:context=".ui.activities.LoginActivity">
<LinearLayout
            android:layout_gravity="center_vertical"
            android:paddingLeft="@dimen/fab_margin"
            android:paddingRight="@dimen/fab_margin"
            android:layout_marginLeft="@dimen/fab_margin"
            android:layout_marginRight="@dimen/fab_margin"
            android:orientation="vertical"
```

```
          android:layout_width="match_parent"
          android:layout_height="wrap_content">
<ImageView
            android:layout_gravity="center_horizontal"
            android:layout_marginBottom="@dimen/fab_margin"
            android:layout_width="120dp"
            android:layout_height="120dp"
            android:src="@drawable/mopany"/>

<TextView
            android:layout_marginBottom="@dimen/medium"
            android:textColor="@color/white"
            style="@style/textview2"
            android:text="Phone Number"/>
<EditText
            android:inputType="phone"
            android:padding="@dimen/medium"
            android:background="@android:drawable/editbox_background"
            android:id="@+id/txtPhone"
            android:drawableLeft="@drawable/phone"
 style="@style/my_edit_text2"/>
<TextView
            android:layout_marginTop="@dimen/fab_margin"
            android:layout_marginBottom="@dimen/medium"
            android:textColor="@color/white"
            style="@style/textview2"
            android:text="Password"/>
<EditText
            android:inputType="textPassword"
            android:background="@android:drawable/editbox_background"
            android:layout_marginBottom="@dimen/fab_margin"
            android:padding="@dimen/medium"
            android:id="@+id/txtPassword"
            android:drawableLeft="@drawable/ic_lock"
 style="@style/my_edit_text2"/>

<TextView
            android:layout_width="wrap_content"
            android:layout_gravity="right"
            android:padding="@dimen/small"
            android:id="@+id/txtForgotPass"
            android:clickable="true"
            android:textColor="@color/colorAccent"
            style="@style/textview2"
            android:text="@string/forgot_pass"  />
<Button
            android:layout_marginTop="@dimen/fab_margin"
            android:id="@+id/btn_login"
            android:layout_width="match_parent"
            android:layout_height="wrap_content"
      android:text="Login" />
```

```
<LinearLayout
        android:layout_marginTop="@dimen/medium"
        android:layout_gravity="center_horizontal"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content">
<TextView
          android:padding="@dimen/small"
          android:clickable="true"
          android:layout_width="wrap_content"
          android:textColor="@color/white"
          style="@style/textview2"
          android:text="@string/register_label"  />
<TextView
          android:padding="@dimen/small"
          android:clickable="true"
          android:layout_width="wrap_content"
          android:id="@+id/txtRegister"
          android:textColor="@color/colorAccent"
          style="@style/textview2"
          android:text="@string/register_label_2"  />
</LinearLayout>
</LinearLayout>
</ScrollView>
</FrameLayout>
```

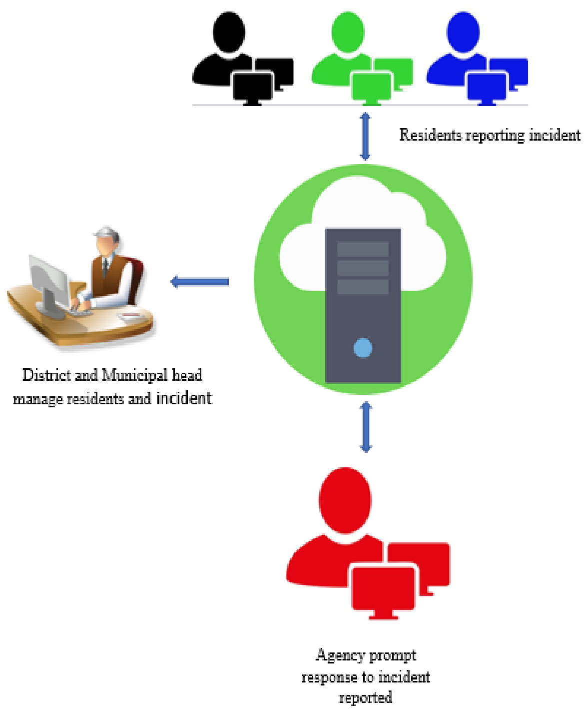
(Source: Abolade et al., 2019)

CREATE POST SCREEN DESIGN

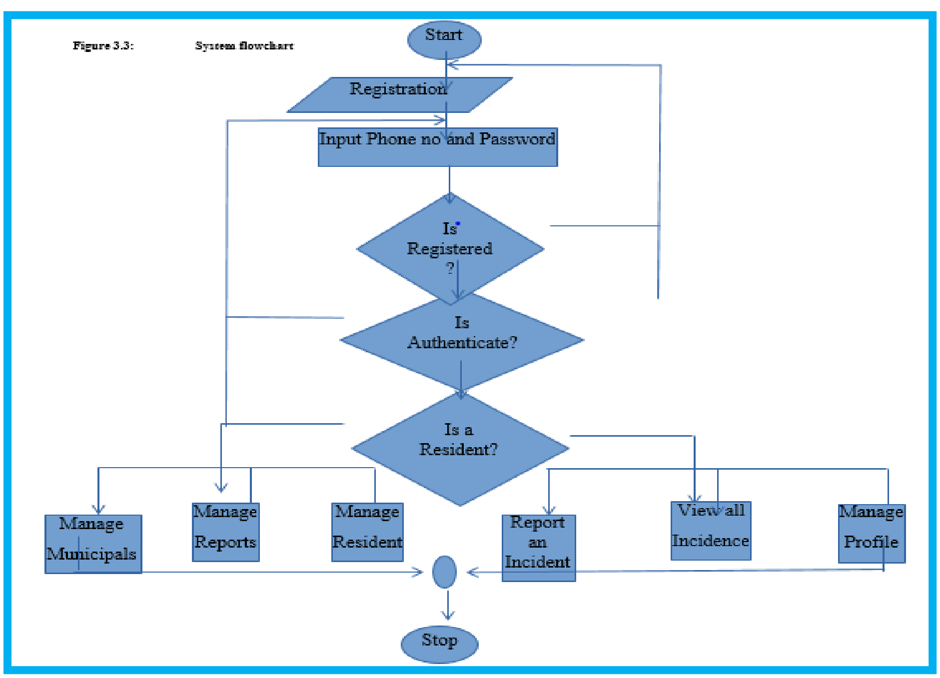
```
<?xml version="1.0" encoding="utf-8"?>
<androidx.coordinatorlayout.widget.CoordinatorLayout
xmlns:android="http://schemas.android.com/apk/res/android"
  xmlns:app="http://schemas.android.com/apk/res-auto"
  xmlns:tools="http://schemas.android.com/tools"
  android:layout_width="match_parent"
  android:layout_height="match_parent"
  tools:context=".ui.activities.CreatePostActivity">
<com.google.android.material.appbar.AppBarLayout
    android:layout_width="match_parent"
    android:layout_height="wrap_content"
    android:theme="@style/AppTheme.NoActionBar.AppBarOverlay">
<androidx.appcompat.widget.Toolbar
      android:id="@+id/toolbar"
      android:layout_width="match_parent"
      android:layout_height="?attr/actionBarSize"
      android:background="?attr/colorPrimary"
      app:popupTheme="@style/AppTheme.NoActionBar.PopupOverlay" />
</com.google.android.material.appbar.AppBarLayout>
<include layout="@layout/content_create_post" />
</androidx.coordinatorlayout.widget.CoordinatorLayout>
```

(Source: Abolade et al., 2019)

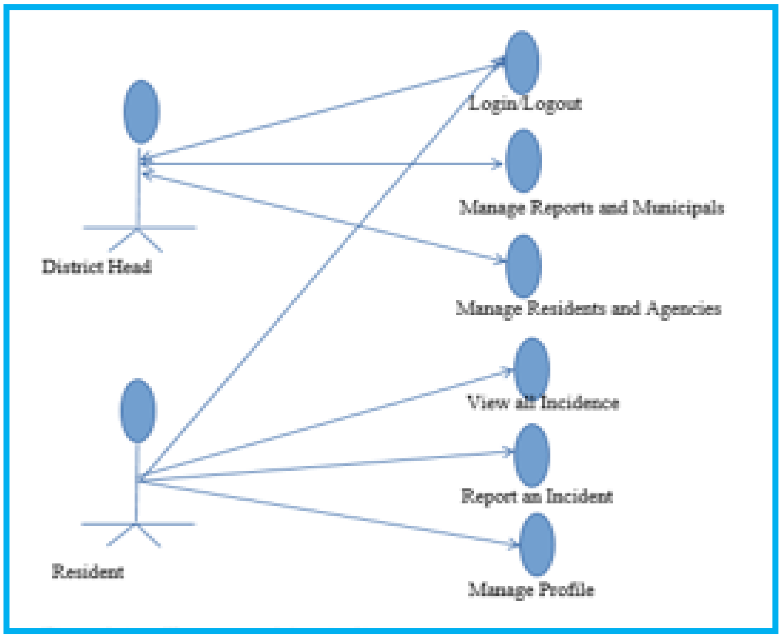
Appendix 16: Overview of proposed Mopani Hotspot reporter system is a 3-tiers architecture



Appendix 17: Proposed Mopani Hotspot reporter system flowchart



18: Proposed Mopani Hotspot reporter system use-case model main diagram



APPENDIX 19: LANGUAGE EDITING LETTER

Department of Communication,
University of Ilorin, Ilorin, Nigeria
13/02/2022

RE: TO WHOM IT MAY CONCERN

This letter is to certify that I have edited the thesis Titled

Urban Households' Vulnerability and Adaptation to Climate Change in Mopani District, Limpopo Province, South Africa

By

Jimoh Musa Yusuf

Student No: 17003332

I hereby certify that I carefully read through the thesis with focus on grammatical errors and spelling mistakes.

Please do not hesitate to contact me for any clarification.

Yours Sincerely,

Dr Oba Abudulkadir Laaro

BSc (University of Lagos), MSc (University of Lagos), Ph.D (Utara University, Malaysia)

e-mail address: obalaaro@gmail.com

+234 810 233 6636

Final Thesis

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