

**“Identifying suitable land uses and possible conflicts through LUCIS analysis and including localised geological circumstances: JB Marks and City of Matlosana local municipalities, South Africa as case studies”**

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## **PREFACE**

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## ABSTRACT

This research is aimed at identifying land use conflicts in the JB Marks and City of Matlosana municipalities, South Africa, which could be used as a framework for future spatial developments. South African cities are experiencing urbanisation at a rate exceeding the capabilities of cities to properly plan city expansion. This leads to urban sprawl which causes the loss of productive agricultural land and valuable biodiversity. This leads to a problem which will lead to issues such as food security, disasters and inequality. Therefore, the study is designed to help tackle these issues. Further objectives for the study are to identify suitable locations for conservation, urban and agriculture land uses and in turn support biodiversity conservation efforts. Therefore, Land Use Conflict Identification Strategy (LUCIS) is used which can identify possible land use conflicts by calculating land use suitability and comparing these suitability metrics. This information allows decision makers to make effective decisions for land use management and support sustainability. By using a literature review criterion are chosen for urban, conservation and agriculture land use suitability. Questionnaires and literature reviews were then used to create weights for the criteria by using the Analytic Hierarchy Process (AHP) method. The weights were used as inputs for weighted overlay in GIS which created the land use suitability maps. By combining the maps land use conflict could be identified and showed a wide variety of conflicts between all three land uses. Most notably the conflict between agriculture and conservation represented the majority of the conflict followed by agriculture and urban conflicts. Furthermore, a Height Above Nearest Drainage (HAND) model was used to identify possible flood risk, which showed a large extent of Potchefstroom and Klerksdorp's urban area has high flood. This accomplished the objectives of identifying hazardous areas and highlighting the value of adding flood risk to LUCIS. The LUCIS method can further be developed by looking at higher levels of public participation and a greater variety of variables. The addition of flood risk is a valuable tool to help future decision and therefore more detailed methods of determining flood risk will add value to such research. By using the maps created land use decisions in the study area can mitigate the effect cities have on the environment by allocating land for the best uses.

**Key terms:** LUCIS, land use management, spatial planning, flood risk, disaster risk, JB Marks municipality, City of Matlosana municipality, GIS, Multi-Criteria Decision Making, HAND

## OPSOMMING

Die navorsing is gemik daarop om grondgebruik konflikte te identifiseer in die JB Marks en City of Matlosana munisipaliteite, Suid-Afrika, wat dan gebruik kan word as riglyn vir toekomstige ontwikkelings in die area. Suid Afrikaanse stede ervaar verstedeliking teen 'n tempo wat nie deur plaaslike stede gehanteer kan word in terme van stedelike uitbreiding. Hierdie uitbreidings lei tot stedelike spreid wat veroorsaak dat produktiewe landbou grond en belangrike biodiversiteit verlore gaan. Dus, is die studie ontwerp om hierdie probleme te help aanspreek. Die studie het ook doelwitte gestel wat grondgebruik geskiktheid wil identifiseer in die area vir bewaring, landbou en stedelike gebruike wat weer ook sal help met biodiversiteit bewaring. Dus, is die LUCIS (Land Use Conflict Identification Strategy) gebruik wat die geskiktheid van grondgebruike bepaal en dan die verskillende areas van geskiktheid teen mekaar opmeet om te bepaal watter areas is in konflik teenoor mekaar in terme van die beste geskikte grondgebruik. Die inligting sal besluitnemers help om meer ingeligte besluite te neem wat effektiewe en volhoubare grondgebruik ondersteun. Deur gebruik te maak van 'n literatuur studie is faktore geïdentifiseer vir stedelike, bewaring en landbou grondgebruike. Vraelyste en verder literatuur studie is gebruik om gewigte te bepaal van belangrikheid vir elke faktor deur middel van die AHP (Analytic Hierarchy Process) metode. Die gewigte is toe gebruik in GIS (Geographic Information System) om 'n geweeegde oorleg (weighted overlay) te doen wat die grondgebruik geskiktheid kaarte geproduseer het. Die kaarte kon toe teen mekaar opgeweeg word om die konflik te identifiseer en het verskeie areas van konflik wel aangetoon. Die meeste konflik kon gesien word tussen landbou en bewaring grondgebruike met konflik tussen stedelike en landbou grondgebruike die volgende hoogste geval van konflik. Daarna is 'n hoogte bo naaste uitloop (HAND) model gebruik om 'n idee te kry van moontlike vloed risiko in die area. Die model het toe aangetoon dat daar baie areas in Potchefstroom en Klerksdorp is wat moontlike hoë vloed gevaar het. Hierdie was weereens een van die studie se doelwitte om te bewys die aanwinst wat die HAND model is tot 'n LUCIS studie en om moontlike ramp gevaar areas te identifiseer. Die LUCIS metode kan verder verbeter word deur gebruik te maak van publieke deelname op 'n groter skaal. Die gebruik van vloed risiko het goed gewerk en meer in diepte metodes van vloed vlaktes bepaal kan meer waarde toevoeg tot die tipe navorsing. Deur hierdie kaarte te gebruik in toekomstige besluitneming kan stede se effek op die omgewing verminder word en sodoende die beste gebruik vir die elke stuk grond aan gewend word.

**Sleutel terme:** LUCIS, grondgebruik bestuur, ruimtelike beplanning, vloed risiko, ramp risiko, JB Marks munisipaliteit, City of Matlosana munisipaliteit, GIS, Multikriteria besluitneming, HAND

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

UN- United Nations

LUCIS- Land Use Conflict Identification Strategy

GIS- Geographic Information Systems

SDF- Spatial Development Framework

HAND- Height Above Nearest Drainage

DEM- Digital Elevation Model

AHP- Analytical Hierarchy Process

SANBI- South African National Biodiversity Institute

CBA- Critical Biodiversity Area

ESA- Ecological Support Areas

WW2- World War Two

SPLUMA- Spatial Planning and Land Use Management Act

DFA- Development Facilitation Act

ENSO- El Niño South Oscillation

DMA- Disaster Management Act

NDMF- National Disaster Management Framework

NGO- Non-governmental Organisation

IDP- Integrated Development Plan

SDG- Sustainable Development Goals

CBD- Central Business District

MCDM- Multi Criteria Decision Making

MAUT- Multi-Attribute Utility Theory

CBR- Case-Based Reasoning

DEA- Data Envelopment Analysis

SMART- Simple Multi-Attribute Rating Technique

GP- Goal Programming

SAW- Simple Additive Weighting

TOPSIS- Technique for Order Preference by Similarity to Ideal Solutions

CR- Consistency Ratio

CI- Consistency Index

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# CHAPTER 1: INTRODUCTION AND BACKGROUND

This chapter discusses the issues which the research aims to address while also introducing the type of research which will be conducted. Furthermore, the study area will be revealed while also mentioning the aims and objectives of the study.

## 1.1 Problem statement and contextualisation

Urbanisation, or rural-urban migration, is increasing in urban centres around the world due to the economic opportunities, services, and variety of facilities present in these areas (Van Maarseveen et al., 2019:1). The United Nations (UNDESA(a), 2018:21) reported a 1.1% rate of urbanisation between 2015-2020 in less developed regions, such as South Africa, which is four times more than the 0.26% found in more developed regions. The report further states that although the rate of urbanisation is expected to decline worldwide over the coming years, the rate in less developed regions is likely to remain more than double that of more developed regions (UNDESA(a), 2018:21). Between 1990-2018 Africa experienced the second highest rate of urbanisation globally and is expected to have the highest rate by 2050 (UNDESA(a), 2018:27-28). South Africa's urban population is growing rapidly, with an estimated 53% of the population residing in urban areas in 2001; this is projected to rise to over 80% by 2050 (UNDESA(b), 2018; Turok, 2012:3). UNDESA(c) (2018) predicts an urbanisation rate of 0.75 for South Africa, which poses a challenge to policy makers and urban planners. Strategies must be devised and implemented to accommodate for the growth, while still ensuring environmental conservation, economic growth, and quality of life through spatial planning (Carr & Zwick, 2005:59).

Spatial planning has long-term effects on the way land is utilised, and determines how spaces are used by allocating, delineating, and sizing space in a way that allows multiple uses to be integrated (Sutanta et al., 2013:761; Sutanta et al., 2010; Greiving & Angignard, 2014:289). The growth in population also leads to a physical growth of a city's urban footprint; this is known as urban sprawl (Bekele, 2005:1). There are different perspectives on urban sprawl; some believe it is created unintentionally through suburban living and commuting; others believe it is a waste of resources such as land and water, and will probably impact biodiversity (Banai & De Priest, 2014). Owusu (2012:2) describes urban sprawl as the physical outward development of a city that leads to low-density neighbourhoods, separated land uses, and the need to commute for economic opportunities. Urban sprawl can also be a consequence of differential urbanisation, which is when more affluent populations move further away from urban centres to improve their living conditions (Geyer & Kontuly, 1993: 170). The South African government mentions the need for more

compact cities and towns in their vision for an ideal urban landscape in the future (COGTA, 2016:12). To achieve this, these compact cities will need to be planned and regulated accordingly.

With the rise in urban population, possible land use conflicts can occur; land uses compete when an area is suitable for more than one use, but cannot accommodate both (Carr & Zwick, 2007:279). When these conflicts arise, a Land Use Conflict Identification Strategy (LUCIS) can be used. The LUCIS method uses GIS (Geographic Information System) maps that identify suitable land uses for a given area of land and overlap these maps to identify conflicts (Gormus et al., 2018:420). When the current land use has a higher suitability metric for a specific piece of land, it will retain that land use; this prevents conflict between different uses (Gormus et al., 2018:419).

This study will focus on the JB Marks and City of Matlosana municipalities. It will use the methods described by Cilliers (2017), applicable to a more urban area with different variables, and will also include dolomite mapping. Cilliers (2017) combines the LUCIS model with data from flood-prone areas, which allows him to identify land use conflict areas, as well as flood-prone areas. The study area contains two of North West Province's primary nodes, Klerksdorp and Potchefstroom; these also form part of a development corridor along the N12 national road (Dr Kenneth Kaunda District Municipality, 2021:211,212). Therefore, these nodes are ideally situated for economic development, which is an attractive factor for rural populations in search of economic opportunities. In addition, the North-West University's main campus is situated in Potchefstroom, which has led to the creation of a science and technology park in Potchefstroom (Dr Kenneth Kaunda District Municipality, 2021:109). According to data obtained from the Lightstone analytics firm, Potchefstroom and Klerksdorp are two of the fastest growing non-metro urban regions in South Africa (Anon., 2021). Quantec (2019) predicts a rise in population of more the 6% for the City of Matlosana area, and nearly 10% for the JB Marks municipality. Between 2001 and 2011, only three provinces, including North West, experienced a net increase of migrants (Maritz, 2015). Maritz (2015) shows that this increase occurred in the area bordering the Gauteng province; thus, Potchefstroom and Klerksdorp are situated in an area that is experiencing an influx in population from other regions. This growth in population may lead to urban sprawl, which could lead to various negative consequences, including pollution, loss of farmland, loss of habitat for endangered fauna and flora, separating poorer communities from work opportunities, and major financial strain on communities because of the need for transport infrastructure, especially for commuting (Osuwu, 2012:1; Rog, 2010:708).

The study area is also heavily dependent on mining activity and agriculture (Dr Kenneth Kaunda District Municipality, 2021:108); thus, it must be considered during the development of the area. Studies show that mining activity is responsible for widespread land degradation and

environmental pollution, which impacts land use suitability (Winde & Stoch, 2015:73). The Mooi River, which supplies drinking water to Potchefstroom, has been severely affected by pollution from the mines and developments along the river (Labuschagne, 2017:5; Annandale & Nealer, 2011). The Schoonspruit River, which runs through Klerksdorp, is a major tributary to the main body of the Vaal River, and impacts the water quality of the Vaal River due to pollution caused by diamond mining on the banks of the Schoonspruit River (Molale, 2012:12; City of Matlosana, 2009:35).

Although productive farmland plays an important role in food security for the country and the economic sector of the region, biodiversity also needs to be conserved by identifying ecosystems that are of critical importance (Ricketts & Imhoff, 2003; Dr Kenneth Kaunda District Municipality, 2021:109-111). As mentioned, the Mooi River is significant, as it supplies Potchefstroom's fresh water supply. The Mooi River is also home to peatlands, which make up only 10% of South Africa's wetlands; these peatlands are the habitat of a variety of rare species, and also contain large amounts of carbon (Van Vuuren, 2010:17-19). The region is also home to the Highveld Nature Reserve, which protects 10,200 hectares of grassland between Potchefstroom and Klerksdorp (Mahlomola et al., 2010:1-2). This conservation effort demonstrates that the area has rich environmental resources that must be protected from agriculture, urbanisation, and other disruptions.

As city development extends, buildings and infrastructure are constructed on more hazardous sites, resulting in more opportunities for disasters and hazardous events to occur (Sapountzaki et al., 2011:1470). Therefore, land use management and planning are essential components of spatial planning, which reduce the impact that natural hazards can have on communities (Banba & Shaw, 2017:8). Enemark (2010:197) emphasises the importance of the role that land management professionals, such as urban planners, play in creating a sustainable urban environment. He also mentions the need for spatially enabled planning, i.e. allowing the characteristics of a space to dictate the activities that should occur in that area (Enemark, 2010:202). Ignoring spatial factors may result in vulnerability to disasters; Okunola (2019) mentions various contributing factors, including the location of a community, environmental degradation of the area, and awareness of potential hazards, such as flooding or sinkhole development. The development of land uses in unsuitable areas can damage the environment, physical infrastructure, and human health (Nolan et al., 2013:34).

Flooding is a natural hazard that causes damage and loss, but the scale of the disaster is directly determined by anthropogenic developments and their location (Dalu et al., 2017:481; Musyoki et al., 2015:8). Flooding can occur regardless of extreme rainfall or climate change because of land uses (Hidayat et al., 2020:3421) located in areas that are vulnerable to flooding, or that create

excess runoff, and that allows people to create informal settlements in hazardous areas (Musyoki et al., 2015:8; Zope et al., 2014:888).

Allowing uncontrolled growth in informal settlements puts the communities in harm's way, not only in terms of flooding but also sinkhole formation. Heath & Oosthuizen (2008:2) emphasise the dangers of sinkhole formation on dolomitic land in the Potchefstroom and Klerksdorp area. Research by Smit (2017:94) indicates the presence of dolomite in the JB Marks municipality (formerly Tlokwe municipality), which reveals the need to include dolomite data in the study. Oosthuizen & Richardson (2011:2) conclude that the rest of the study area is also vulnerable to the effects of dolomite. Dolomite is a dangerous geological formation that is prone to ground surface instability that causes sinkholes (Oosthuizen & Richardson, 2011:1; Van Schalkwyk, 2017:167). These sinkholes cause damage to property, infrastructure, and the environment, which has a major economic, environmental, and social impact. Therefore, it is vital to ensure that urban developments are situated on stable ground, and away from dolomitic land, which is prone to sinkhole formation.

These dangers reveal the importance of identifying suitable land uses for an area before any development occurs. Oranje & Merrifield (2010:30) mention how planning has changed in the 21st century. They emphasise the need for effective use of scarce resources in urban areas, and for creating systems in planning that facilitate dialogue between different spheres of government and society. Cilliers (2017:2) identifies the lack of incorporating spatial data on disaster-prone areas when allocating land uses in a municipality's Spatial Development Framework (SDF). Therefore, introducing a LUCIS analysis, along with data on flood-prone areas and dolomite sites, could address the shortcomings of certain SDFs, especially considering the lack of such analyses in South Africa in the context of urban areas and mining regions (Cilliers, 2019:9).

The land uses of interest in the LUCIS model are grouped into three categories namely, conservation, agriculture, and urban (Carr & Zwick, 2005:59-60; Cilliers, 2019:2). These categories of land use each have certain criteria for determining their suitability for an area of land.

Using the LUCIS model, the study will identify land use conflicts and suitability by taking the various factors into consideration. A LUCIS study was done on the JB Marks municipality in 2010, but it did not integrate a Height Above the Nearest Drainage (HAND) analysis in the suitability maps (Cilliers & Drewes, 2010). Therefore, by adding the data from a HAND analysis, this study aims to supplement the previous LUCIS analysis and demonstrate the value of adding such data. Furthermore, the HAND procedure can identify flood-prone areas in the study area and compare them to the suitability maps (Cilliers, 2019). Flooding is a hydrometeorological hazard that is

responsible for the majority of economic losses that are caused by natural hazards in Sub-Saharan Africa (Schneiderbauer & Ehrlich, 2004:12; Van Niekerk & NemaKonde, 2017:3). The dangers of flooding are not always limited to the 100-year flood line, as Cilliers (2017:6) reported. Cilliers' (2017) study on the Greater Tuang Local Municipality indicates the benefits and cost-effectiveness of using a HAND procedure analysis to supplement spatial planning. The HAND procedure uses a location's vertical height above the nearest drainage network to determine the flow and amount of water that would run through the area (Zhang et al., 2018:2; Johnson et al., 2019:2406). By using Digital Elevation Models (DEM), the topography and drainage networks can be studied and used for calculations to form a HAND analysis in ArcGIS (Nobre et al., 2011:13-15; Zhang et al., 2018:2).

## **1.2 Research aims and objectives**

The study's research aim is to create a framework through LUCIS analysis for the region of JB Marks and City of Matlosana to guide future developments and land use conflicts.

### **1.2.1 Research objectives**

The study aims to achieve the following 4 objectives while working towards the research aim:

- Creating a land use suitability map that highlights land use conflicts in the study area.
- Identifying possible hazardous environments for current and future developments in terms of flooding and surface instability.
- Aiding in protecting critical biodiversity and productive agricultural land from urban sprawl, mining activity, and other competing land uses.
- Demonstrating the value of incorporating more detailed analyses on flooding and dolomite presence in a LUCIS study.

## **1.3 Summary**

The aims and objectives will drive the study's design to ensure the above-mentioned goals are met. The problems and issues discussed are all of high importance and by using the methods described, a framework to help tackle these issues will be formed.

## **CHAPTER 2: RESEARCH METHODOLOGY AND STUDY DESIGN**

This section describes the study in more detail by looking at how the research will be structured. This will include explaining the methods used to gather data, analyse the data and the limitations regarding the research.

### **2.1 Study context**

The study will use a mixed research methodology. Mixed research methods use qualitative and quantitative data, either concurrently, sequentially, or both (Cohen et al., 2018:32). The literature review will incorporate existing research regarding urban land use, which will comprise qualitative and quantitative data. This data will justify the variables chosen for this study and serve as background information for the empirical research. The empirical research will be conducted in various stages. The first stage will focus on the formulation of initial suitability maps, which will identify areas suitable for urban, agricultural, or conservation land uses. The urban land uses will comprise residential, commercial, and industrial uses. These maps will be formulated by applying the Analytic Hierarchy Process (AHP) to the variable datasets and using the weighted overlay procedure in ArcGIS ArcMap. The AHP entails ranking variables according to their importance for the decision-making process; they are then assigned a corresponding proportion or weight (Brunelli, 2015:2). This allows the creation of a relative measurement that enables a comparison of intangible values, such as the qualitative data from variables that affect the suitability of a particular land use (Brunelli, 2015:2). Various sources of information will be used to formulate these relative measurements. The primary source will be questionnaires completed by experts in urban planning, with specialisation in the management of land uses. The urban land uses will consist of separate suitability maps for residential, commercial and industrial use. The questionnaires will be used to determine the importance of different factors that influence the suitability of an area regarding a certain land use. The questionnaires will name the factors and prompt the participants to rank the variables according to their importance (in their opinion). The conservation variables in the study will be ranked according to the South African National Biodiversity Institutes' (SANBI) guide on land use planning regarding protected areas, critical biodiversity areas (CBA), and ecological support areas (ESA) (SANBI, 2018). The suitability layer for agriculture land uses will be created by considering other studies and their methods of identifying suitable agricultural land. The primary data will be supplemented by expert reports and research on the variables. This phase of the study will identify flood-prone areas through the HAND procedure by using a digital elevation model.

The data that will be used for the GIS analysis will be sourced from various stakeholders, including government and private institutions. The main data source for the variables' spatial data is sourced from the planning firm that formulated the Dr Kenneth Kaunda District Municipality Spatial Development Framework.

The next phase will entail the LUCIS analysis, which will compare the various suitability maps for each land use and create a suitability map of the area for all the land uses. This final suitability map will then be analysed alongside the map of flood-prone areas to identify possible hazardous areas, especially relating to residential areas.

## **2.2 Population and sampling**

The population for the questionnaires will consist of experts in the field of urban planning. The sample groups from these populations will indicate how important certain factors are to the different land uses. The target population is therefore South African professionals who are familiar with the context of the study area.

Using expert sampling, a sample group for each field of study will be developed. Expert sampling refers to recruiting participants who have expertise in the research topic (Maccallum et al., 2019:153). This sampling method is normally used in studies where there is a lack of observational data (Etikan et al., 2016:3); thus, due to the lack of data in the urban planning field regarding the importance of certain factors on land use suitability, the method fits the study.

The sample size for the urban planning experts will consist of 8 participants. Participants for the sample group will be sourced according to their expertise, familiarity with the study area, and their availability. Participants would need to be experienced in the field of land use layout, and be familiar with the urban environment of the study area, or at least the urban context of South Africa as a whole. Ideally, the sample group will comprise experts from the academic institutions, the public sector, and the private sector.

## **2.3 Recruitment of participants**

Participants will be identified at academic institutions, private practices, and departments in the public sector. Once identified, they will be contacted via email to establish their willingness to participate. This allows potential participants sufficient time to decide whether they would like to participate, whereas they may feel forced to help if asked in person or telephonically (Oliver, 2010:27).

## **2.4 Process of obtaining informed consent**

Once participants agree to participate in the questionnaires, they will receive a consent form. The consent form will provide information on the study and its aims, and what will be expected of the participants. This form then needs to be signed and sent back before they will be able to participate in the study. The form can be found in Annexure A.

## **2.5 Data collection**

As mentioned previously, the primary data collection tool for this study is a questionnaire which can be seen in Annexure B. Once all the variables are identified, the questionnaire will be formulated accordingly. The questionnaire will ask participants to rank relevant criteria in terms of their importance to different land uses. As soon as the informed consent form has been signed and returned, the questionnaire will become available to be completed anonymously. This process will be explained to participants through the informed consent forms.

The spatial data that will be used for the variables, and the eventual mapping of land use conflicts, will be gathered from various sources. The majority of the data will be sourced from Maxim Planning Solutions; these spatial data sets were used to create the SDF for the Dr Kenneth Kaunda District.

## **2.6 Study design**

The study will follow a multiphase, mixed methods design. This means that qualitative and quantitative data will be used concurrently or sequentially, depending on what research is required for the various stages of the study (Cohen et al., 2018:41). The literature review will cover both qualitative and quantitative data, as it provides context and background to the study and its objectives. The questionnaire will source quantitative answers from the participants, which will aid in ranking the different qualitative variables for the empirical research. The empirical research will therefore include qualitative and quantitative data. The qualitative data from variables for the agriculture and conservation aspects will be converted to quantitative measures through the AHP method to conduct a weighted overlay analysis through ArcGIS.

## **2.7 Limitations of the research**

The research is based on the study area's context regarding its socio-economic aspects, physical structure and environmental factors. Therefore, the study methodology and design are applicable to the study area and should be adjusted when the research is applied to another study area, according to its characteristics and context. The study uses the HAND model, which is a method of predicting flood risk, but is not as accurate as full flood risk reports formulated by hydrologists.

Therefore, the HAND model results should be taken as an indication of where flood risk may occur, and should be used in conjunction with other flood risk indicators for more reliable results. The criteria used for the LUCIS was based on the available data and is not an exhaustive list.

## **2.8 Summary**

The study design uses literature and participant responses to create a database which can be used to create the framework for spatial decision making. The chapter explained the methods of gaining the participant responses as well as the manner in which the responses will be analysed. The literature which will fall within the literature review were also described and some important sources of information are mentioned.

## CHAPER 3: SPATIAL PLANNING IN SOUTH AFRICA

The following chapter will discuss the theoretical framework that this study forms a part of, as well as the legislative background of land use planning and disaster management in South Africa. Furthermore, the section will elaborate on the need for this research and how it adds value to the field.

### 3.1 Theoretical framework

Land use is a descriptive term that refers to how land is designated based on how it is perceived or consumed by humans; these designations include residential, industrial, or commercial uses (ESPON, 2012:13). Control measures for land uses and buildings have existed since the start of urban civilisation, but the systems we use for land use management today were devised in the late 19<sup>th</sup> century as a tool to solve health and social problems (Rashid, 2009:117). Since then, the design of cities has evolved from city beautification plans to more participatory and holistic strategies for managing the urban landscape (Kaiser & Godschalk, 1995:365; UNCCD, 2022:11). Metternicht (2018:9) defines land use planning as the assessment of land and water potential by considering economic and social conditions; this enables the adoption of the most suited land use for the benefit of the people, while also protecting natural resources.

South Africa's spatial planning and land use management has been heavily influenced by the former colonial regime, which means that many of the post-World War 2 (WW2) spatial planning models have shaped the development of the South African urban environment (Horn, 2019:959). The first of these models saw urban planning as an exercise in the physical design of a city, and was used for the first 20 years after WW2 in Britain and around the world. Planning was considered an extension of architecture, which led to the perception that aesthetics was as important as the functionality of a city. Early schemes created by Ebenezer Howard and Le Corbusier greatly influenced the post-war movement concerning the way planners imagined the perfect city (Taylor, 1998). Le Corbusier's vision of a city was modernistic in its aesthetic and functional design, which attempted to create different zones for single land uses, with major highways used as rapid movement corridors between the zones (Taylor, 1998; Fitting, 2002:74). Howard's vision, on the other hand, was to urbanise the countryside and move away from the metropolitan system by creating cities that can only grow to a certain size; thus, his vision combined the economic opportunities of the urban landscape with the natural beauty and clean air of the countryside (Taylor, 1998; Tizot, 2018:16, Hall *et al.*, 2003:23). Howard's garden city was one of the first to create separate zones or wards for different residential neighbourhoods, which influenced the notion of creating neighbourhood units in post-war planning (Hall *et al.*,

2003:36). The garden city was pre-planned to the finest detail, with different land uses specifically allocated to different areas as Fig. 3-1 illustrates. The centre of the city would be dominated by large public buildings, a marketplace, and a well-kept garden. Surrounding the centre would be a series of roads in concentric rings, which would create blocks for residential use. At the edge of the residential area would be a grand avenue providing space for schools and gardens, while also acting as a barrier to the industrial zone at the edge of the concentric city. To transport goods and ease the traffic inside the city, the industrial zone would be connected to a railway system; this would also act as the urban edge where no further urban development could occur and where the agriculture belt would start (According to Howard as cited by Clark, 2003:91-92). As can be seen by the short explanation of Howard and Le Corbusier’s models, urban management and design followed a form of “blueprint” planning wherein all aspects of a city, such as the transportation layout and land use placement, were pre-determined by urban planners (Taylor, 1998). New Towns were consequently created, where residential areas were physically separated, with each neighbourhood furnished with its own shopping centre, school, and green spaces, while industrial areas were totally isolated from other sectors of the town (Taylor, 1998). These models are different forms of master planning and had a great influence on the planning system of South Africa, a former colony of Britain; however, the 1970s saw a heavy backlash against these models due to a lack of public participation (Horn, 2019:961).

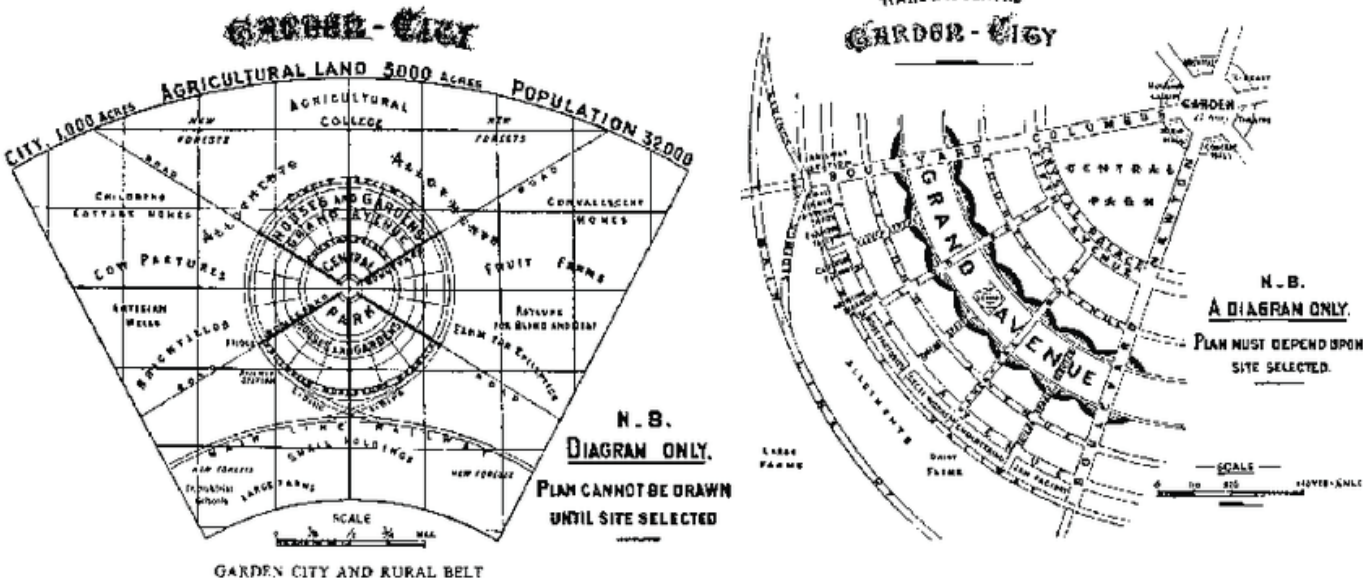
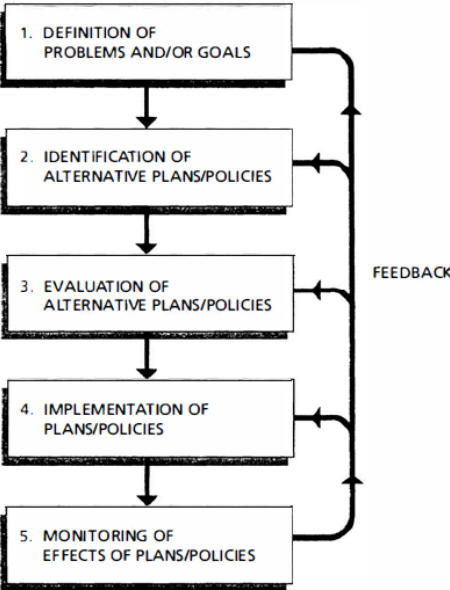


Figure 3-1: Diagrams for the principle of the Garden City (Legeby, 2010:29).

Taylor (1998:159) claims there was a shift in urban planning from an art form to a more scientific process, which was driven by the ideas of systems planning and the rational process view in the mid-1960s. The systems theory considers a city's different land uses and activities as interconnected systems that influence one another (Batty 1982:253; Taylor, 1998:61). As can be seen in Fig 3-2, the rational process view was a procedural view of planning that took scientific evidence into account when creating plans for an urban system (Taylor, 1998:71). This meant that the distribution of land no longer followed a master plan that focused on the aesthetics of a city; instead, different variables were considered to find the best suited area for a specific land use. In South Africa in the 1970s, the focus of the rational and systems views of planning was to create separate black communities and townships by moving industrial growth to these areas rather than in the white cities. This was done to prevent black people from migrating to the white areas to seek employment (Horn, 2019:963). They understood that the placement of industrial land uses would influence the demographic of the area surrounding the industries due to work opportunities and the need for a black workforce. Therefore, they used the way in which land uses and activities interact to achieve their goal of racial segregation.



**Figure 3-2: Diagram of planning as a rational process (Taylor, 1998:68).**

In the late 1980s, a new form of urban planning, namely communicative planning, started to develop. This type of planning viewed the practice of urban planning as an interdisciplinary process between various stakeholders, where public participation plays a major role in deciding

the final plans for the city (Alikaei *et al.*, 2020:2; Taylor, 1998:122). The movement away from determining urban planning decisions by using scientific values alone was due to the realisation that there is great value in the knowledge of the inhabitants and other stakeholders that cannot be measured quantitatively, such as social aspects (Alikaei *et al.*, 2020:2; Perera, 2017:55). Documents, such as the Spatial Planning and Land Use Management Act (SPLUMA), that South Africa uses as a spatial planning framework (which will be discussed in full later) uses communicative planning principles as a central part of its implementation, with public participation included as an important factor for planning decisions. This meant that land use planning was no longer only decided by the urban planner, but was a decision made by various stakeholders, including the residents who would be affected by the plans.

Since communicative principles gained acceptance, the public has had a greater influence on their environment's development; however, there is still a need for control, especially since the importance of environmental conservation has been highlighted in every aspect of modern life (Taylor, 1998:152). Therefore, any land use planning in the modern time needs to take environmental, public, economic, and social aspects into account.

### **3.2 Legislative framework for spatial planning in South Africa**

#### **3.2.1 Planning legislation and history in South Africa**

The current spatial layout and land use management of South African cities have been influenced by the laws of the apartheid regime of old. In the early part of the 20<sup>th</sup> century, laws were passed in South Africa that made it illegal for people of colour to own land in urban regions, which led to the creation of townships on the outskirts of urban areas (Turok, 2012:7; Ebrahim & Muresherwa, 2021:559). Turok (2012:11) mentions that the mass forced removals that occurred across South Africa during the 1950s led to non-white residents being forced to move to the peripheries of urban areas; they were not allowed to live in the inner city, or to operate businesses without special permits. As early as 1913, the first legislation was put into place to separate races on a national scale, with the first forms of local land use planning that supported this segregation being implemented in the 1920s (Van Wyk & Oranje, 2014:355). These laws have led to a situation in current day South Africa where many low-income households are in poorly situated neighbourhoods (Newton & Schuermans, 2013:581). Furthermore, this segregated spatial form necessitates longer commutes, resulting in higher carbon emissions and greater service costs for municipalities (Turok, 2012:21).

In response to these challenges, the post-apartheid government created the Development Facilitation Act, 67 of 1995 (DFA). The DFA was implemented mainly to streamline the process

of development, especially for low-income housing, to ensure a faster turnaround time for low-income housing development applications (Berrisford, 1997:57; Emdon, 1994:89; Rigby & Diab, 2003:172). The DFA was used to create provincial tribunals with the authority to override certain older legislation; this was done to fast-track development by removing certain restrictive conditions, servitudes, and planning legislations that could hamper housing developments (Emdon, 1994: 91; South Africa, 1995:28). The DFA set certain parameters for the tribunals to use in making land use decisions; these included guiding principles, namely, integrating the segregated black areas and cities, creating more compact cities, developing residential areas closer to work opportunities, and implementing diverse land uses while ensuring sustainable land development (Emdon, 1994: 91; South Africa, 1995: 10-12). The DFA was originally created as a framework to bridge the gap between apartheid planning laws and new planning legislation (Rigby & Diab, 2003:170).

The Spatial Planning and Land Use Management Act, 16 of 2013 (SPLUMA) only came into effect in 2015, as the first comprehensive and cohesive legislative framework to guide development across the entire country (Nel, 2016:80; Van Wyk & Oranje, 2014:357). SPLUMA's goal is to create more integrated and cohesive municipal development, and to help rectify the spatially segregated nature of South Africa's urban environment by situating people closer to their work and basic services (South Africa, 2013:2; Van Wyk & Oranje, 2014:357). SPLUMA requires each municipality to create a Spatial Development Framework (SDF) that indicates the desired spatial layout for the next 5 years, as well as a longer-term plan of 10 to 20 years for spatial growth. The SDF is a tool that includes maps for land use and for the desired spatial pattern, while incorporating SPLUMA's development principles (Cilliers, 2019:2; South Africa, 2013:32). These SDFs should therefore aid land use decisions within the municipality by considering provincial and national spatial goals, while also implementing economic, environmental, and social objectives (South Africa, 2013:32; Van Wyk & Oranje: 2014:357).

SPLUMA lays out the following development principles (South Africa, 2013:18-20):

**(a) The principle of spatial justice, whereby—**

- i. past spatial and other development imbalances must be redressed through improved access to and use of land;
- ii. spatial development frameworks and policies at all spheres of government must address the inclusion of persons and areas that were previously excluded, with an emphasis on informal settlements, former homeland areas and areas characterised by widespread poverty and deprivation;

- iii. spatial planning mechanisms, including land use schemes, must incorporate provisions that enable redress in access to land by disadvantaged communities and persons;
- iv. land use management systems must include all areas of a municipality and specifically include provisions that are flexible and appropriate for the management of disadvantaged areas, informal settlements and former homeland areas;
- v. land development procedures must include provisions that accommodate access to secure tenure and the incremental upgrading of informal areas; and
- vi. a Municipal Planning Tribunal considering an application before it, may not be impeded or restricted in the exercise of its discretion solely on the ground that the value of land or property is affected by the outcome of the application;

**(b) the principle of spatial sustainability, whereby spatial planning and land use management systems must—**

- i. promote land development that is within the fiscal, institutional and administrative means of the Republic;
- ii. ensure that special consideration is given to the protection of prime and unique agricultural land;
- iii. uphold consistency of land use measures in accordance with environmental management instruments;
- iv. promote and stimulate the effective and equitable functioning of land markets;
- (v) consider all current and future costs to all parties for the provision of infrastructure and social services in land developments;
- v. promote land development in locations that are sustainable and limit urban sprawl; and (vii) result in communities that are viable;

**(c) the principle of efficiency, whereby—**

- i. land development optimises the use of existing resources and infrastructure; (ii) decision-making procedures are designed to minimise negative financial, social, economic or environmental impacts; and
- ii. development application procedures are efficient and streamlined and timeframes are adhered to by all parties;

**(d) the principle of spatial resilience, whereby flexibility in spatial plans, policies and land use management systems are accommodated to ensure sustainable livelihoods in communities most likely to suffer the impacts of economic and environmental shocks; and**

**(e) the principle of good administration, whereby—**

- i. all spheres of government ensure an integrated approach to land use and land development that is guided by the spatial planning and land use management systems as embodied in this Act.
- ii. all government departments must provide their sector inputs and comply with any other prescribed requirements during the preparation or amendment of spatial development frameworks;
- iii. the requirements of any law relating to land development and land use are met timeously;
- iv. the preparation and amendment of spatial plans, policies, land use schemes as well as procedures for development applications, include transparent processes of public participation that afford all parties the opportunity to provide inputs on matters affecting them; and
- v. policies, legislation and procedures must be clearly set in order to inform and empower members of the public.

Land use planning is mainly affected by the following principles from the above act. Principle **a** (iii) and (iv) both specifically mention the need for land use schemes to help provide better access to land for disadvantage communities, while also ensuring that informal settlements and other disadvantaged areas form part of formal land use schemes and are incrementally upgraded. Environmental factors that must be considered in land use management are explained in principle **b** (ii), (iii), (vi). The principles of **c** (i) and (ii) refer to economic, social, and environmental aspects that must be protected through land use decisions. Flexibility in land use schemes is emphasised in principle **d** to ensure that spatial plans can adapt to sudden changes or community shocks. The whole of section **e** is concerned with ensuring land use schemes are implemented with public participation and transparently, with an integrated approach between different spheres of government.

### **3.2.2 Disaster management and spatial planning**

Sutanta et al. (2009:343) and Greiving & Angignard (2014:292) maintain that every hazard has a spatial dimension; a disaster occurs at a certain geographic location; therefore, spatial elements need to be taken into consideration when disaster risk reduction initiatives are being formulated. Cilliers (2019:1) and Benedict (2009:31) support Greiving and Angignard's point by stating that urban or spatial development planning is one of the most effective ways to implement disaster risk reduction. This section will explain how these disasters are caused, what legislation South Africa has in place to prevent and mitigate these devastating events, and how it influences land use management.

### 3.2.2.1 Natural hazards and disasters

A natural hazard can be defined as an extreme phenomenon or event of biological, geophysical, or hydrometeorological origin, which occurs naturally (Alcántara-Ayala, 2002:108-109; Boccard, 2019:2). According to a report on the natural hazards and disasters of Africa, hydrometeorological hazards accounted for 61% of the disaster events in Africa between 1950-2015, with 36% attributed to biological hazards and only 0.35% to geophysical hazards (Mulgeta et al., 2017:7).

Hydrometeorological hazards include floods, sand or dust storms, droughts, tropical cyclones, heat waves, wildfires, hail or lightning storms, and strong winds (Schneiderbauer & Ehrlich, 2004:12; Van Niekerk & NemaKonde, 2017:3). Climate variability is mainly to blame for these hydrometeorological hazards, with one extreme event possibly causing multiple hazards; for example, a tropical cyclone leading to floods and landslides (Manyena, 2016; Wu et al., 2016:1). Most of these events in sub-Saharan Africa can be attributed to the El Niño South Oscillation (ENSO) phenomenon; of these hazards, droughts and flood disasters are responsible for the majority of disaster-related economic losses and deaths (Van Niekerk & NemaKonde, 2017:3).

In sub-Saharan Africa, biological hazards account for 3% of disasters from 1960 to 2015 (Mulgeta et al., 2017:19). Biological hazards are organic substances that present a threat to the well-being of humans and other organisms, including pathogenic microorganisms, viruses, toxins, spores, fungi, bio-active substances, and biological vectors (Van Niekerk & NemaKonde, 2017:9).

Geological or geophysical hazards include earthquakes, volcanic eruptions, tsunamis, landslides, subsidence, and mudflows (Schneiderbauer & Ehrlich, 2004:12; Niekerk and NemaKonde, 2017:8). Africa has comparatively little seismic activity; the only regions in Southern Africa that are not on relatively stable intra-plate regions are in Botswana and Mozambique. This does not mean that maximum size earthquakes cannot happen in Southern Africa, but they are less frequent (Mulgeta et al., 2017:13-14). In many of South Africa's provinces, dolomite sinkholes are distressing geological hazards, but the Gauteng province experiences the most subsidence and sinkhole events, with 23% of the province comprising dolomite land (Buttrick et al., 2011; Constantinou & Van Rooy, 2018:2) The most common cause of sinkhole formation on dolomite land is an influx of groundwater caused by leakages in water pipes in urbanised areas (Kleinhans & Van Rooy, 2016).

Disasters only occur when these hazardous events meet vulnerable human populations (Boccard, 2019:3; Birkmann, 2006:9). These natural hazards form a vital part of the earth's ecosystem, as it has shaped the planet's landscape over time. If these hazardous events were to occur in unpopulated areas, it would not be considered a disaster (Leahy, 2017; Boccard, 2019:3). The

worldwide overall average annual inflation-adjusted losses caused by natural hazards for the past 30 years is US\$140 billion; 2017 was the costliest year ever recorded in terms of economic losses (Van Niekerk, 2019:10; Löw, 2019). Costs relating to economic losses were much lower in 2018 and 2019, but remained higher than the 30-year average (Van Niekerk, 2019:10; Löw, 2019). In 2019, an estimated 9 000 people succumbed to disaster events triggered by natural hazards, with 29% of these deaths occurring in Africa. This is alarming since only 15% of the world's disasters were recorded in Africa, which makes the ratio between deaths and the number of natural disasters much higher than the rest of the world (Löw, 2019). South Africa is not excluded from these losses, with droughts in the Cape Town region that threatened to leave 4.2 million people without water between April and June of 2018, and six other provinces feeling the effect of a multi-year drought (Van Niekerk, 2019:10). This drought cost more than R1.2 billion in damages; 2017 also recorded major economic losses of more than R4 billion between June and October, due to wildfires in Knysna and floods in Cape Town (Van Niekerk, 2019:10). Recent flooding in the KwaZulu-Natal Province led to at least 443 deaths. The Department of Human Settlements and the Department of Public Works estimated the infrastructure damage to be at a value of R5.6 billion, with almost 4000 houses completely destroyed (Dawood et al., 2022). These statistics show that South Africa is vulnerable to disasters that are caused by natural hazards and indicate that poor settlement planning can increase this vulnerability (Van Niekerk, 2019:10).

### **3.2.2.2 Disaster management**

South Africa currently uses the Disaster Management Act No.57 of 2002 (DMA). Its formulation started in 1994 in reaction to severe flooding in the Western Cape province (Van Niekerk, 2014:859). The DMA was introduced to reduce disaster risk, to mitigate the negative impact of disasters, and to improve post-disaster response and recovery through a multidisciplinary approach (South-Africa, 2002). Following the creation of the DMA, the National Disaster Management Framework (NDMF) was created in 2005 to help implement and integrate the concept of disaster management between national, regional, and local spheres of government, as well as NGO's, the private sector, and the public sector (Van Niekerk, 2006:103). The DMA gives guidance on how disaster risk management should be interpreted in South Africa. The NDMF indicates how the various objectives given in the DMA can be achieved (Van Niekerk, 2014:861).

The South African government has required that all local and district municipalities add disaster management plans to their Integrated Development Plans (IDPs) (South Africa, 2002). The Municipal Systems Act No.32 of 2000 states that each municipality should have an IDP (South Africa, 2000). Each IDP gives context-specific solutions, in a spatial extent, for challenges in their respective municipalities to help achieve long-term sustainable development in the area (Santhia

*et al.*, 2018:590; Louw & Van Wyk, 2011:17). The spatial component of these IDPs that should integrate disaster risk management consists of Spatial Development Frameworks (SDFs) (Cilliers, 2019:2). The importance of an SDF and how land use planning forms part of it has already been discussed. By integrating high risk disaster zones into land use plans, geographical vulnerability can be lowered (Roy & Ferland, 2015:76).

According to the DMA it is a disaster risk when there is a chance of a natural or human-induced hazards occurring in vulnerable areas that could cause harmful consequences, including loss of life, livelihood, or property, disruption of economic activities, injury to people, or environmental damage (Louw and Van Wyk, 2011:16). The main method for lowering this risk is to use risk reduction initiatives, which are processes that can help reduce an area's vulnerability and limit the loss sustained during a disaster (Louw & Van Wyk, 2011:17; Sapountzaki *et al.*, 2011:1446). Spatial planning has long-term effects on the way land is utilised. It determines how spaces are used by allocating, forming, and sizing space in a way that allows multiple uses to be integrated (Sutanta *et al.*, 2013:761; Sutanta *et al.*, 2010; Greiving & Angignard, 2014:289). As city development extends, buildings are constructed on more and more hazardous sites; this creates more opportunities for disasters and hazardous events to occur (Sapountzaki *et al.*, 2011:1470). Land use planning is considered an effective practice for lowering disaster risk. This is done by steering development away from dangerous locations and addressing geographical vulnerability, while developing more sustainable communities (Roy & Ferland, 2015:73). For this reason, land use management and planning is an essential part of spatial planning; it can reduce the impact that natural hazards can have on communities (Banba & Shaw, 2017:8).

Unfortunately, a lack of integration between urban planning and disaster management can be found in the various IDPs. According to an assessment of South Africa's municipal disaster management, only 36% of district municipalities, 60% of metros and 17% of local municipalities have fully integrated disaster management plans in their IDPs (Botha *et al.*, 2011:66). Without disaster management forming part of an IDP there will be a lack of disaster risk mitigating initiatives in urban planning and development (Botha *et al.*, 2011:66). During an informal review of ten municipal SDFs Cilliers (2019:2) noticed that many of the SDF documents fail to mention disaster management, with the maps rarely indicating areas where disasters are prone to happen. This hampers the effectiveness of integration that is sought after in modern day disaster risk management. Changes in land uses, settlement policies, population distribution and degradation of habitat are all processes that lead to more vulnerable communities being exposed to greater hazards (Van Niekerk & Wisner, 2014:3).

### **3.3 Need for land use planning**

Modern forms of land use planning started as a tool to address social and health problems within cities. However, modern cities have a greater variety of issues that require attention. These problems include transport congestion, pollution, separation of economic opportunities from low-income residents, segregation of income classes, health issues, and food security (Cervero *et al.*, 2017:1; Drewes & Cilliers, 2010:2; Paz *et al.*, 2020:1; Speck, 2018:25; Van Niekerk, 2018:69; Yiran *et al.*, 2020:3). These problems pose a challenge to the Sustainable Development Goals (SDG) as published by the United Nations (UN) in 2015, which aims to create greater equality, prosperity, and sustainability across the world (UN, 2015). Many of these issues can be attributed to urban sprawl, past planning policies, and urbanisation, which will be discussed in this section, while also considering how land use planning can mitigate the problem and improve sustainability.

#### **3.3.1 Urban sprawl**

##### **3.3.1.1 Defining urban sprawl**

Urban sprawl is considered a major problem, especially in South Africa's urban areas, with the country boasting some of the lowest urban densities in the world (Marais *et al.*, 2020:1). This phenomenon has various definitions but can be described as urban growth with low-density developments and separated land uses which expands past city boundaries, where it occupies rural or agricultural land (Bekele, 2005:1; Karakayaci, 2016:815; Rog, 2010:711). According to Yasin *et al.* (2020:57-60) urban sprawl, like any phenomenon, has certain characteristics. These qualities can be traced back to the low-density and dispersed nature of urban sprawl, which leads to separated and segregated land uses that create disjointed social and economic structures. This leads to higher transport costs and dependence on automobiles for commuting. Furthermore, large single-use land uses and the creation of polycentric developments are present in cities with urban sprawl. Polycentric developments refer to cities having more than one activity centre. Instead of having one Central Business District (CBD) where most of the economic activity occurs, the city has multiple centres at its periphery, where population growth and economic activity sometimes exceed that of the CBD (Lin *et al.* 2012:2). These polycentric developments are then connected to one another by urban sprawl, and create extended urban regions (Sinclair-Smith, 2014:134). Therefore, urban sprawl mainly refers to the expansive nature of an urban area with low-density and an undefined urban boundary.

##### **3.3.1.2 Causes of urban sprawl**

The reasons for urban sprawl have been widely studied and include a variety of factors. Table 3-1 shows a breakdown of the most common factors that lead to urban sprawl, as identified by

Karakayaci (2016:816), and Habibi & Asidi (2011:138); one of the main factors is zoning and the separation of land uses. Zoning was introduced after the industrial revolution to help separate the population from factories, in the interest of public health (Rog, 2010:708). While the initial aim of zoning was done for health reasons, it quickly led to a separation of all land uses, and was used as an instrument for racial segregation (Bekele, 2005:11; Rog, 2010:708; Yasin *et al.*, 2020:59). South Africa has an infamous history of racial segregation controlled by apartheid zoning laws, which created informal black townships on the city's outskirts (Yiran *et al.*, 2020:13).

Population growth and the resulting need for housing has been identified as another major driver of urban sprawl (Bekele, 2005:11; Habibi & Asadi, 2011:137; Karakayaci, 2016:816). Furthermore, Yiran *et al.* (2020:13) state that population growth in urban areas is exacerbated by South Africa's rural-urban migration trend, which inflates the natural population growth in urban areas. South Africa is classified as a developing country, which entails the population moving to cities in search of work opportunities (Bekele 2005:8); new inhabitants often procure housing at the peripheries due to the high costs of housing in formal neighbourhoods within the city boundaries. Pienaar (2002:5) discusses the reasons behind high land values within cities and the need for living in low-cost peripheral neighbourhoods. He states that land use patterns are created that marginalise the poor and that benefit only a small group of residents in the urban area; this can be attributed to the lack of proactive spatial planning, as well as the private sector's influence over zoning laws. The South African government has developed thousands of social and subsidised housing projects, but most of these projects are located at the periphery of urban areas where land is inexpensive. This locates people far from services and economic activities (Sahabodien, 2016:22). The lack of infill development and density increasing projects in established neighbourhoods has forced those with the lowest income to travel the farthest for economic and social activities (Turok, 2012:32). As a developing country, South Africa does not have the resources to satisfy housing needs through public funding; this forces people to create informal settlements (Pienaar, 2002:15; Sahabodien, 2016:22). Furthermore, Bekele (2005:8) identifies the relationship between increasing incomes and the move away from city centres to larger houses with more land in the suburbs connected to the city. This move, steered by preference, and the use of private cars allow people to move away from congested urban centres (Bekele 2005:8; Rog, 2010:713).

**Table 3-1: Factors leading to urban sprawl.**

Category	Factor
Economic	<ul style="list-style-type: none"> <li>• Economic growth</li> <li>• Increasing income</li> <li>• Price of land</li> <li>• Subsidies</li> </ul>
Demographic	<ul style="list-style-type: none"> <li>• Population growth</li> <li>• Rural urban migration</li> </ul>
Housing	<ul style="list-style-type: none"> <li>• More space per person</li> <li>• Greater freedom of choice</li> <li>• Government housing</li> </ul>
Transportation	<ul style="list-style-type: none"> <li>• Private car ownership</li> <li>• Cheaper public transport</li> <li>• Road infrastructure</li> </ul>
Inner city problems	<ul style="list-style-type: none"> <li>• Social problems</li> <li>• Lack of green open space</li> <li>• Small housing options</li> <li>• Damaged infrastructure</li> <li>• Pollution</li> <li>• Unsafe environment</li> </ul>
Regulatory	<ul style="list-style-type: none"> <li>• Poor land use planning/zoning</li> <li>• Weak enforcement of existing plans</li> <li>• Racial segregation policies</li> </ul>

### **3.3.1.3 Effects of urban sprawl**

In the preceding sections, urban sprawl is defined and the causes thereof discussed; the effect it has on an urban area and its surroundings ought to be reviewed. Urban sprawl has been thoroughly studied since the start of the millennium; from these studies, mostly negative impacts have been observed. This section of the study will focus on these observations, as it relates to land use planning's capacity to address these issues.

#### 3.3.1.3.1 Environmental effects

The environment surrounding the city is the most important factor that is impacted by urban sprawl. Urban sprawl is defined as low density urban development that leads to encroachment on and loss of land rich in natural resources, which play vital roles in natural ecosystem services, agriculture, and wildlife habitats (Bekele, 2005:15; Shao *et al.*, 2021:251). When green spaces are replaced by urban infrastructure, the vegetation that supplies ecosystem services is also lost; this may lead to unforeseen consequences such as soil erosion, landslides, flooding, and water pollution, while also removing carbon sequestering plant life (Shao *et al.*, 2021:249). Furthermore, encroachment on agricultural land can lead to food security issues, while also contributing to economic losses in areas where agriculture occupies a large part of the local economy (Yasin *et al.*, 2020:63). The importance of the natural land that surrounds the urban areas cannot be overstated, and therefore the need to protect them from urban sprawl is of utmost importance. Along with land losses, urban sprawl requires residents to commute further, which leads to more automobile use and, consequently, more greenhouse gas emissions (Bekele, 2005:14; Rog, 2010:715; Yasin *et al.*, 2020:63). Han (2020:11) demonstrates the direct increase of carbon dioxide in urban areas when rapid urban expansion occurs.

#### 3.3.1.3.2 Economic effects

As already discussed, the loss of agricultural land can lead to large economic losses in developing countries, such as South Africa, where agriculture plays a significant role in the local economies. With a more dispersed urban structure, local authorities must supply a wider service area with services and infrastructure such as water, refuse removal, and roads, which raises costs and, in turn, the taxes needed for funding (Bekele, 2005:14; Yasin *et al.*, 2020:63). Furthermore, higher income residents and businesses that move away from urban centres into peripheries cause a withdrawal of wealth; this leaves the lower income residents behind, resulting in a concentration of low-income households in city centres, and fewer employment opportunities (Habibi & Asidi, 2011:139; Rog, 2010:716; Bekele, 2005:14). When green spaces are replaced by urban structures, there is a lack of ecological services, which can lead to flooding and landslides as Shao *et al.* (2021:249) states. This, in turn, creates disasters that cause damage to infrastructure and people. The result is higher medical and construction costs to handle the aftermath of such events.

#### 3.3.1.3.3 Social aspects

Ewing (1997:117) looked at the psychological impact that urban sprawl has on residents; he identifies the negative impact that a lack of access to community facilities, services, and employment opportunities can have on residents, which is especially severe when they do not have access to private vehicles. Furthermore, it identifies that there is a lack of spaces in sprawling suburbs where residents can come together for activities and stimulation, with the effect that they have no sense of place or community. As cities grow wider and more dispersed, the travel time between work, home, and social services increases, which creates greater transport needs and, in turn, prolongs travel time even more due to traffic congestion (Bekele, 2005:14; Yasin *et al.*, 2020:61). As mentioned before, urban sprawl can separate income classes, which may lead to service disparity. This means that wealthier neighbourhoods have a large tax reserve and need fewer social services; therefore, more funding can go towards infrastructure and service delivery in these wealthier areas (Bekele, 2005:14). This leaves certain areas with fewer services, jobs, and lower quality infrastructure; this discourages outside investment and leaves these areas economically and socially vulnerable.

#### 3.3.1.4 Land use conflicts due to urban sprawl

The negative effects of urban sprawl are well documented; however, a secondary negative impact of urban sprawl is the fact that it encourages land use conflicts. With cities encroaching on agricultural and environmentally sensitive land, conflict is bound to happen. Housing developers and local municipalities searching for land to provide housing for its citizens are battling with farmers and environmentalists regarding which land is suitable for these housing projects. Furthermore, with larger service areas for municipalities to cover, more services, roads, and facilities are needed; these land uses simultaneously compete with private urban uses for residences, commercial properties, and industries. This eventually leads to a land use conflict between service delivery and profit.

### 3.3.2 Fragmentation and urbanisation

As the previous section explains, South Africa suffered under an apartheid regime that segregated urban areas by race; this has led to city structures where formal city neighbourhoods and suburbs are surrounded by informal settlements. These informal settlements are placed far from work opportunities and services, which has an economic impact on residents and creates the need for time-consuming commutes (Horn, 2019:964; Turok, 2012:21; Visagie & Turok, 2020:357). This fragmentation is also uneven in terms of population density. Turok (2012:20) reports a major disparity in densities between former white suburbs in Cape Town (4-12 persons per hectare) and

the surrounding informal settlements (100-150 persons per hectare). The high density of informal settlements is prevalent in most developing cities across South Africa (Visagie & Turok, 2020:353). This disproportionate population distribution creates challenges in terms of service delivery and land uses. With higher density, land use conflicts become prevalent. In high density peripheral settlements, preference will always be given to residential uses instead of public amenities and recreation spaces, even though these settlements are far from other public facilities in formal neighbourhoods. Due to the high densities and lack of regulation, factors such as natural hazards and environmental dangers are overlooked when people occupy land within the settlement (Visagie & Turok, 2020:356).

Urbanisation creates even more issues regarding land use conflict and contributes to the urban sprawl problem, as mentioned earlier. Since the 1980s, urbanisation has skyrocketed due to apartheid laws no longer being enforceable, and the attractiveness of economic opportunity in the urban areas (Bekele, 2005:8; Turok, 2012:12). Urbanisation contributes directly to the growth of informal settlements, as new inhabitants with low-income are forced to find affordable housing on urban outskirts.

### **3.3.3 Sustainability**

Skidar (2003:1930) defines true sustainability as the simultaneous balancing of environmental, economic, and social aspects; Fig. 3-3 demonstrates this with a Venn diagram. This suggests that one aspect cannot prosper at the expense of the other two. This concept is found in the UN's SDG, where the goals have linked environmental, social, and economic aspects, which means one aspect will not improve at the expense of another (Stafford-Smith *et al.*, 2017:912).

According to SDG Goal 11, making cities and human settlements inclusive, safe, resilient, and sustainable is especially important (UN, 2015). All the goals have objectives that support the overall goal, and SDG 11 is no different. Land use planning can play a major role in many of these objectives by creating better access to green spaces and services, protecting environmental assets, lowering disaster risk, and better integrating urban and rural areas to create sustainable, liveable communities (UN, 2015; Godschalk, 2004:5).

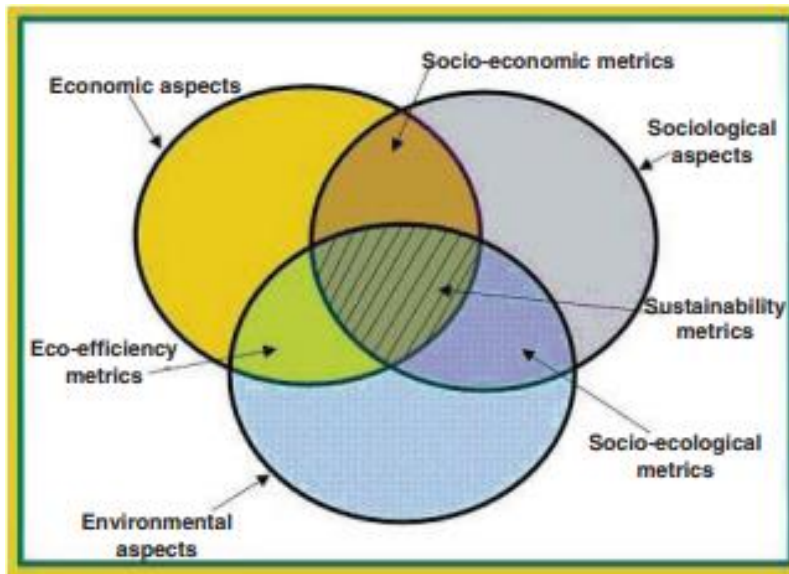


Figure 3-3: The Venn diagram representing sustainability (Skidar, 2003:1930).

The previous section discusses urban sprawl and how it creates various challenges for the goal of sustainability in cities. The negative effect that urban sprawl has on environmental, social, and economic aspects directly contradicts the SDG of the UN; therefore, it needs urgent attention by using the help of land use planning.

### 3.3.4 Effective land use planning

Habibi & Asadi (2011:140) acknowledges that urban sprawl is a major issue, but also sees a solution to this problem; implementing policies to create urban boundaries, supports smart growth, and aim to decrease long commutes. One of the greatest contributors to urban sprawl and unsustainability in cities is the lack of effective land use planning (Metternicht, 2018:4; Nel, 2015:83; Karakayaci, 2016:816). South Africa is no different, with past spatial planning systems and zoning laws leading to the fragmented format of cities today (Nel, 2016:81).

#### 3.3.4.1 Criticisms of zoning

Zoning refers to the deliberate separation of land uses by allowing only certain types of buildings and land uses in specific areas (Nel, 2016:82; Talen, 2012:331). As mentioned before, it originated as a tool for separating polluting industrial activities from residential areas, but in countries such as the USA zoning was used to segregate races (Nel, 2016:82; Serkin, 2020:754; Talen, 2012:332). Racial zoning was used in California during the early 1900s, with certain neighbourhoods reserved for certain races. Even after these laws were outlawed, zoning was used to make predominantly black neighbourhoods less desirable by locating industrial uses within them (Talen, 2012:332). As discussed in section 4.2, one of the main objectives of South

Africa's land use planning policies of the previous century was racial segregation. The USA was also the first country to use zoning as it was meant to be implemented. The town of Euclid implemented six zoning categories, with different land uses allowed in each category, while also restricting building height, coverage, and property setback lines. This is where the term Euclidean zoning comes from when referring to conventional zoning practices, which used zoning to separate incompatible uses from one another (Serkin, 2020:755). Zoning was further used to solve land use conflicts and to protect the property value of primarily single-family homes (Nel, 2016:83).

Talen (2012:330) emphasises the view that a city should encourage the mixing of people, activities, and uses; this cultivates social well-being, economic growth, and sustainable living through the proximity of services and activities. Nel (2016:83) criticises zoning as a land use management system, as it leads to mono-functional areas. These areas prohibit multi-family homes, which exclude the poor, and cause a disconnect between residential and non-residential uses. This disjointed form necessitates commuting between workplaces and homes, while sprawling, low-density, mono-functional residential zones create sustainability issues (Nel, 2016:84). Eventually, these zoning systems create barriers between people, and inhibit a city's role as a promoter of human exchange (Talen, 2012:341).

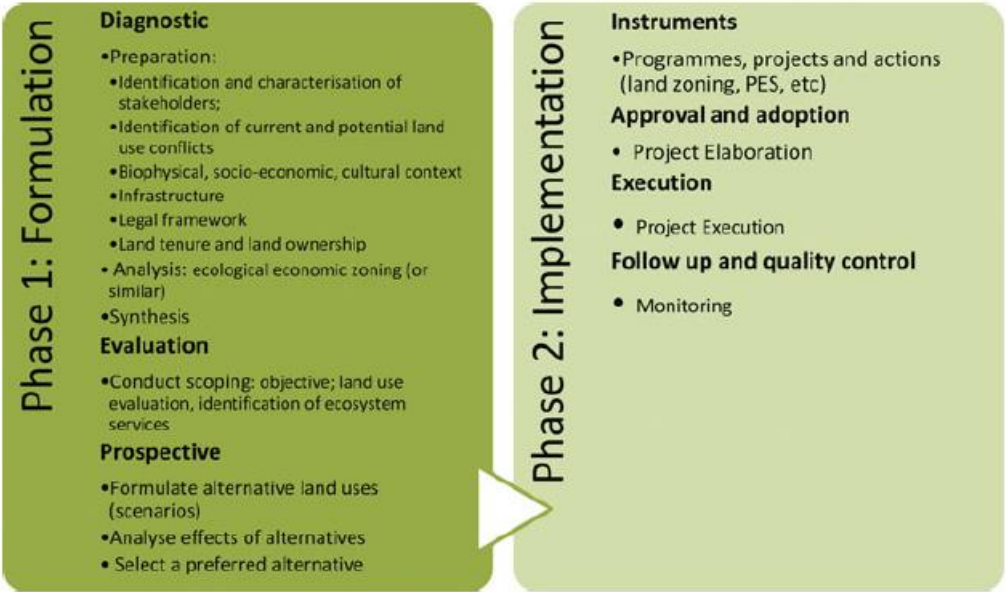
#### **3.3.4.2 Future of land use planning**

The first attempt at solving the traditional method of Euclidean zone planning was to introduce conditional and special uses that provide more flexibility. Furthermore, different variants of reviews were introduced to enable plans to evolve alongside cities (Talen, 2012:342). However, current planners are sceptical toward land use management that is too flexible due to its unpredictable nature, and therefore opt for an approach closer to that of the early zoning schemes. These early zoning schemes used a smaller grain of zoning, which allowed a greater variety of uses in a zone, while also creating better links between different zones. These smaller zones were also based on location characteristics, which means, for example, that areas next to busy commercial roads would contain businesses with apartments above, and quieter streets would have houses that also function as businesses. Furthermore, diversity of use could be higher in the inner city and lower in the periphery, placing housing at walking distance from employment and services. These principles were all part of spatial planning in the early 20<sup>th</sup> century, but were forgotten somewhere along the way and were replaced by the race and conflict obsessed system (Talen, 2012:342).

Nel (2016:88) supports a land use system that zones locations according to their characteristics, instead of a broad-based system. He mentions the use of natural and urban zones, where the

natural zones focus on environmental conservation and urban zones will change as the complexity and size of the urban area grows. Furthermore, functional zones should be used for residential, urban core or corridor, and industrial areas. This means that residential areas would focus on residential buildings and local amenities, while the more complex urban cores and industrial zoning ought to focus on what uses are harmful and should be disallowed, rather than determining what uses are permitted. By allowing a mix of density and housing types with ancillary activities in these functional zones, diversity and integration will be encouraged, which would lead to more compact communities with a reduced need for commuting.

Metternicht (2018:13) agrees that there is a need for land use planning to be flexible in its design and implementation. Fig. 3-4 shows the process that he proposes. Regarding this study, the important part is the formulation phase. The process of identifying current land uses, opportunity for development, limitations, and ecosystem services of the area is just as important, if not more so, than the implementation (Metternicht, 2018:13). Therefore, the future of land use planning lies in the flexibility of preparation and implementation, with a focus on mixed-use developments that allow for diversity and integration.



**Figure 3-4: Steps for land use planning process (Mettrrnicht, 2018:13).**

Deutsche Gesellschaft für Internationale Zusammenarbeit, DGIZ (2011: 29), has set up a list of principles for land use planning that they propose will create flexible and effective land use systems. These principles emphasise sustainability, as well as a multi-disciplinary and multi-sector approach; this includes community knowledge of the environment and possible strategies

for land use conflict solutions. Furthermore, local objectives and higher-level objectives are well integrated with each other, and each strategy is formulated according to each location's needs and characteristics. Lastly the land use planning should have definitive spatial goals for specific places and regions to avoid land use conflict, while also being future-orientated and flexible enough to change with the area.

#### **3.3.4.3 Role of land use planning in sustainability**

For any spatial development to be considered a socially, economically, and environmentally sustainable development, it needs to balance competing land uses and create a consensus on the best land use for the purpose of sustainability (DGIZ, 2011:23). Metternicht (2018:4) uses the case study of a town in Ethiopia where the lack of land use management led to informal settlements encroaching on livestock grazing fields, conflicts of land use, strain on water resources, and overall negative impacts from long-term land use changes. This shows that there will always be a need for some sort of land use planning to prevent land use conflicts and protect natural resources; this is especially true in South Africa where informal settlements can just as easily grow into undesired spatial forms.

### **3.4 Summary**

With land use planning being blamed for many of the problems prevalent in today's cities, it is easy to conclude that land use planning should be overhauled, or even removed entirely. However, many of these issues can only be fixed by effective land use planning, as the previous paragraphs demonstrate. The need for change in implementing land use planning is emphasised in the literature, and new strategies for formulating and enforcing land use plans have been at the forefront of spatial planning research. Most of the issues discussed involve land use conflicts, where the suitability of certain land uses is in question. These conflicts lead to sustainability issues and need to be at the forefront of formulating land use plans. By resolving these land use conflicts, optimal spatial usage can be obtained and the drain on natural resources can be eased. Even though land use conflict is not the core of every urban problem, it certainly needs to be considered when attempting to achieve the UN sustainability goals.

## **CHAPTER 4: USE OF GIS IN LAND USE PLANNING**

### **4.1 Geographic Information System (GIS)**

GIS provides decision makers with a way of solving spatial problems by manipulating and analysing spatial data, while allowing users to visualise geographical features of study areas (Carver, 1991:321; Hamza & Chmit, 2022). GIS is complex to define due to its constant progress, but Maguire (1991:11) provides a simple definition; GIS is an information system that uses databases of spatial and non-spatial data to capture, store, manipulate, analyse, and display real world information. The first incarnation of GIS originated in Canada in the 1960s as a tool to help local governments determine the various land uses assigned to different areas by digitising maps and doing basic measurements of its features (Longley *et al.*, 2005:2). Over the years, different uses for GIS have been identified. Once map makers could digitise geographical information, they were able to automate the map making process by manipulating, copying, and editing the data. Furthermore, people started using GIS for environmental studies by placing different components of the environment in different layers that could be displayed and analysed in GIS. Eventually, GIS became a crucial element of observing the earth; it utilises remote sensing and combines these observations with other data sources (Longley *et al.*, 2005:3).

### **4.2 GIS-based multi criteria decision-making (GIS-MCDM)**

Multi Criteria Decision Making (MCDM) is a technique that originated in the 1970s as an alternative to previous decision-making processes, which lacked the means of considering various alternatives and outside factors, such as pollution and health factors, when choosing site locations for spatial plans (Carver, 1991:322). MCDM is valuable in the spatial planning decision-making process, where there are various alternatives and evaluation criteria that must be organised and prioritised (Malczewski, 2006:703). MCDM has grown over the last couple of decades, with various methods designed for different applications and fields, but all the methods operate on the principle that criteria are given weights to represent their importance in the problem (Feizizadeh & Blaschke, 2013; Kumar *et al.*, 2022: 800; Velasquez & Hester, 2013: 63). Table 4-1 summarises the most common methods of MCDM (Bakar, 2021:204; Budiprasetyo *et al.*, 2022:114; Campos & Moreira, 2022:97; Makki *et al.*, 2022:12; Marlinda, 2020; Putri *et al.*, 2022:320; Velasquez & Hester, 2013):

**Table 4-1: Summary of MCDM methods**

<b>Method</b>	<b>Description</b>	<b>Field of application</b>
Multi-Attribute Utility Theory (MAUT)	This method assigns a utility to each consequence or alternative by allowing decision-makers to rank their preference and create a decision matrix.	Economics, construction, environmental management, energy management, and agriculture.
Analytic Hierarchy Process (AHP)	This method relies on experts' rankings of variables to create a pair-wise comparison and to form weights for different alternatives.	Urban planning, performance ratings, policy, and political strategy.
Case-Based Reasoning (CBR)	CBR considers similar cases and recommends the most comparable cases to the current decision-making problem.	Business, medicine, insurance, and engineering.
Data Envelopment Analysis (DEA)	The method uses a linear programming technique to rank the efficiency of different alternatives on a scale of 0-1.	Economics, medicine, agriculture, business, and road safety.
Fuzzy Set Theory	This theory allows for imprecise inputs by considering the evolution of information, and is based on the classical set theory.	Economics, the environment, medicine, social aspects, and engineering.
Simple Multi-Attribute Rating Technique (SMART)	SMART is a form of MAUT where each alternative is given a value on a scale and	Construction, environmental management, logistics, manufacturing, and military.

	subsequently weighted by comparing the alternatives.	
Goal Programming (GP)	This method is a pragmatic programming method that uses mathematics to choose the best alternative from an infinite number of alternatives.	Production planning, scheduling, health care, portfolio selection, distribution systems, energy planning, water reservoir management, wildlife management.
ELECTRE	This technique uses outranking methods according to concordance analysis.	Environmental, transportation, energy, and economics.
PROMETHEE	There are various iterations of this method, but it is also an outranking method, similar to ELECTRE.	Hydrology, environmental management, logistics, finance, manufacturing, and energy.
Simple Additive Weighting (SAW)	SAW gives a value to an alternative by using the sum of criteria scores multiplied by a weight determined by the decision-maker.	Finance, business, and water management.
Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS)	The method uses a ranking system that considers the best and worst scenarios simultaneously through a computing algorithm.	Environmental management, transportation, economics, and energy.

When these MCDM techniques are combined with GIS, spatial decision-making problems can be resolved by using the judgement values of MCDM and the geographical data used in GIS (Malczewski, 2006:703). GIS-MCDM is the combination of the two elements and is a powerful tool which came into use in the 1990s, and which has gradually become one of the most widely used methods of land use suitability evaluation (Feizizadeh & Blascke, 2013:3; Malczewski,

2006:704; Yu *et al.*, 2009: 3585). In this relationship, the MCDM weighs the different criteria according to their importance, and is then used in GIS to create weighted overlay maps that represent the most suitable areas according to the weighted criteria (Feizizadeh & Blaschke, 2013:3; Carver, 1991:327).

#### **4.3 Use of GIS-MCDM in land use planning**

As the previous paragraphs explained, GIS-MCDM is a tool that is widely used in land use planning to establish land use suitability. GIS allows for a wide range of criteria in different measurements to be analysed in a cost effective and timely manner. By combining it with MCDM the number of criteria or factors needed for land use suitability can be reduced (Feizizadeh & Blaschke, 2013:3). The greatest value of GIS-MCDM is that a decision-maker can input criteria values into GIS procedures, according to their preferences, and immediately receive feedback. This can then be used for policy decisions and evaluation of alternatives (Malczewski, 2006:717).

Initially GIS was unaffordable to most due to hardware costs and software limitations, but it has since become an important tool for urban planners in developed and developing countries, especially in terms of land use planning (Yeh, 1999:878). By using the remote sensing data available today, GIS can be used to track land cover and land use changes faster than ever before. Furthermore, it enables planners to better understand land use cover and use changes and patterns, as well as what drives these changes, by combining remote sensing data with socio-economic, biophysical, and census data (Shao *et al.*, 2021:242). With these capabilities, GIS is an important tool to for identifying land use conflicts through remote sensing.

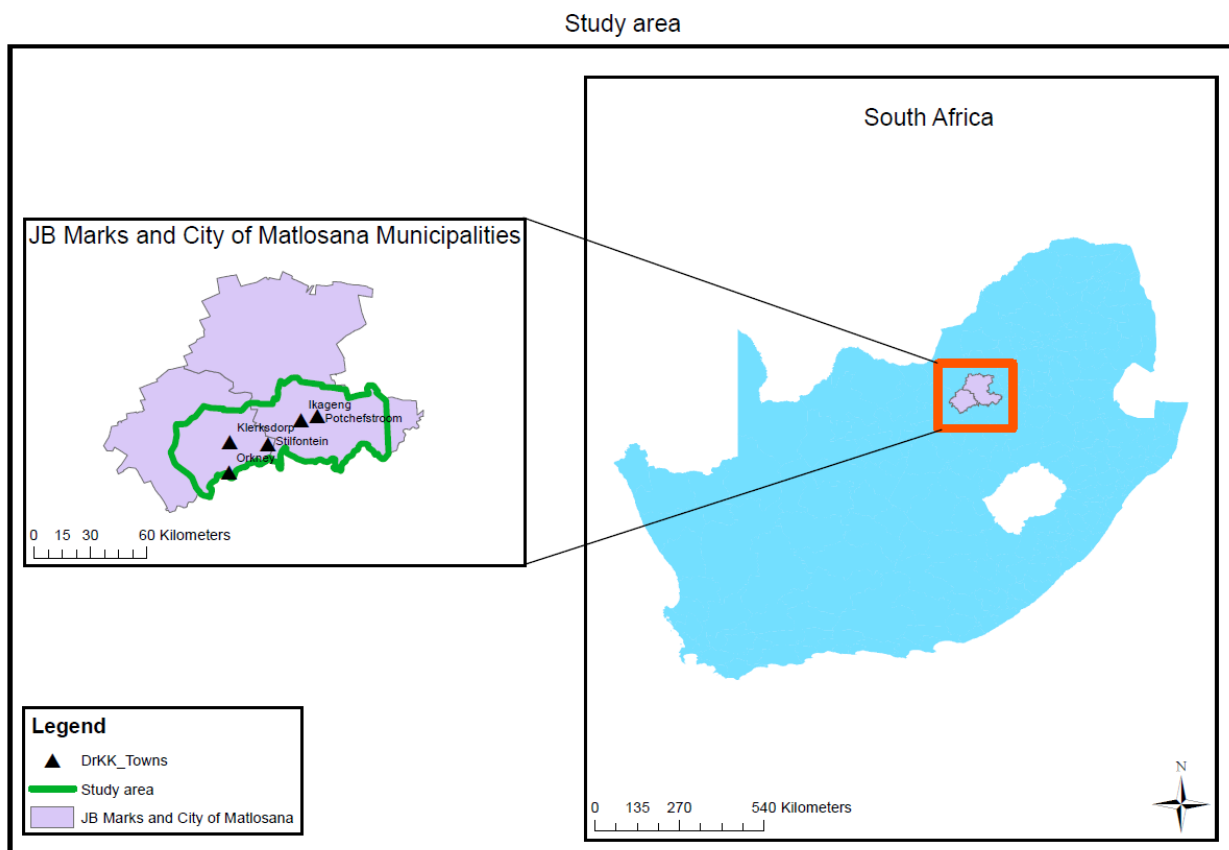
Spatial planning decisions must consider various alternatives and criteria that stem from different sources, with conflicting or incomparable values (Malczewski, 2006:703). The literature demonstrates how MCDM helps with these challenging decisions, and highlights the advantages of combining these methods with GIS when land use patterns are being evaluated.

## CHAPTER 5: STUDY AREA CONTEXTUALISATION

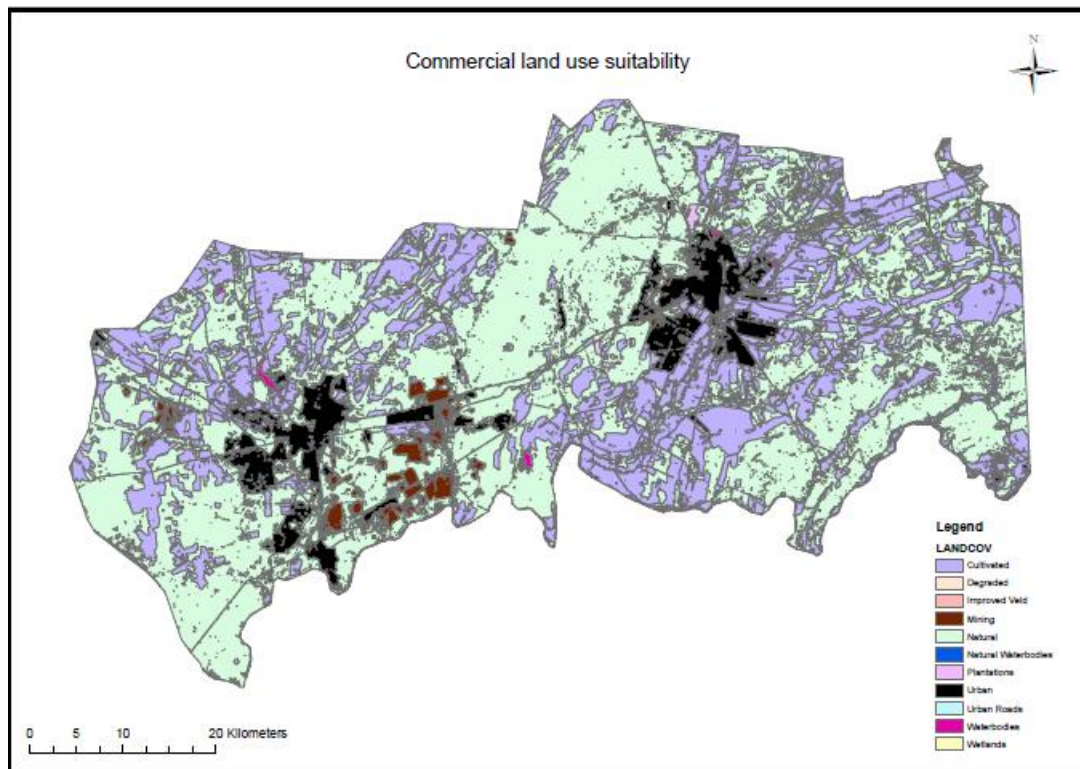
The study area will include the JB Marks and City of Matlosana municipalities, but will mainly focus on the areas surrounding Potchefstroom and Klerksdorp, as demonstrated in Fig. 5-1. This chapter will highlight the vulnerabilities of the area and past disasters that have occurred there, while also expounding on the demographic and socio-economic conditions.

### 5.1 Study area

The study area was selected because these two urban areas are the main nodes of the Dr Kenneth Kaunda district and are experiencing the highest urbanisation in the district (Dr Kenneth Kaunda District Municipality, 2021:211-212). Furthermore, the area has socio-economic, environmental, and disaster risk aspects that must be considered for land use decisions.



**Figure 5-1: Map of the study area.**



**Figure 5-2: Map of the land cover in the study area.**

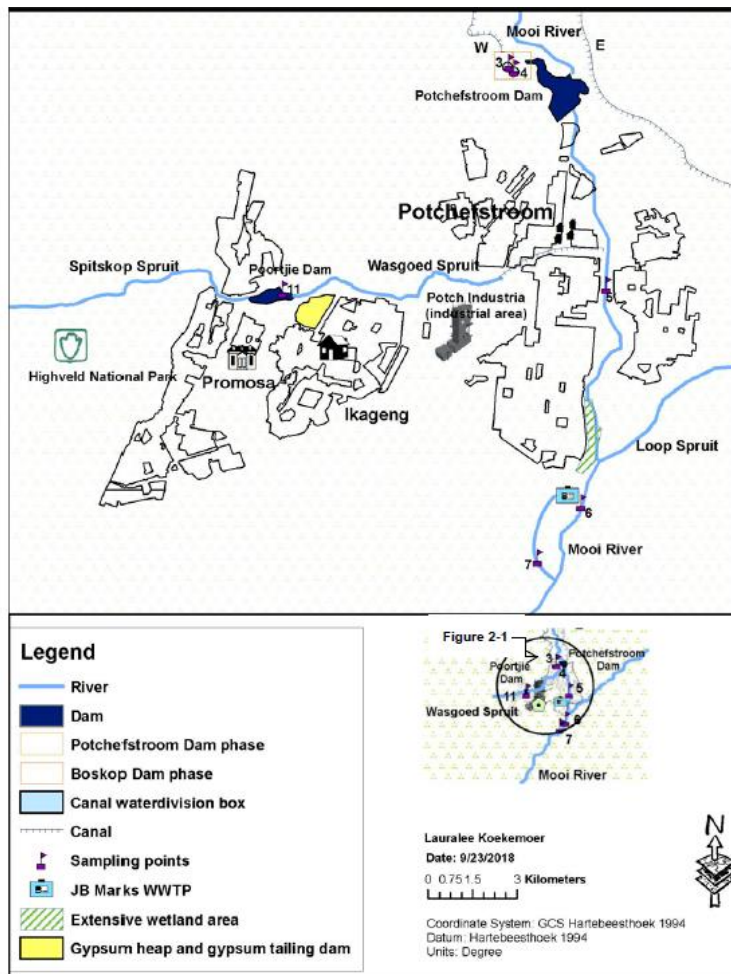
Fig 5-2. shows the land cover of the study area. The three main categories of land cover in the area are urban, agricultural, and natural environment. The natural land covers approximately 201 567ha area, while cultivated land takes up 101 720ha. The urban footprint in the study area covers 26 448ha and can be mainly attributed to Klerksdorp, Orkney and Potchefstroom. Mining also has a large footprint around the City of Matlosana's urban area occupying around 7 851ha of the surrounding land.

## **5.2 Study area vulnerability and disasters**

According to the UNISDR (2015:31), vulnerability can be defined as “the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.” Recent studies have identified various indicators that can be used to determine a community's vulnerability to hazards. Okunola (2019) mentions these studies and reveals that factors like location, housing standards, former experiences of hazards, health, residential characteristics, inadequate construction, environmental degradation, hazard awareness, cultural attitudes and practices, and ineffective communication each play a role in a community's vulnerability. Adger (2006:270) states that vulnerability is driven by actions promoting self-interest, whether deliberate or unintentional, that interacts with the physical and ecological systems. These actions and variables that create

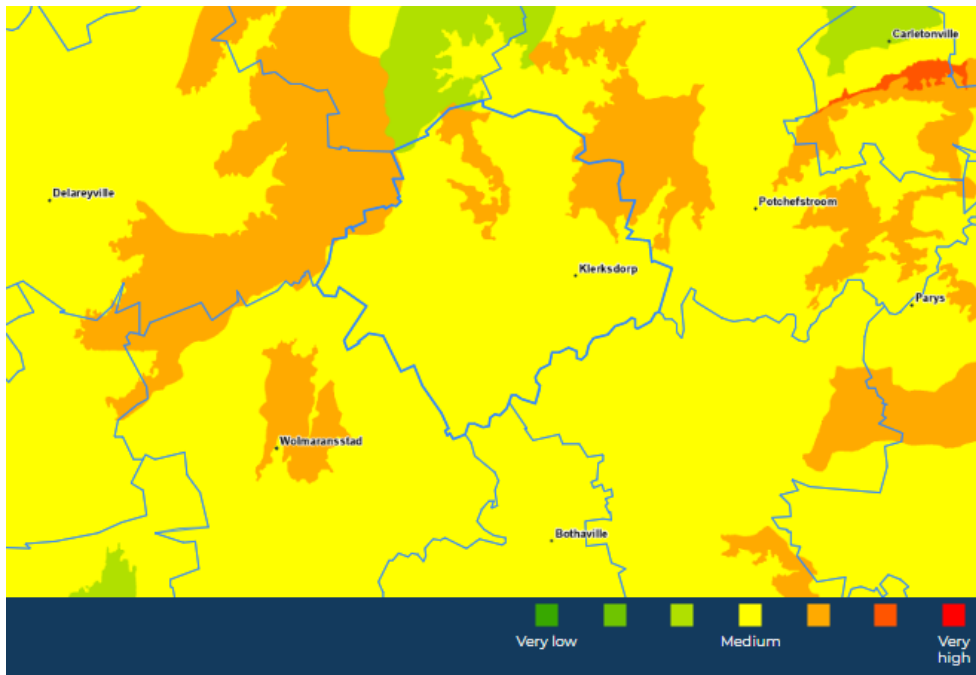
vulnerability can be categorized under physical, political, social, economic, cultural, and technological headings (McEntire, 2001:191). According to Masterson et al. (2014:98), certain household and individual characteristics make certain groups of people more vulnerable to disasters; these include gender, race, household composition, education, poverty, age, and housing tenure. This is supported by the data released by Stats SA in 2017. Vulnerability also has a temporal scale, which means that a system or community's level of vulnerability will change, either suddenly, in the case of a hazardous event or over a longer period, as a result of the development process (Schneiderbauer & Ehrlich, 2004:18).

As mentioned, when natural hazards interact with the vulnerabilities of a society, it leads to disasters. The study area of the research project is no different, with various vulnerabilities leaving it susceptible to disasters. One major vulnerability of the study area is the number of residents living in informal dwellings. The JB Marks municipality has almost 15% of its residents living in informal dwellings, while the City of Matlosana has just under 9% of its population without formal housing (Dr Kenneth Kaunda District Municipality, 2021:37). These structures are extremely vulnerable to flooding, earthquakes, and other natural hazards prevalent in the area. As can be seen in Figure 5-3, Wasgoed Spruit runs through Ikageng and Promosa (townships within the JB Marks municipality that fall within the Potchefstroom urban edge) which are defined as informal settlements with a mix of formal and informal housing (Taruza, 2016:92). The UN Habitat defines these informal settlements as areas with sub-standard housing and infrastructure that are prone to be located in geographically hazardous areas. (UN-habitat, 2015:1). The proximity of sub-standard housing to a waterway (Wasgoed Spruit) creates a higher risk of disaster. Furthermore, sinkhole formation is a concern in the study area, with Klerksdorp and Potchefstroom located partially on dolomite deposits (Heath & Oosthuizen, 2008:2; Oosthuizen & Richardson, 2011:20-21). It is especially concerning in the township of Ikageng, where large parts of the informal settlement are located within areas identified as having a high risk of sinkhole formation (Smit, 2017:84).

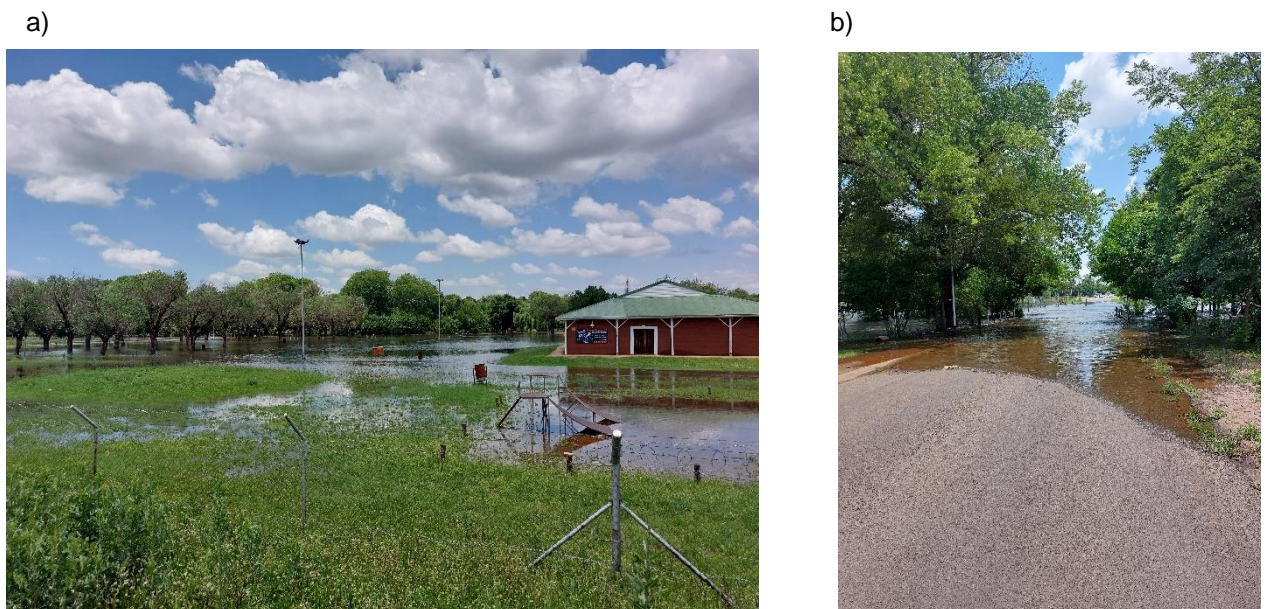


**Figure 5-3: The location of the Mooi River and Wasgoed Spruit within Potchefstroom (Koekemoer, 2019:10).**

Furthermore, as Fig. 5-4 illustrates, both municipalities are located within an area identified as having a medium risk of flooding. Recent rains in the North West and Gauteng Provinces have caused the Mooi River’s banks to overflow and have caused localised flooding, as can be seen in Fig. 5-5. Even though the flooding has not caused major loss or damage as of 15 November 2022, it illustrates the danger of flooding in the Potchefstroom region.

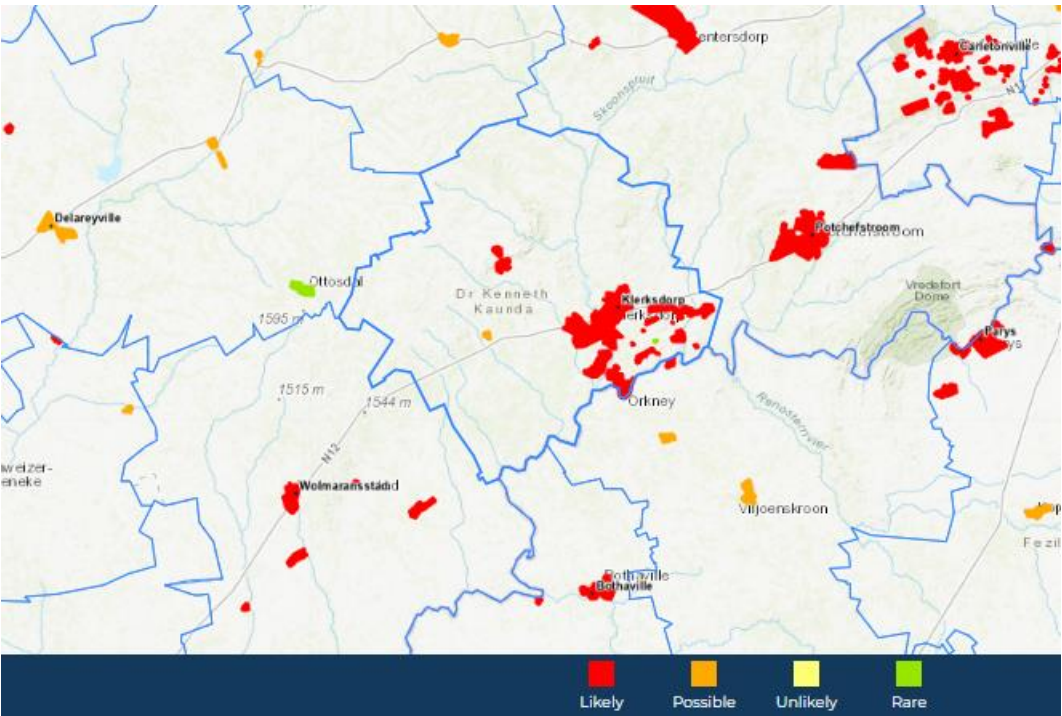


**Figure 5-4:** A map showing the risk of flooding in the Dr Kenneth Kaunda district (CSIR, 2019).



**Figure 5-5:** a) The Trim Park in Potchefstroom flooded by water from the Mooi River. b) Retief Street bridge crossing the Mooi River in Potchefstroom flooded (Own images, 2022).

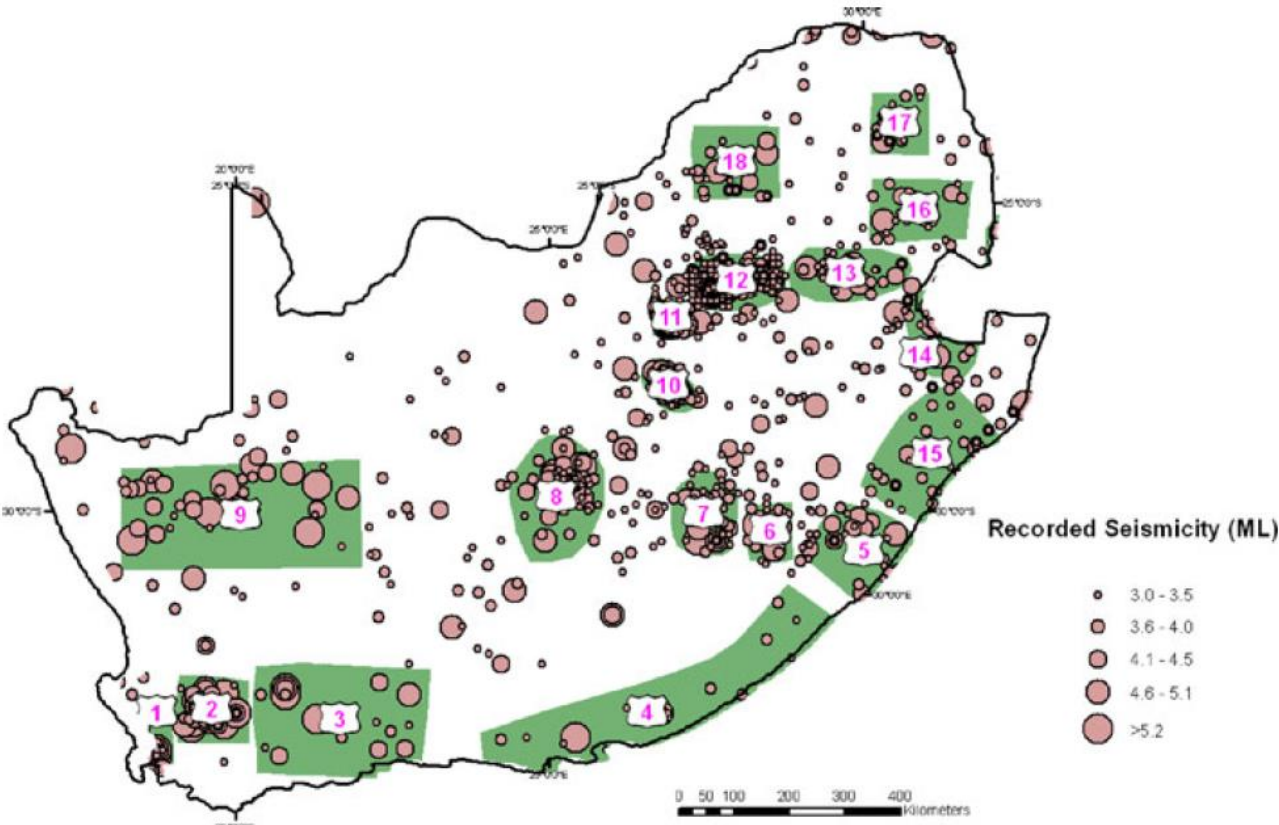
As mentioned before, disasters occur when vulnerable conditions interact with natural hazards, such as wildfires, floods, earthquakes, and sinkholes (JB marks, 2022:302). In 2011, the former Tlokwe Municipality, now JB Marks Municipality, experienced a major wildfire disaster, with 13 different wildfires occurring in rural areas surrounding Potchefstroom, which resulted in two people losing their lives, as well as an estimated R43 million in damages to infrastructure, livestock, and grazing (Wiggil, 2011:1). Fig. 5-6 clearly shows a high risk of wildfires in both the Potchefstroom and Klerksdorp regions.



**Figure 5-6: Map showing the risk of wildfires in the Dr Kenneth Kaunda district (CSIR, 2019).**

Singh *et al.* (2011:390) highlight the high volume of earthquakes that impact the region of Klerksdorp, with number 11 on Fig. 5-7 representing the Klerksdorp mining district. Furthermore, Klerksdorp is located within the Witwatersrand Basin, which accounts for over 90% of South Africa’s seismic activity (Saunders *et al.*, 2016:294; Kgaswane *et al.*, 2002:378). This means that there is the risk of earthquake disasters in the study area, and such disasters have already occurred in the City of Matlosana municipality. On 5 August 2014, a ML5.5 magnitude earthquake hit Orkney, a neighbouring town of Klerksdorp. As shown by Fig. 5-8, this led to the death of one person, caused damage to 1446 homes, and resulted in a total of R148 million in damage to public amenities in Orkney and the surrounding towns (NWCSTM, 2015; Midzi *et al.*, 2014:741-744). This earthquake was the biggest since 9 March 2005, when a ML5.3 magnitude hit the

Klerksdorp/Stilfontein area, causing an estimated R20 to R30 million in damage, as can be seen in Fig. 5-8 (Durrheim *et al.*, 2006:1-2; Pule *et al.*, 2014). Although Potchefstroom and Klerksdorp are less prone to sinkhole formation than the Gauteng province, the presence of dolomite in the area creates the risk of a disaster, especially when settlements are erected on these hazardous areas surrounding the towns (Heath & Oosthuizen, 2008:2; Meintjies, 2016:177; Oosthuizen & Richardson, 2011:29).



**Figure 5-7:** A map showing the distribution of earthquakes from different clusters around South Africa (Singh *et al.*, 2011:390).

(a)



(b)



**Figure 5-8: Picture (a) shows the damage in Stilfontein after the 2005 earthquake (Durrheim, 2006:2) and picture (b) shows damage to a house in Orkney from the 2014 earthquake (BBC, 2014).**

### **5.3 Socio-economic and demographic factors**

Long *et al.* (2007:143) believe that land use changes are driven by socio-economic factors as much as physical conditions, and that this is a dynamic relationship depending on social change. Socio-economic factors such as economic development, urbanisation, and demographic patterns greatly influence land use patterns over time (Handavu *et al.*, 2019:1; Rovani *et al.*, 2020:1).

Almost 90% of the district's residents live in the JB Marks and City of Matlosana municipalities; these are also the biggest contributors to the district's GDP, at 35.72% and 58.88% respectively. JB Marks Municipality experienced the greatest growth and the City of Matlosana showed negative growth between 2006 and 2016 (Dr Kenneth Kaunda District Municipality, 2021:41). The JB Marks Municipality hosts 56% of high-income individuals (earning more than R 1 200 000 per annum); most households in the district earn between R8 000 and R11 000 per month, and only 10% of households have a monthly income of more than R30 000 (Dr Kenneth Kaunda District Municipality, 2021:43). Furthermore, the communities of the study area depend heavily on agricultural and mining activities in the area; however, mining activities are slowing down and creating fewer job opportunities (Dr Kenneth Kaunda District Municipality, 2021:93).

Access to basic services is an important consideration for any resident; Table 5-1 shows the percentage of residents who have access to basic services in the Dr Kenneth Kaunda district (Dr Kenneth Kaunda District Municipality, 2021:37). These basic services are significant for the study because it influences land use planning. Access to electricity, drinking water, and a sewerage

system are provided by bulk services, and is a variable that will be used to determine land use suitability. Quantec (2021) estimates that the population of the City of Matlosana Municipality will increase by almost 10% between 2021 and 2031, while the population of the JB Marks Municipality is expected to rise by nearly 20% in the same period. South Africa has an average population density of 49 persons per square kilometre; however, the JB Marks Municipality has a density of 68.1, while the City of Matlosana has a prodigious 130.4 people per square kilometre (Quantec, 2022). These high densities, especially in the City of Matlosana, places huge pressure on infrastructure and service delivery in the area. While the effect of population growth has already been explained in earlier passages.

**Table 5-2: Percentage of residents able to access basic services.**

Municipality	Electricity	Drinking water	Connected to sewerage system	Formal dwelling
City of Matlosana	96	85.4	95.4	91.6
JB Marks	94.8	89.9	77	85.5

**5.4 Summary**

The chapter looked at the context of the study area with regards to disasters risk. Various vulnerabilities were identified in the municipalities physical and socio-economic conditions. These vulnerabilities have already led to disasters and show the risk which remains in the study area. This highlights the need to consider disaster risk in spatial planning and how disasters impact residents directly. Clear vulnerability sinkhole formation and flooding was identified which could be lowered through spatial interventions.

## CHAPTER 6: EMPIRICAL FINDINGS

The empirical findings will be discussed in this chapter, which starts by explaining the process of LUCIS and the role MCDM plays in the process. Case studies of how LUCIS was used in other countries will also be discussed to explain the process and benefits of the method. Thereafter, the variables used as criteria for each land use is explained followed by an explanation of the AHP method and how the criteria were used. Lastly the various outputs from the GIS procedures are presented. The land use suitability maps are the first to be discussed, followed by the HAND model. Finally, the land uses are compared and presented in a conflict map along with a flood risk map.

### 6.1 Land Use Conflict Identification Strategy

MCDM is a valuable tool for determining land potential; when combined with GIS it creates a system for identifying land use suitability (Mugiyo *et al.*, 2021:2). Land use suitability identification uses these MCDM techniques to analyse large quantities of spatial data, and thereby to identify flood-prone agricultural fields, ecological corridors, and urban growth patterns (Cilliers, 2019:2). The MCDM technique used for the land use suitability analysis is the AHP method. Land use suitability will be calculated for residential, industrial, and commercial uses, which will form the urban layer, while suitability maps will be created for conservation and agriculture uses as well.

Carr and Zwick (2005:71) state that the LUCIS' main aim is to identify future land use conflicts between urban, conservation, and agriculture land uses, but adds that it could aid in local spatial planning decision-making, environmental management, and population modelling. Various similar studies have been done internationally and showed the importance of the research. In the city of Jinan, China strong conflict was discovered between cultivated, construction and ecological suitable land. This conflict occurred in 25% of the study area and was concentrated in the areas where the environment transitions from urban to rural areas (Dong *et al.*, 2021:13). Another example of how land use conflicts are present in urban areas is from a study done in the Bucharest Metropolitan Area, Romania. This study identified high levels of conflict between future residential developments and the semi-natural areas that provide ecological services (Ioja *et al.*, 2013:116). Both studies show how urban land uses are in constant conflict with natural land uses. This emphasises the value of identifying these conflicts before they lead to the loss of valuable agricultural and ecological land.

The LUCIS uses suitability maps created for agriculture, conservation, and urban land uses to evaluate whether or not there are any conflicts between them (Cilliers, 2019:2). In order to create these suitability maps, an area needs to be evaluated according to spatial criteria to determine its

suitability by using MCDM techniques (Carr & Zwick, 2005:63). When a land use has a suitability metric higher than any other category, it can maintain its land use or future land use, but when it has the same metric as another category of land use it has a conflict with the other land use (Gormus *et al.*, 2017:419).

**6.1.1 Criteria**

Each land use has its own set of criteria chosen for the MCDM process, which were gathered from different research studies that used a similar methodology. The factors considered for the different land uses are not exhaustive and were based on the available data for the study area. Each land use has a different set of suitability criteria due to the different goals each land use has in terms of what constitutes a suitable area (Gormus *et al.*, 2017;422).

**6.1.1.1 Urban land uses**

The urban land uses criteria were selected according to studies done by Cilliers (2019), Gormus *et al.* (2017), and Mu (2006). Table 6-1, 6-2, and 6-3 show the criteria chosen for the residential, commercial, and industrial land uses. The residential land use criteria focus on proximity to essential services and work opportunities. Therefore, these criteria aim to be within a 30-minute walking distance, which, according to Bohannon & Andrews’ (2011:183) research, is around 2km. The commercial uses will focus on proximity to economic activity, residential areas, and bulk services. Keeping commercial uses within walking range helps commuters and other residents to avoid motor vehicles and create mixed-use neighbourhoods of compatible uses (Koster & Rouwendal, 2012:754). Industrial areas were treated as noxious uses and were considered incompatible with the other land uses. The criteria chosen were influenced by local spatial plans as well as research by Cilliers (2019) and Gormus (2017).

**Table 6-1: Residential land use**

Criteria	Explanation
Geophysical structure	This refers to the slope, which will be measured in % incline, with any area above 15% given the lowest suitability rating.
Distance to residential	The Euclidean distance to other residential areas, up to 1km away. Any area farther than 1km will have the lowest suitability.

Bulk services	The Euclidean distance from electricity substations and water lines. The closer the land is to existing bulk services, the cheaper developments will be.
Roadways	The Euclidean distance to the nearest roads, with areas farther than 3km given the lowest suitability grade. Connectivity is an important factor to consider for any urban land use.
Social services	The Euclidean distance to the nearest schools and health services, with any area farther than 2km given the lowest suitability metric.
City centre	The Euclidean distance from the city centre or economic nodes, up to 3km away. Having a shorter distance can increase pedestrian activity over motor vehicle travel (Farr, 2011:17; Mehaffy, 2010:45). A distance farther than 3km will be given the lowest suitability grade.
Distance to industrial area	The Euclidean distance from industrial areas, with any area closer than 500m given the lowest suitability metric.
Pollution	The Euclidean distance from environmental pollution, such as landfills and waste treatment centres, with areas closer than 250m given the lowest suitability grade.
Sinkhole formation	The presence of dolomitic geological structures creates a risk of sinkhole formation. Any area situated on dolomitic land will be given the lowest suitability grade.
Railway	The Euclidean distance from railway lines. In this study, railway lines will be treated as noise pollution due to the ineffective passenger railway system in South Africa (Anon., 2022). Areas closer than 500m will be given the lowest suitability grade.

**Table 6-2: Commercial land use**

<b>Criteria</b>	<b>Explanation</b>
Geophysical structure	This refers to the slope, which will be measured in % incline, with any area above 15% given the lowest suitability rating.

Distance to residential	The Euclidean distance to residential areas, up to 2km away. Any area farther than 2km will have the lowest suitability.
Bulk services	The Euclidean distance from electricity substations and water lines. The closer the land is to existing bulk services, the cheaper developments will be.
Roadways	The Euclidean distance to the nearest roads, with areas farther than 1km given the lowest suitability grade. Connectivity is an important factor to consider for any urban land use.
Health services	The Euclidean distance to the nearest health facilities, with areas farther than 2km given the lowest suitability grade.
City centre	The Euclidean distance from the city centre or economic nodes, up to 1km. This is important for increasing agglomeration effects (Yang <i>et al.</i> , 2019:22). A distance farther than 1km will be given the lowest suitability grade.
Distance to industrial area	The Euclidean distance from industrial areas, with any area closer than 250m given the lowest suitability metric.
Pollution	The Euclidean distance from environmental pollution, such as landfills and waste treatment centres, with areas closer than 250m given the lowest suitability grade.
Sinkhole formation	The presence of dolomitic geological structures creates a risk of sinkhole formation. Any area situated on dolomitic land will be given the lowest suitability grade.

**Table 6-3: Industrial land use**

<b>Criteria</b>	<b>Explanation</b>
Geophysical structure	This refers to the slope, which will be measured in % incline, with any area above 15% given the lowest suitability rating.
Distance to residential	The Euclidean distance to residential areas. Any area closer than 500m will have the lowest suitability.

Bulk services	The Euclidean distance from electricity substations and water lines. The closer the land is to existing bulk services, the cheaper developments will be.
Roadways	The Euclidean distance to the nearest roads, with areas farther than 1km given the lowest suitability grade. Connectivity is an important factor to consider for any urban land use.
Health services	The Euclidean distance to the nearest health facilities, with areas farther than 2km given the lowest suitability grade.
City centre	The Euclidean distance from the city centre and other activity nodes. Any distance farther than 5km will be given the lowest suitability metric.
Distance to industrial area	The Euclidean distance from industrial areas, with the potential for agglomeration effects in mind. Any area farther than 2km will be given the lowest suitability metric.
Landfill	The Euclidean distance from landfills, up to 5km. Proximity to landfills is important for industries with large amounts of waste.
Sinkhole formation	The presence of dolomitic geological structures creates a risk of sinkhole formation. Any area situated on dolomitic land will be given the lowest suitability grade.

### 6.1.1.2 Agriculture land use

The criteria chosen for this layer were determined by studies done previously to determine suitable agricultural land (Bozdag et al., 2016; Cilliers, 2019; Mugyio *et al.*, 2021; Pramanik, 2016; Puntsag, 2014; Yalew *et al.*, 2016). The soil type data from (ARC, 2006) categorised into broad land types. These land types were given a percentage of high potential soil within the area. These percentages were used to group the soil types in high, moderate and low potential agriculture land. Areas with over 50% high potential soil were categorised as high potential soil, while anything between 30% and 49% were labelled as moderate potential soil. Any percentage lower than 30% was given a low soil potential label. Table 6-4 shows the criteria and provides a short explanation of each.

**Table 6-4: Agriculture land use**

<b>Criteria</b>	<b>Explanation</b>
High-potential agriculture	The ground identified by data from Maxim planning solutions as high-potential agriculture land will be given the highest suitability grade, with other areas receiving grades according to their soil types.
Distance from roads	The Euclidean distance to the nearest roads, up to 3km. Areas farther than 3km from roads will be given the lowest suitability rating. Roads are important for transporting goods to and from farms.
Slope	This refers to the slope, which will be measured in % incline, with any area above 25% given the lowest suitability rating.
Distance from pollution	Distance from industrial land uses, with areas closer than 1km given the lowest suitability grade.
Existing farmland	Areas with existing farmland will be given the highest rating, followed by natural areas and other land uses.

### **6.1.1.3 Conservation areas**

The criteria chosen to determine the suitability for conservation, shown in Table 6-5, were taken from the South African National Biodiversity Institute's (SANBI) recommendations on land use regarding the conservation of important biodiversity (SANBI, 2017) as well as research from Cilliers (2019).

**Table 6-5: Conservation land use**

Criteria	Explanation
CBA-1, CBA-2, ESA-1, ESA-2 and protected areas.	The CBAs are critical biodiversity areas that are crucial for ecosystem-, species-, and ecological process conservation, while ESAs are areas that provide ecological support to protected areas or CBAs. Protected areas are protected under the Protected Areas Act. (SANBI, 2017)
Wetland clusters	Wetlands are areas that are in a transitional phase between terrestrial and aquatic because of a high water table that covers the ground in shallow water and performs important ecological services (Omar <i>et al.</i> , 2016:1861).
Other natural areas	These are other natural areas that do not serve critical ecological services or form part of important biodiversity plans (SANBI, 2017).

**6.2 Analytical Hierarchy Process (AHP)**

MCDM techniques have been discussed as well as the different methods that have been used in various field of study. The most commonly used method in spatial planning, and especially in GIS land use suitability studies, is the AHP method (Feizizadeh & Blaschke, 2013:3). In AHP a problem is structured according to a hierarchy, which is formed by a process of prioritisation of elements according to evaluation criteria (Saaty, 1994:22). AHP was developed in the 1970's by Thomas Saaty and uses pairwise comparisons to evaluate alternatives according to various criteria, and to calculate their respective weights (Loken, 2007;1587, Sharma *et al.*, 2022:2000). These weights are given numerical values according to judgements from experts and are represented in a square matrix (Saaty, 1994:25; Sharma *et al.*, 2022:2001). By using the fundamental scale in Table 6-6 (Saaty,1994:26) criteria can be judged in importance on a scale of 1-9.

**Table 6-6: Fundamental scale**

<b>Number of importance</b>	<b>Definition</b>
1	Two criteria of equal importance
3	Criterion is moderately more important
5	Criterion is of strong importance
7	Criterion is of very strong importance
9	Criterion is extremely important
2,4,6,8	Used as compromise for the above values

By using these values as a rating system, the criteria for this study were ranked according to judgements by urban planning experts and methodologies of similar research studies. These rankings were placed into a square matrix as can be seen from Fig. 6-1 to Fig. 6-5. When the element on the vertical axis is more important than the element on the horizontal axis, the value will be a whole number between 1 and 9. For example, geophysical structure was judged as being more important than the distance to residential areas and received the number 2 in their pairwise comparison at the top of Fig. 6-1. The judgements for the urban land uses were determined by questionnaires sent to urban planners, which asked participants to rank the criteria according to their importance for suitability. An average was then created from the 8 participants' answers to determine the overall importance of each variable and to create the pairwise comparison matrix. The agriculture and conservation judgements were made using Case Based Reasoning (CBR). CBR is helpful because it uses solutions from past studies with similar problems to help create solutions for new problems (Chen *et al.*, 2022:1, Kuo, 2010:5559). As mentioned above, the criteria were chosen by consulting similar research, and the same studies were used to determine the judgements by determining how their rankings of similar variables were constructed. By combining CBR with AHP, it is possible to create weights for multiple attributes without necessarily requiring the use of surveys for expert judgements.

Matrix	Geophysical structure	Distance to residential area	Bulk services	Roadways	Railways	Social services	City centre	Distance to industrial area	Pollution	Sinkhole formation	normalized principal Eigenvector
	1	2	3	4	5	6	7	8	9	10	
Geophysical structure	1	2	1/4	1/2	4	1/3	3	5	2	3	( 10,11% 6,52% 29,71% 14,22% 2,88% 19,51% 4,14% 2,01% 6,68% 4,22% )
Distance to residential	1/2	1	1/5	1/3	3	1/4	2	4	1	2	
Bulk services	4	5	1	3	7	2	6	9	5	6	
Roadways	2	3	1/3	1	4	1/2	3	6	3	4	
Railways	1/4	1/3	1/7	1/4	1	1/5	1/2	2	1/3	1/2	
Social services	3	4	1/2	2	5	1	4	7	3	4	
City centre	1/3	1/2	1/6	1/3	2	1/4	1	2	1/2	1	
Distance to industrial	1/5	1/4	1/9	1/6	1/2	1/7	1/2	1	1/4	1/3	
Pollution	1/2	1	1/5	1/3	3	1/3	2	4	1	2	
Sinkhole formation	1/3	1/2	1/6	1/4	2	1/4	1	3	1/2	1	

Figure 6-1: Pairwise comparison matrix for residential suitability criteria.

Matrix	Distance from industrial area	Geophysical structure	Sinkhole formation	Bulk services	Roadways	City centre	Health centre	Distance from residential areas	Pollution	0	normalized principal Eigenvector
	1	2	3	4	5	6	7	8	9	10	
Distance from industrial	1	1/3	1/2	1/4	1/5	1/2	4	2	3	-	( 6,11% 14,20% 9,36% 21,29% 30,62% 9,36% 2,09% 4,12% 2,86% 0,00% )
Geophysical structure	3	1	2	1/2	1/3	2	5	4	5	-	
Sinkhole formation	2	1/2	1	1/3	1/4	1	5	3	4	-	
Bulk services	4	2	3	1	1/2	3	7	5	6	-	
Roadways	5	3	4	2	1	4	9	6	7	-	
City centre	2	1/2	1	1/3	1/4	1	5	3	4	-	
Health centre	1/4	1/5	1/5	1/7	1/9	1/5	1	1/3	1/2	-	
Distance from residential	1/2	1/4	1/3	1/5	1/6	1/3	3	1	2	-	
Pollution	1/3	1/5	1/4	1/6	1/7	1/4	2	1/2	1	-	
0	-	-	-	-	-	-	-	-	-	1	

Figure 6-2: Pairwise comparison matrix for commercial suitability criteria

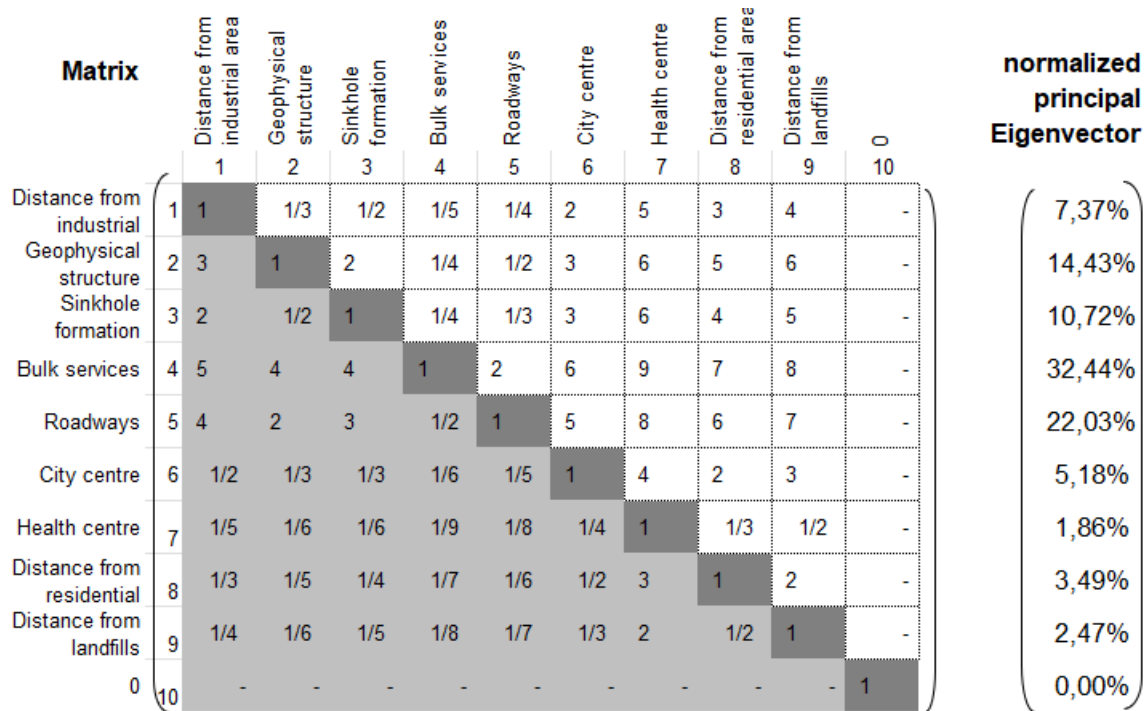


Figure 6-3: Pairwise comparison matrix for industrial suitability criteria

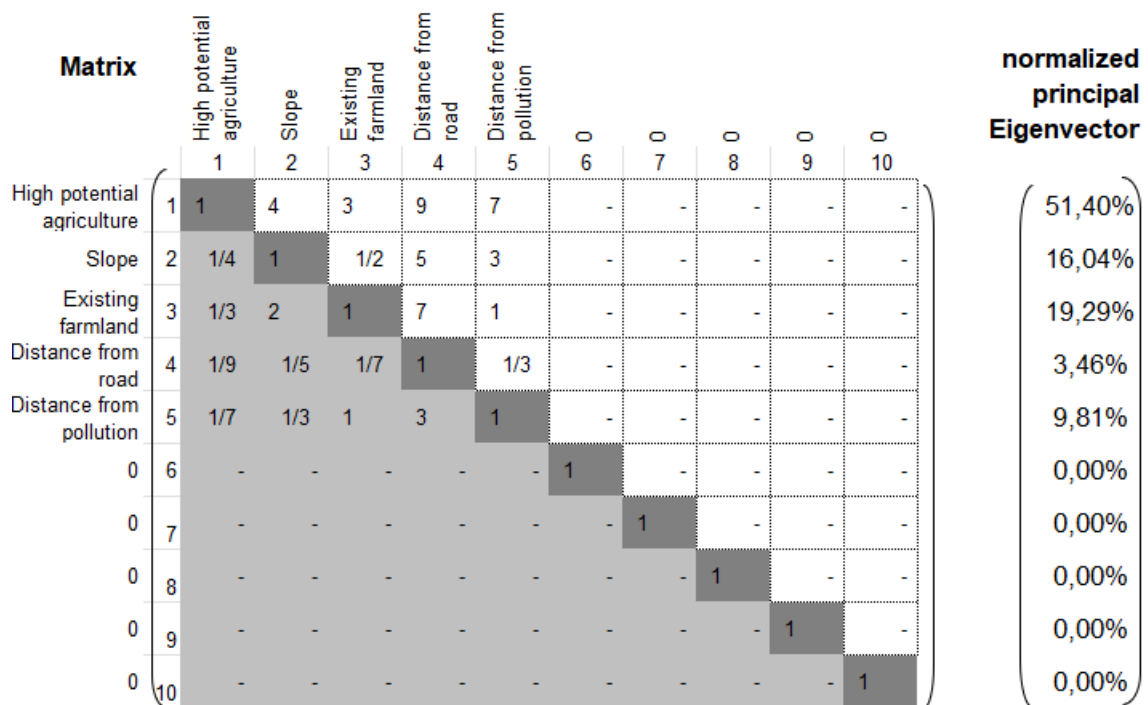
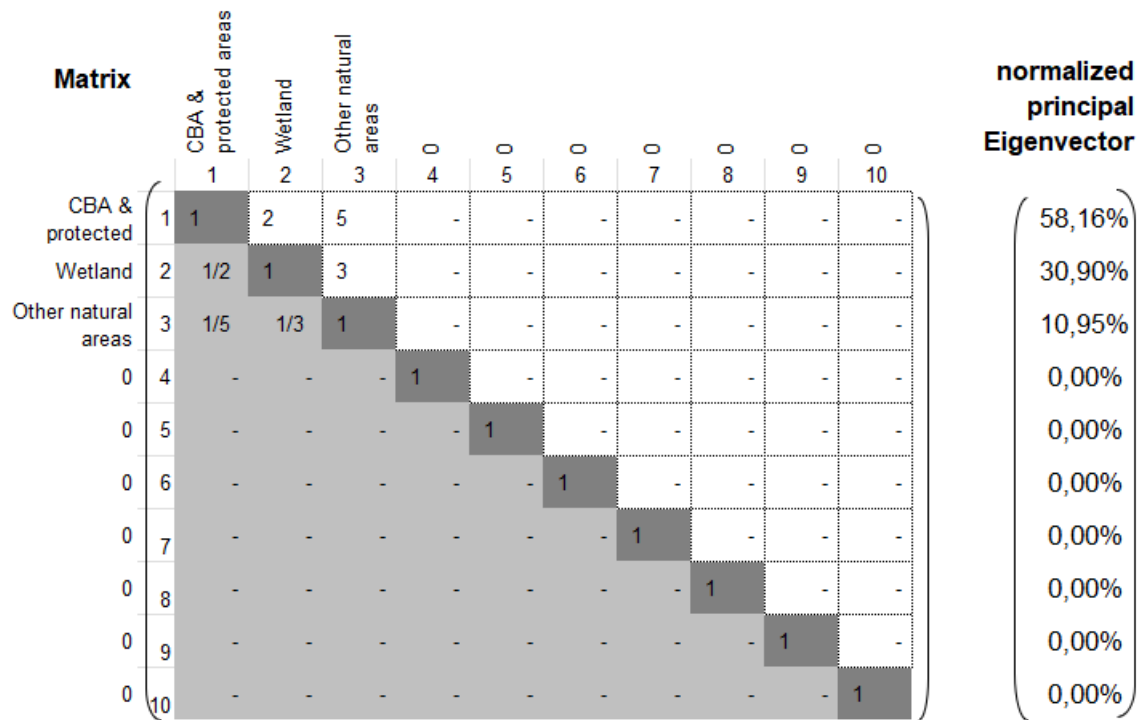


Figure 6-4: Pairwise comparison matrix for agriculture suitability criteria



**Figure 6-5: Pairwise comparison matrix for conservation suitability criteria**

The normalized principal Eigenvector in Fig. 6-1 to Fig. 6-5 represents the weight that was given to each attribute. This technique was proposed by Thomas Saaty (as cited by Tomashevskii, 2015:774) as a method to derive weights from the pairwise comparisons. The pairwise comparison matrices were derived from an AHP template created by Goepel (2013). The template uses the Eigenvector formula as seen in Fig. 6-6 to calculate the weights.

$$\Delta\omega_i = \sqrt{\frac{1}{n-1} \sum_{k=1}^n \left( \frac{n}{\lambda_{\max}} a_{ik} \omega_k - \omega_i \right)^2}, \quad i = 1, \dots, n,$$

**Figure 6-6: Eigenvector method (Tomashevskii, 2015:775).**

A consistency ratio (CR) is used in AHP to determine the consistency of the pairwise comparisons and indicates the chance that the judgements were generated at random. The CR is calculated by using  $CR = CI/RI$ ; RI (random index) is the average of the consistency index (CI). The CI is calculated by  $CI = \frac{\lambda_{\max}}{n-1}$ , where  $\lambda_{\max}$  represents the principal Eigenvalue of the matrix and n is the order of the matrix. The CR must be below 0,1 for the pairwise comparisons to be considered relatively consistent (Feizizadeh & Blaschke, 2011:10; Dai *et al.*, 2001: 265). The five pairwise comparisons of this study have consistency ratios of 0,07 and lower, which can be considered as relatively consistent in its judgements.

### **6.3 Land use suitability maps**

To create the land use suitability maps for each land use, weighted overlay was used in ArcGIS. By using the Raster Calculator function from ArcGIS, these industrial, residential, and commercial suitability maps were combined to create an urban suitability map. All the data used was sourced from Maxim Planning Solutions, except for the Digital Elevation Model data for the slope (DALRRD, 2021), the electrical substation locations (Eskom a, 2014; Eskom b, 2014), and the soil type data (ARC, 2006).

#### **6.3.1 Weighted overlay**

Weighted overlay uses different raster layers and combines them by placing them on an equal measurement scale and giving them weights according to their relative importance (Zakaria, 2022: 1396). The raster layers are the different criteria chosen for each land use type. All the datasets were projected to the Universal Transverse Mercator Projection using Zone 35S in the WGS 1984 Datum. The first step in creating these weighted overlay maps was to resize the shapefile data of each variable to the size of the study area by using the Clip tool in ArcGIS. Thereafter, the multiple buffer and Euclidean distance tools were used to create distance ranges in metres around the features. By using the multiple buffer tool, buffers can be created at certain distances around the input features (ESRI, 2022). The Euclidean distance tool measures the Euclidean distance from each cell to a certain source or set of sources and creates a raster output with categories of distances from the source (Alzamili *et al.*, 2015: 1333). The multiple buffer tool provided polygon outputs, which then had to be transformed into raster layers by the polygon to raster tool. The Euclidean distance outputs were already in raster format. Thereafter, each dataset was reclassified to change the value attributes of each dataset to match the allocated values that are given in Table 6-7 to 6-11. Thereafter, the weighted overlay could be performed according to the weights given to each criterion for each type of land use.

**Table 6-7: Residential suitability**

<b>Criteria</b>	<b>Allocated values</b>					<b>Weight%</b>
	<b>5</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	
Geophysical structure	5%<	5-10%	10-12.5%	12.5-15%	15%>	10,1
Distance to residential area	500<	500-1000	1000-1500	1500-2000	2000>	6,5
Bulk services	250<	250-500	500-750	750-1000	1000>	29,7
Roadways	500<	500-1000	1000-2000	2000-3000	3000>	14,2
Social services	500<	500-1000	1000-1500	1500-2000	2000>	19,5
City centre	250<	250-500	500-750	750-1000	1000>	4,1
Distance to industrial area	3000>	2000-3000	1000-2000	500-1000	500<	2
Pollution	1000>	750-1000	500-750	250-500	250<	6,7
Sinkhole formation	No dolomite	N/A	N/A	N/A	Dolomite	4,2
Railway	2000>	1000-2000	750-1000	500-750	500<	2,9

**Table 6-8: Commercial suitability**

<b>Criteria</b>	<b>Allocated values</b>					<b>Weight%</b>
	<b>5</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>	
<b>Geophysical structure</b>	5%<	5-10%	10-12.5%	12.5-15%	15%>	14.2
<b>Distance to residential area</b>	250<	250-500	500-750	750-1000	1000>	4.1
<b>Bulk services</b>	250<	250-500	500-750	750-1000	1000>	21.3
<b>Roadways</b>	250<	250-500	500-750	750-1000	1000>	30.6
<b>Health services</b>	500<	500-1000	1000-1500	1500-2000	2000>	2.1
<b>City centre</b>	500<	500-1000	1000-2000	2000-3000	3000>	9.4
<b>Distance to industrial area</b>	2000>	1500-2000	1000-1500	500-1000	500<	6.1
<b>Pollution</b>	1000>	750-1000	500-750	250-500	250<	2.9
<b>Sinkhole formation</b>	No dolomite	N/A	N/A	N/A	Dolomite	9.4

**Table 6-9: Industrial suitability**

Criteria	Allocated values					Weight%
	5	4	3	2	1	
<b>Geophysical structure</b>	5%<	5-10%	10-12.5%	12.5-15%	15%>	14.4
<b>Distance to residential area</b>	2000>	1500-2000	1000-1500	500-1000	500<	3.5
<b>Bulk services</b>	250<	250-500	500-750	750-1000	1000>	32.4
<b>Roadways</b>	250<	250-500	500-750	750-1000	1000>	22
<b>Health services</b>	500<	500-1000	1000-1500	1500-2000	2000>	1.9
<b>City centre</b>	1000<	1000-2000	2000-3000	3000-5000	5000>	5.2
<b>Distance to industrial area</b>	500<	500-1000	1000-1500	1500-2000	2000>	7.4
<b>Landfill</b>	1000<	1000-2000	2000-3000	3000-5000	5000>	2.5
<b>Sinkhole formation</b>	No dolomite	N/A	N/A	N/A	Dolomite	10.7

**Table 6-10: Agriculture suitability**

Criteria	Allocated values					Weight%
	5	4	3	2	1	
<b>High-potential agriculture</b>	High-potential	N/A	Moderate potential	N/A	Low potential	51.4
<b>Distance from roads</b>	500<	500-1000	1000-2000	2000-3000	3000>	3.5
<b>Slope</b>	10%>	10-15%	15-20%	20-25%	25%>	16
<b>Distance from pollution</b>	3000>	2000-3000	1500-2000	1000-1500	1000<	9.8
<b>Existing farmland</b>	Cultivated	N/A	Natural	Mining	Urban	19.3

**Table 6-11: Conservation suitability**

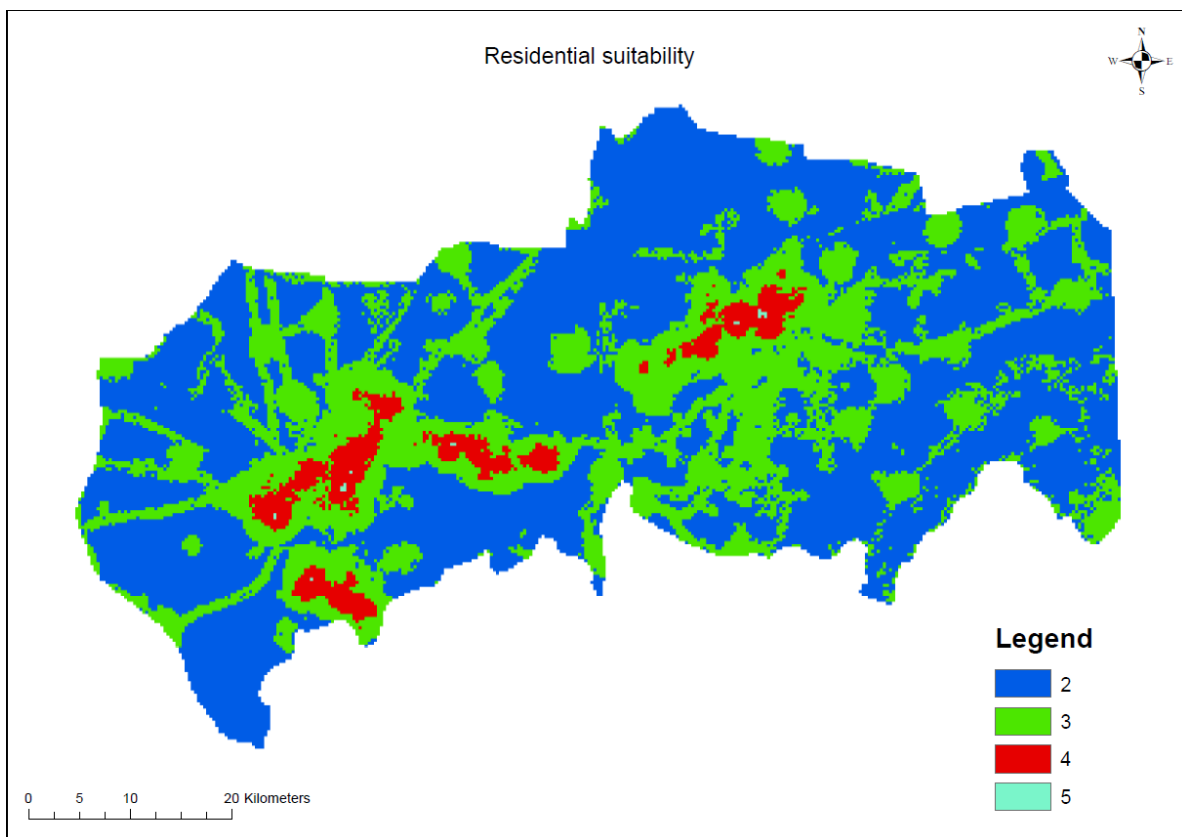
Criteria	Allocated values					Weight%
	5	4	3	2	1	
<b>CBA-1, CBA-2, ESA-1, ESA-2 and protected areas.</b>	CBA-1 and protected areas	CBA-2	ESA-1	ESA-2	Other areas	58.2
<b>Wetland clusters</b>	CBA-1	N/A	ESA-1	ESA-2	Other areas	30.9
<b>Other natural areas</b>	Natural	N/A	Cultivated	Urban	Mining	10.9

### 6.3.2 Land use suitability maps

Fig. 6-7 to 6-11 represent the weighted analysis outputs which created suitability maps for each land use with a cell size of 300. The maps have a rating system for areas on the map on the following scale:

- 1- Very low suitability
- 2- Low suitability
- 3- Moderate suitability
- 4- High suitability
- 5- Very high suitability

The areas with suitability of 4 or higher will be used to determine the conflict between the urban, conservation, and agriculture land uses. Thus, if two land uses have a suitability of 4 for a specific cell, they conflict with one another.



**Figure 6-7: Map of residential suitability**

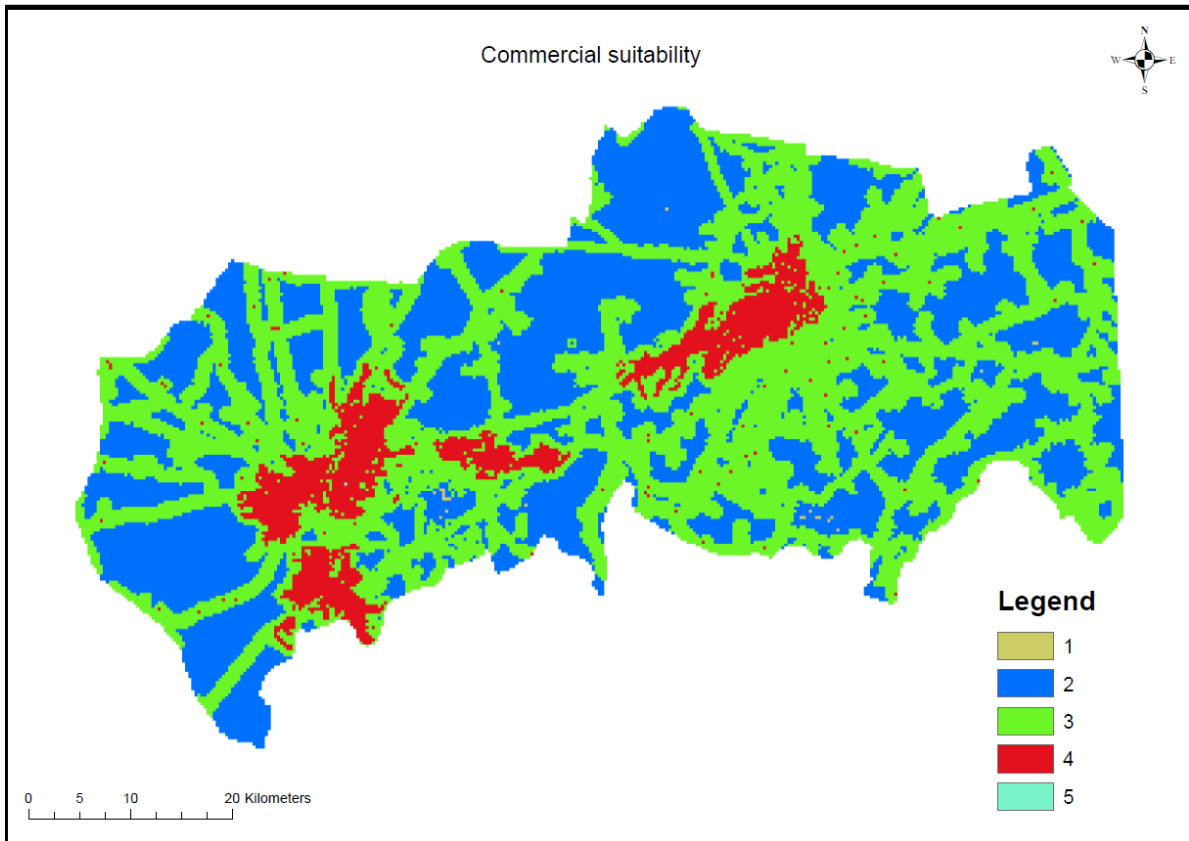


Figure 6-8: Map of commercial suitability

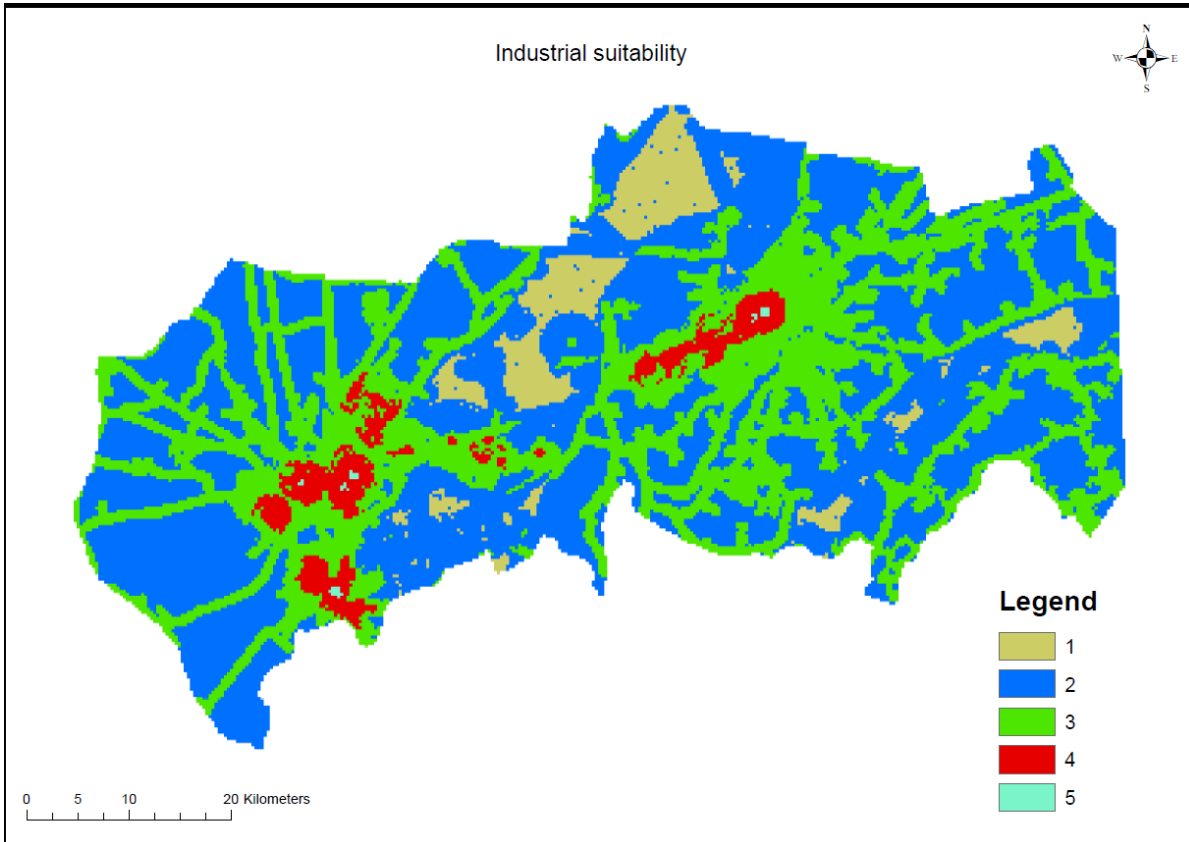
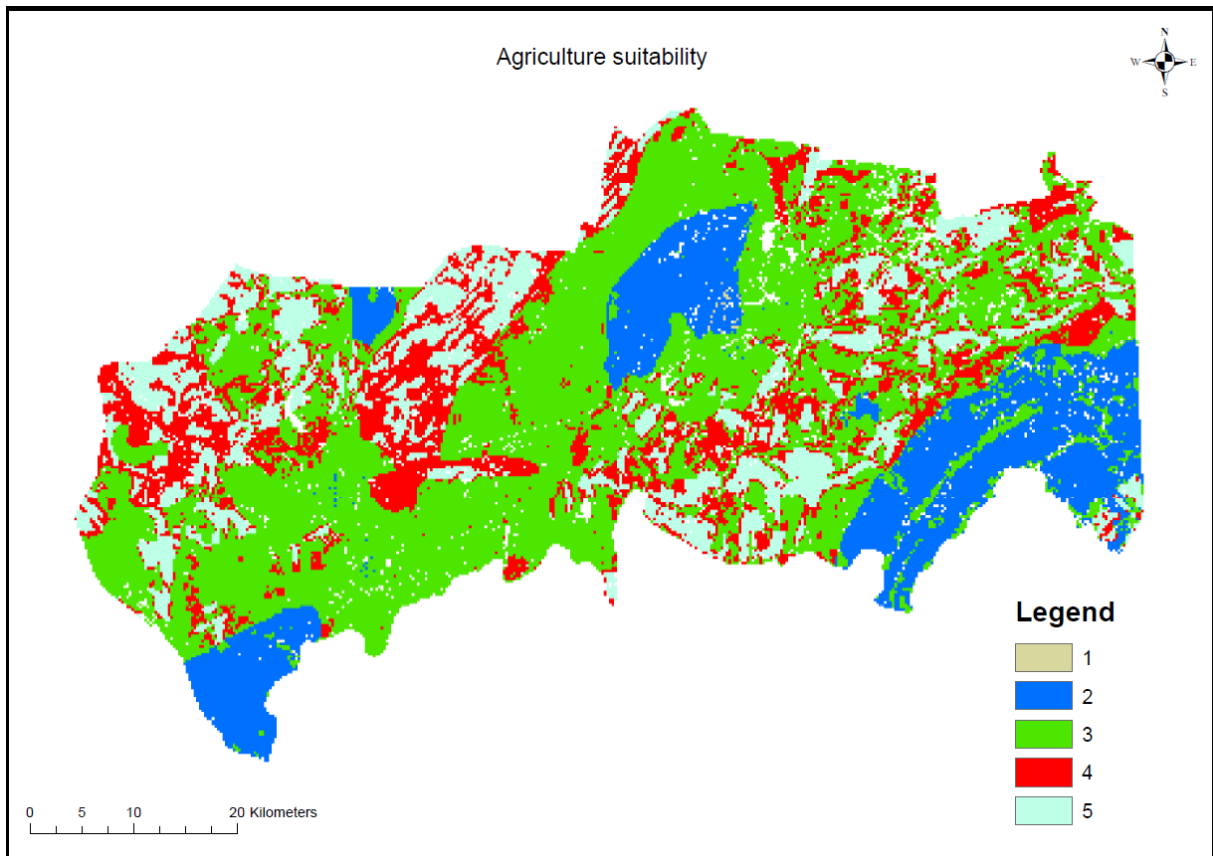
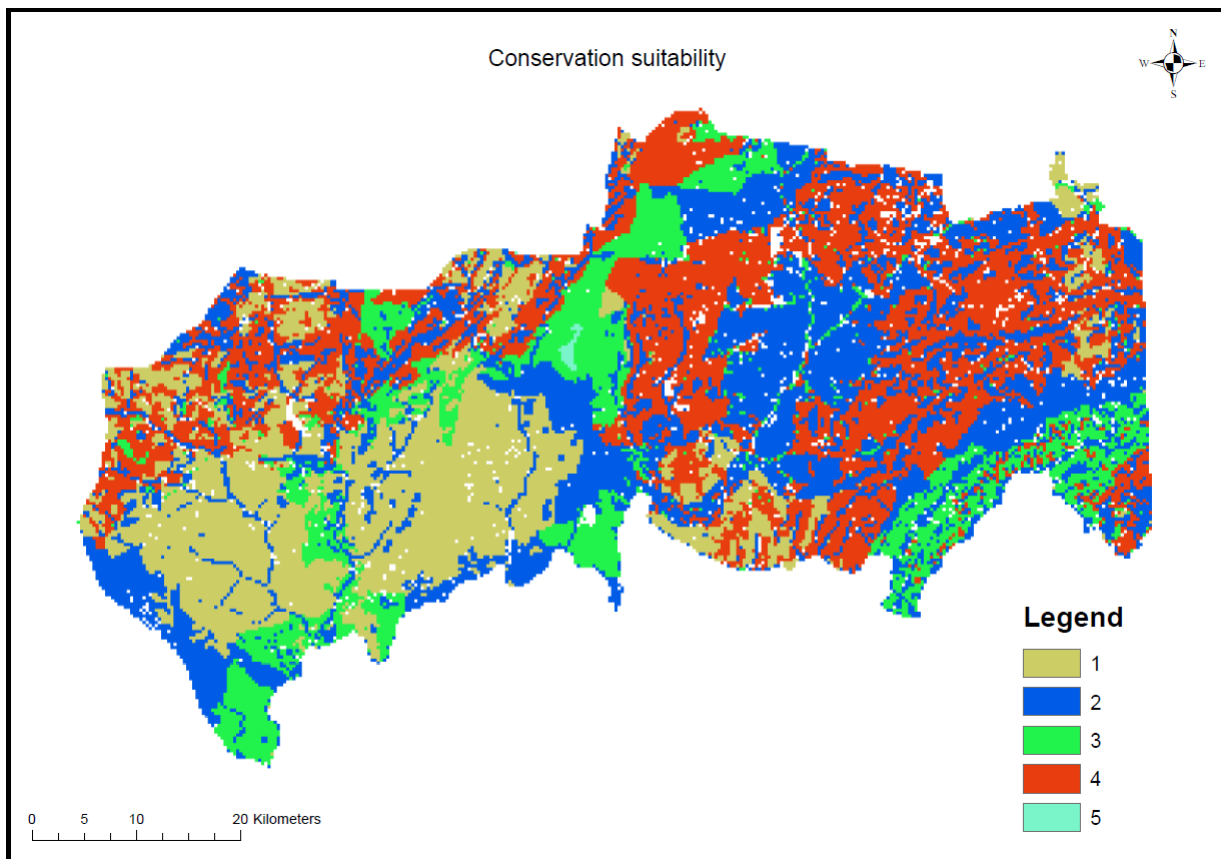


Figure 6-9: Map of industrial suitability



**Figure 6-10: Map of agriculture suitability**



**Figure 6-11: Map of conservation suitability**

Fig. 6-7 shows no locations of very low suitability for residential development, but only 205 ha are perfectly suited to it. Commercial suitability is the greatest between the three urban land uses, with at least 13 032 ha within the study area highly suited for commercial development. Fig. 6-7 to 6-9 all show that the highest suitability for the respective uses is around the already settled urban area. Industrial land uses are especially concentrated around urban areas, as Fig. 6-9 clearly shows large areas that are unsuitable for industrial development outside the urban areas. This observation can be attributed to the high values assigned to proximity to roads and bulk services criteria. The commercial and industrial uses mimic the road network structure, as is expected because of the high value that is placed on road proximity.

Fig. 6-10 illustrates a great amount of high suitability in the study area. With measurements over 170 000 ha receiving high suitability grades, it is clear to see why agriculture has been identified as a major economic driver in the region. Furthermore, most of the areas that are not highly suitable are given moderate suitability metrics. Agriculture also represents the smallest amount of low suitability land and is mostly found in the steep terrain from the outer reaches of the Vredefort Dome.

Conservation is an important factor to consider and Fig. 6-11 shows the amount of area that needs to receive high-priority conservation efforts. Most of the JB Marks municipality area contains land with high to very high suitability for conservation. The total highly suitable land in the study area accounts for 99 504 ha. The most urbanised region in the study area, namely the City of Matlosana, has far less land suitable for conservation due to the urban footprint, but possibly also due to the presence of the large-scale mining outside of Klerksdorp. The area best suited for conservation is found the farthest away from both major urban centres, in the middle of the study area.

#### **6.4 Height Above Nearest Drainage (HAND)**

Fig. 6-12 was created by using the HAND tool, provided by Dilts (2015), and the 25m DEM, provided by the DALRRD (2021). The HAND procedure uses the DEM of an area to determine the drainage network by using computations to create a hydrological coherent DEM, construct flow paths, and define drainage channels (Nobre *et al.*, 2011:15). The output from the finalised HAND procedure provides a normalised drainage version of the DEM, which represents the vertical distance between any cell on a slope and the drainage outlet cell of a mutually connected flow path (Nobre *et al.*, 2011:28). The original output from the HAND tool was reclassified into five classes that can be seen in Fig. 6-12. The high-risk flood areas are 2 m above the nearest

drainage outlet point. Each class is 2 m higher than the previous one up until 8m. Any cells higher than 8m was classed as very low-risk areas for flooding. Areas closer to streams at lower elevations have a higher susceptibility to flooding; thus, the lowest elevations have the highest flood risk (Rincon *et al.*, 2018:282). The biggest stretch of very high flood risk runs along the Mooi River banks, a river which runs through Potchefstroom. 44 784 ha of land in the study area is at very high risk of flooding, while another 22 032 ha is at high-risk levels. However, most of the study area is suited for development, with 223 533 ha deemed to be at a much lower risk level for flooding.

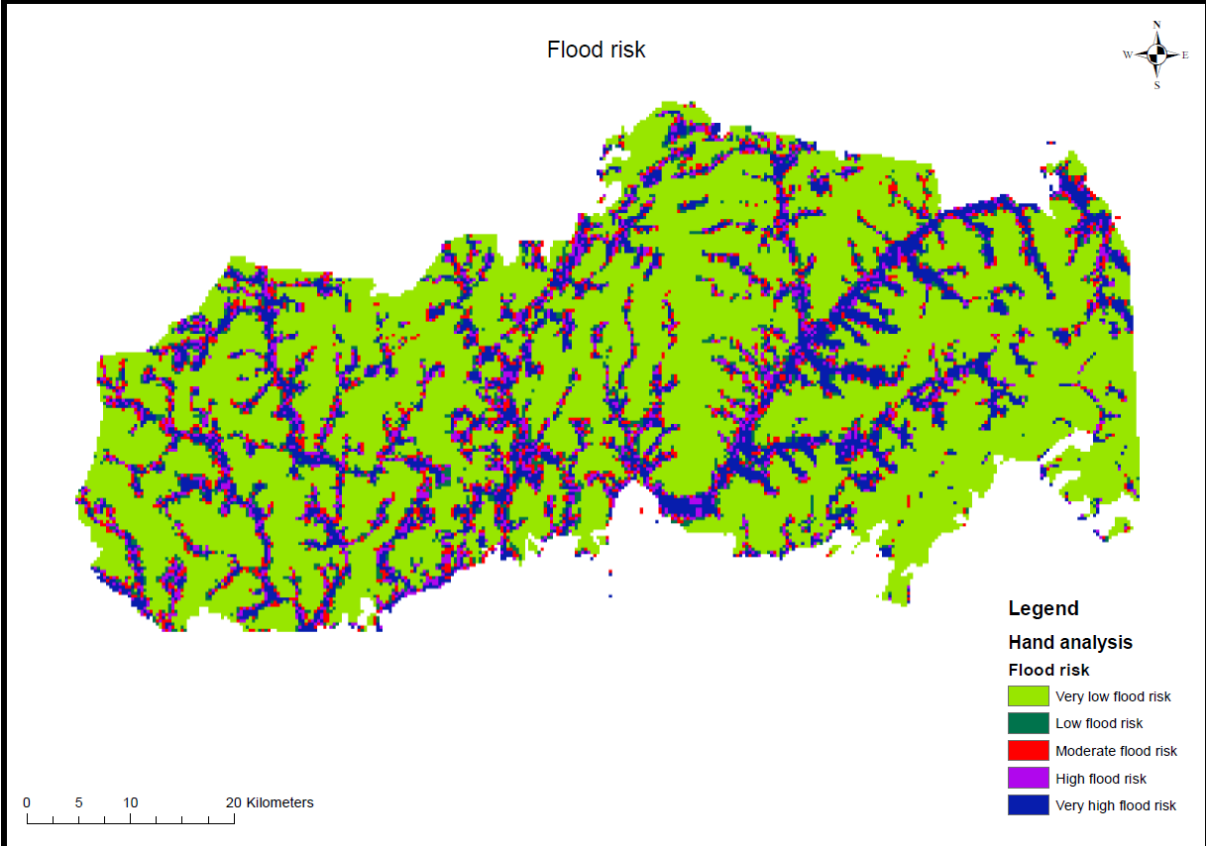
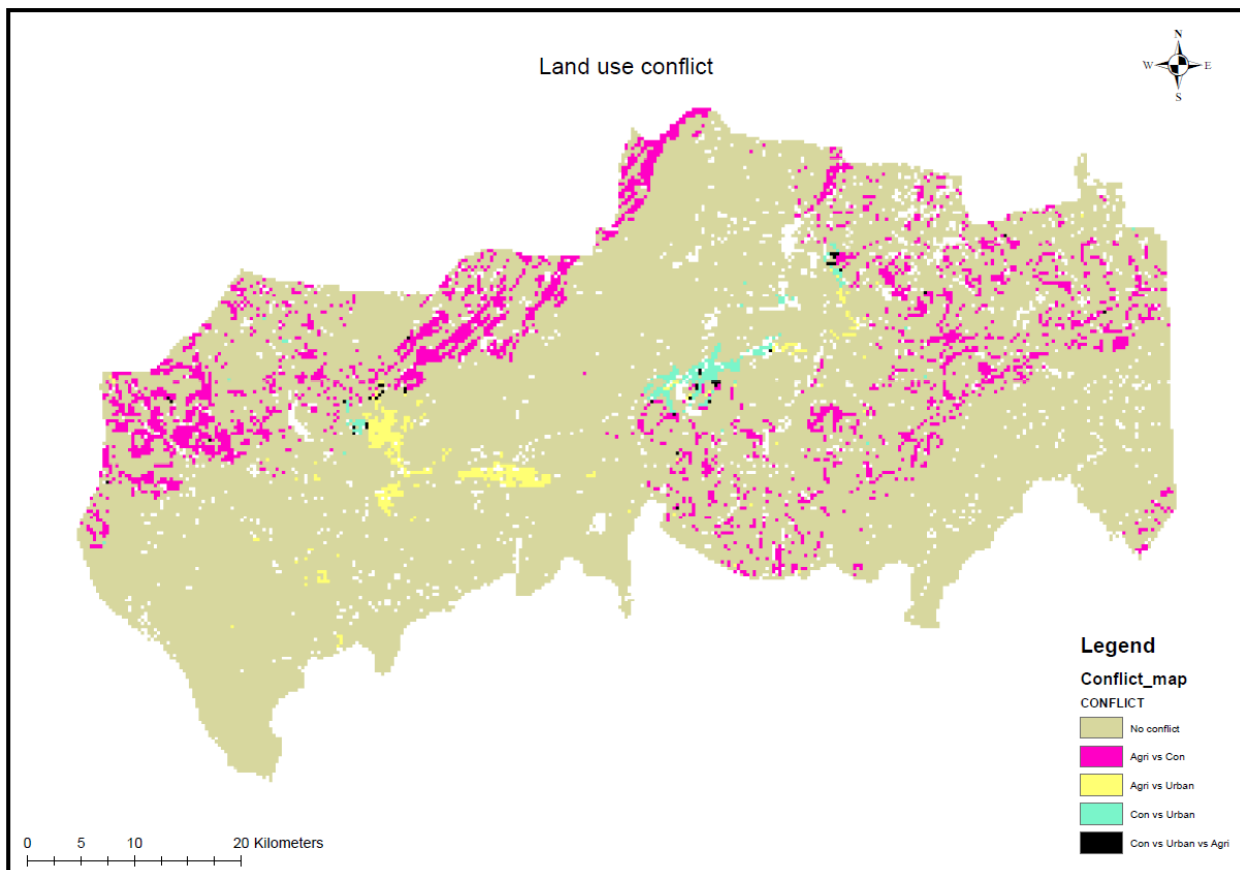


Figure 6-12: Map of flood risk in the study area

## 6.5 Land use conflict results

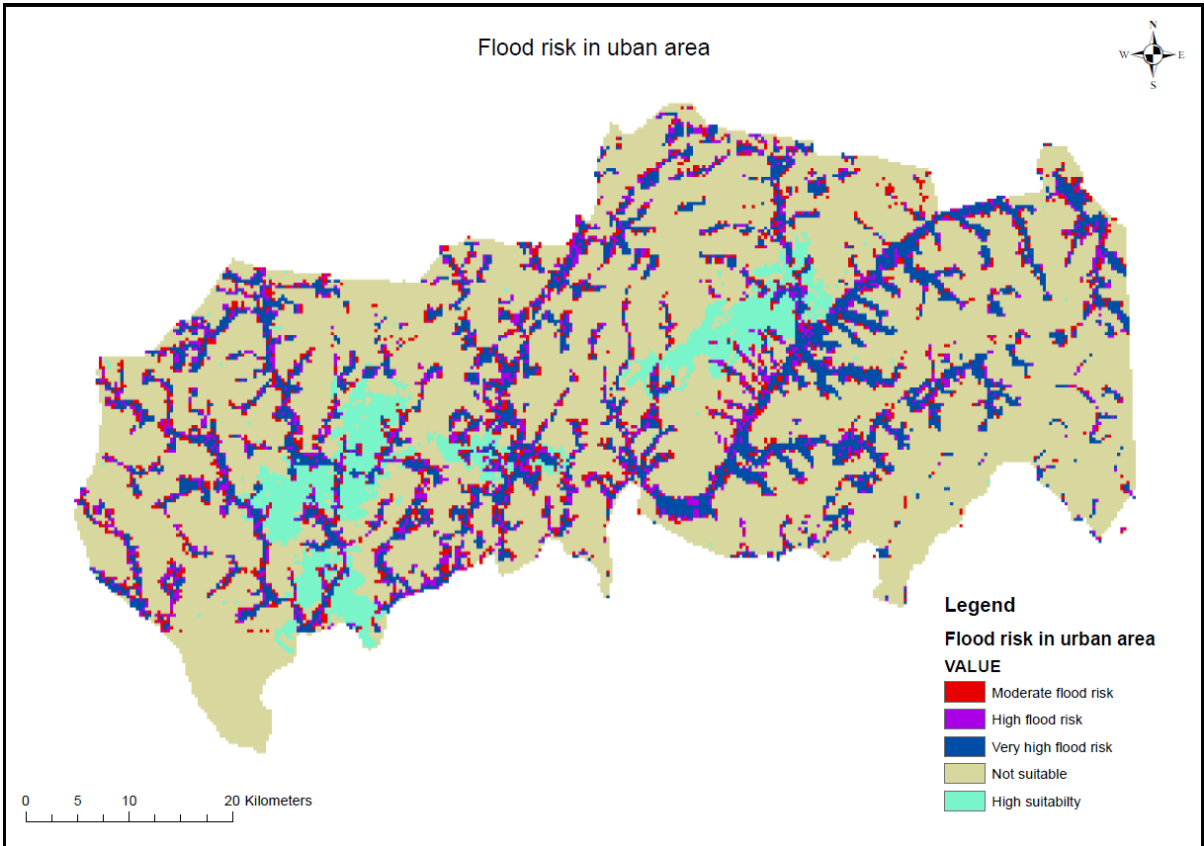
The last step of the empirical research requires the land use suitability maps to be compared to one another in order to identify the possible conflicts and to determine the effect the flood risk map has on the urban suitability. As stated before, the conflicts were identified by using the Raster Calculator in ArcGIS and using each suitability map as a raster layer. The Raster Calculator uses mathematical expressions from map algebra to produce raster outputs from raster inputs (Caner & Aydin, 2021:7). The three urban land uses were combined using this method and identified all the cells with a suitability rating of 4 or higher in the three raster layers. Fig. 6-13 shows the result of the raster calculation for the land use conflict identification. Finally, the flood risk map was layered over the urban suitability map at 50% transparency, which allows both the urban suitability layer as well as the flood risk map to be seen. The two lowest levels of flood risk were also removed to allow for better examination of the high flood risk areas in relation to the urban suitability.



**Figure 6-13: Map of the land use conflict**

Conflict was identified between all three land uses, and even conflict between all three land uses in the same cells. The greatest conflict occurs between conservation and agriculture land uses, with 27 711 ha of land experiencing this conflict. Agricultural and urban conflict mostly occurs near the Klerksdorp and Stilfontein region, with a total of 3 681 ha of conflict in the study area.

The conservation and urban conflicts seem to be located near Potchefstroom and the Highveld nature reserve, which is situated just west of Potchefstroom. Most of the conflict is located in that region and accounts for the majority of the 1 953 ha of conservation-urban conflict. Finally, in some areas, conflict seems to exist between all three land uses, which indicates that no single one of the land uses has an outright claim for superior suitability. These conflicts occur on only 396 ha of the study area and are by far the smallest amount of conflict.



**Figure 6-14: Flood risk to the urban area**

Fig. 6-14 illustrates how the flood risk runs through the urban suitability areas. The Mooi River has the biggest effect on the region as well as the urban area of Potchefstroom, as the figure shows. The flood risk comparison is performed with the urban area because it is the area where most people would be impacted by a flood. The area near Stilfontein just east of the major urban suitability area around Klerksdorp is almost completely comprised of high-risk flooding sites and makes urban development difficult in that region.

**6.6 Summary**

The empirical results showed how the AHP process created weights that could be used as inputs for the weighted analysis. The outputs from the different weighted analysis created the suitability maps followed by the conflict maps. The HAND model was created using a different method of

GIS processing where topographical features were used to determine the flood risk. The land use suitability maps illustrated how the urban land use suitability is concentrated around current infrastructure and thus the value of compact urban growth. The frequency of high value conservation areas are concentrated near waterways and further from the urban and mining areas. This shows the influence human settlements and activities have on the environment.

## **CHAPTER 7: DISCUSSION**

The study's aim is to create a framework through LUCIS analysis for the region of JB Marks and City of Matlosana to guide future developments and land use conflicts, and in achieving this aim, several objectives were kept in mind. The discussion will be formulated according to the research objectives.

### **7.1 Identifying land use conflict through land use suitability maps**

By using the expert judgements from the participants, criteria for urban land use suitability were identified and weighed according to importance. These weights add to the knowledge base regarding how sites should be chosen and what criteria are deemed to be important. These criteria lead to the creation of three land use suitability maps that illustrate how urban structures benefit from proximity to infrastructure, economic activity, and social services. Fig. 6-7 to 6-9 represent these different urban land uses and their suitability. These maps show that urban land use suitability overlaps between the different types. This does not necessarily entail competition between the three types of land use, but rather shows that these land uses can be mixed according to compatibility, especially in the case of commercial and residential land uses, which would create shorter commuting distances, less traffic, and increased densities according to the literature reviewed for this study. While industrial areas were treated as containing noxious activities and added as a push factor in the study, some industries, especially newer types of industry, such as technology manufacturing and renewable energy, are compatible with residential and commercial uses. From the industrial suitability, it was apparent that even though land is cheaper and space is more abundant in the peripheries, industrial developments should take place closer to urban nodes and add to the compactness of cities rather than encouraging urban sprawl. Interestingly, the participants overall judged access to roadways and bulk services as the most important factor for commercial land use, and proximity to residential uses as one of the least valuable aspects. This has led to a very widespread distribution of suitable land for commercial use, due to the abundance of roads and bulk services in the study area, even if residential areas were not in proximity.

The literature emphasises the importance of agriculture, not only in terms of global food security but also with regard to the economy of the study area. Therefore, the insight gained by doing a suitability analysis for agriculture was very valuable. In gathering information for criteria development and weight judgements, the abundance of different suitability analysis studies around the world became apparent, as well as the lack of such studies concerning South Africa. Each study that was consulted used different criteria and different weights according to the

location and produce cultivated. However, certain criteria remained constant throughout the research. This included slope, soil potential, and current land uses. Fig. 6-10 shows that much high-potential agriculture land is available. This could mainly be attributed to the abundance of high-potential soil in the area. It is however noted that this abundance can be highly affected by mining activities that form another major part of the region's economy; therefore, finding a balance between these uses is important, especially because the effect they have on agriculture suitability can be seen on the map produced in fig. 6-10.

Finally, the conflict identification showed how easily land uses can be in competition with one another. The most common conflict, as illustrated in Fig. 6-13, is the competition for land between agriculture and conservation. The land uses are of equal importance for human survival, but a compromise will be required to ensure sustainability on both fronts. Urban uses are in conflict with both uses at certain locations in the study area. These conflicts will only grow as urban sprawl increases and land is sacrificed for such development, which will only increase the need to protect other areas of similar land use. Therefore, reserving high suitability areas for development for each respective land use, especially urban areas, is important for ensuring that land can be effectively used between different sectors. The clearest form of conflict is where the three uses are simultaneously in direct conflict with each other. Fig. 6-13 indicates that the Highveld Nature Reserve will be under constant pressure from urban expansion, as a conflict exists between the two land uses. Fortunately, this area is a nature reserve and is protected under the Protected Areas Act, but similar crucial biodiversity areas are not protected and are vulnerable to either agriculture or urban land uses. Identifying these suitability metrics and conflict locations is, therefore, extremely important to help drive spatial planning into a sustainable direction.

## **7.2 Identifying hazardous and vulnerable environments in the study area**

The literature reveals many different forms of vulnerability to disasters in the study area that need to be addressed outside of land use management. However, an issue that land use planning can assist with is the spatial layout. One objective that was relayed is the need to identify hazardous events and vulnerabilities in the study area. It is shown that flood analysis is of great value in dealing with these vulnerabilities. The vulnerabilities identified in the area are numerous. Firstly, the housing standards of many residents within the study area are not capable of withstanding any sort of flooding. These people live in informal housing and many of them are close to waterways, such as Wasgoedspruit in Ikageng. The main reasons identified for this are the lack of planning in peripheries, past planning regulations causing people to live on these peripheries, and the fact that people cannot afford housing closer to urban centres. This knock-on effect causes residents to spend the little money they have to travel into town for work and shopping and prevents them from improving their living standards. By mixing land uses and identifying

better areas for residential usage these issues can be eased. This is where the value of residential land use suitability is evident. By utilising the maps in this study, local governments can better place subsidised and government housing and keep informal settlers from staying in unsuitable areas. Furthermore, the HAND analysis is a procedure that needs little information and can increase flood risk identification without lengthy and costly hydrological surveys. The procedure does not guarantee no flooding would occur in a given area, but adds another form of disaster prevention that may lower the effects of a disaster. Another big disaster risk identified is the presence of dolomite in the study area, especially Ikageng. By adding sinkhole formation as a factor in the land use suitability analysis, other sites could be identified that are situated outside these dolomite clusters. Sinkholes forming in dolomite land causes millions of Rands of damage in Gauteng and could just as easily occur in the study area, if lessons learnt from past mistakes are not taken to heart.

### **7.3 Aiding in the protecting of biodiversity and agricultural land**

Conservation and sustainability are at the forefront of any urban planning or land use study conducted in the past two decades. This study is no different, as one of its objectives is to aid biodiversity conservation and food security by suggesting methods for protecting agricultural and natural land. By identifying the high-potential agriculture land, steps can be taken to ensure the future safeguarding of this land. The same can be said for the ecologically sensitive areas. In the literature consulted, the idea of creating sustainable cities was mentioned numerous times, especially in the land use fields. Fig. 6-11 is a map that can be used to ensure that the best areas for conservation remain unharmed from urban or agricultural land use. In the study area, there are a number of locations of critical biodiversity, and the area also contains the Highveld Nature Reserve and numerous private nature reserves. The effect of urban expansion and mining is clear to see on the conservation suitability map, where one side of the study area shows more land that must be conserved than the other; although it could have been the case, even without the effect of the above-mentioned land uses, their presence and effect cannot be ignored. The fact that the most highly suited conservation land is situated the farthest from human settlements shows the effect urban societies have on the biodiversity of the planet. Another factor that may skew which land should be conserved is the presence of the Mooi River. When Fig. 6-11 is compared to the flood risk map in Fig. 6-12, it is clear to see the ecological importance of such a river and how the areas surrounding it are of conservation importance. This is supported by the literature which highlighted the importance of peatlands in the Mooi River area. Unfortunately, the presence of rivers in the urban region of Klerksdorp and Orkney cannot cause them to be considered as highly suitable for conservation. This can be seen in the Potchefstroom region as well, where the land west of the Mooi River is of lower suitability due to the presence of the Potchefstroom urban land

cover. Furthermore, the Highveld Nature Reserve and Mooi River are close to urban settlements and therefore the ability to identify the areas that need protection around these settlements is vital in preserving the ecological services provided by them.

#### **7.4 Value of GIS-MCDM, HAND model and its influence on spatial planning**

Additionally, the value of GIS as a spatial analysis tool was once again made apparent. The strides the technology has made in making the system more freely available and user-friendly means that an ever greater number of researchers can use it for similar studies. By combining it with MCDM, a great variety of problems can be addressed. GIS-MCDM has evolved into a technique that can be used in any form of spatial problem or decision. There are, however, limitations regarding its use, especially in more remote areas, owing to the lack of easily accessible and up-to-date spatial data. This may be a reason why these studies have taken place more readily in developed countries where remote sensing data and spatial plans are more up-to-date. The HAND model showed its value in the study by aiding the identification of hazardous regions in the area which is mostly overlooked in LUCIS studies. The advantage of the HAND model is the little input data needed to create the flood risk output, which makes it useful in remote areas where the DEM is possible the only available input for flood modelling. It was concerning to observe how out-of-date and inaccessible some of the SDF's in the study area were. One of the ways in which spatial planning has evolved in recent times is the value placed on public participation and local knowledge. This is however hampered in South Africa by a lack of alignment between government spheres and the lack of publicly available spatial plans and land use schemes, as the literature states. The LUCIS research is a framework that would help supplement the lack of up-to-date spatial plans.

#### **7.5 Summary**

The chapter looked at the empirical results along with the literature review and discussed what was learned from these results. The first section discussed the importance of the different factors that were considered for the land use suitability analysis and how the conflict between different land uses was identified. Thereafter, the vulnerability and disaster risk were discussed. The study highlighted various areas of vulnerability, especially regarding flood risk. Furthermore, the chapter looked at how biodiversity has been aided by the study by identifying areas for conservation which are at risk of urban sprawl. Finally, the value of the methods and processes used in the research was discussed and how the LUCIS method adds to spatial planning.

## **CHAPTER 8: PLANNING RECOMMENDATIONS**

As the discussion highlighted, the aim of this study was to identify land use conflicts and to create maps that could be used as a framework for future developments. This aim was met by using ArcGIS and MCDM techniques to identify criteria for the different land use suitability's and their importance to each. These land use suitability maps were then evaluated and combined to form land use conflict identification maps that could be used to see where possible conflicts would occur. Additionally, flood risk modelling was done through the HAND technique to add disaster risk reduction to the process by comparing it with the urban land use suitability areas. These maps of land use suitability and conflict can be used to aid in future land use placement and policy decisions. Additionally, the following planning recommendations can be taken from this study.

### **8.1 Recommendations regarding spatial planning legislation**

The research reviewed for this study shows a clear link between spatial planning and disaster management. This recognition has also been included in South Africa's spatial planning legislation through the DMA and SPLUMA; however, certain rules and principles are not being applied in spatial planning in South Africa and render the legislation ineffective. Some of the SDFs used in this study to survey the study areas were outdated and were formulated more than 5 years ago without any amendments made to them. If newer versions of SDFs and land use schemes do exist, they are inaccessible to most, as they are not made available online for public use or comment. In an era where public participation is being emphasised, making such changes could benefit the whole area by introducing new ideas and possibly making amendments to the current spatial plans.

Natural hazards and possible disaster risks must be accounted for in the development of SDFs. The research shows, however, that many spatial plans lack the integration of such data. However, this lack of integration is not policed and therefore many spatial plans lack the inclusion of such research. Legislation from the DMA and SPLUMA need to be enforced more rigidly to ensure uniformity across all spheres of government and South African municipalities. There is no doubt that land use and spatial planning have a major effect on disaster risk, as the literature has shown. If, however, residents are not informed of the dangers of settling outside the formulated urban structure, they will likely continue to do so. Therefore, making spatial plans readily available to residents will help them make more informed decisions. Furthermore, the enforcement of legislation needs to be improved, as the presence of informal settlements have made apparent what could occur if urban sprawl is left unchecked. Spatial planning is only as effective as its implementation.

## **8.2 Recommendations regarding the use of LUCIS as a framework**

The LUCIS research shows that large areas of the study area have high suitability for the different land uses, but that some will come into conflict with each other. These conflicts need to be resolved in all the areas of the study area to ensure sustainable development. Policies need to be formulated in a manner that does not impair one land use in favour of another. Therefore, planners in the area would do well to set up comprehensive strategies to identify the best use for each area exhibiting conflict; this can be done through public participation, disaster risk evaluation (in terms of urban land uses), and other detailed multi-criteria decision-making methods.

Areas such as the Highveld Nature Reserve should stay unchanged as much as possible by driving urban development away from the area and not allowing illegal settlements in the protected area. Furthermore, assets such as the Mooi River need to be considered in every urban decision to ensure lower levels of pollution and lower disaster risk, and to protect the ecological services it provides. The study area is rich in crucial biodiversity and is in danger of being converted to agricultural or mining land. There is plenty of high potential agricultural land that falls outside these areas that have not been used to their full potential and need to be developed first. Therefore, the local municipalities should enforce compatible, non-invasive uses in the areas that need to be conserved.

In terms of urban development, the suitability maps show how much of the high suitability land is shared between residential, industrial, and commercial land uses. The most important conclusion from this is that the urban footprint should be kept compact and consist of a mix of land uses. The industrial uses may be kept apart, but should still be within a reasonable distance from commercial and residential uses to ensure a connectivity. According to modern research, the mixing of uses is the future of land use planning. The study shows that the criteria used encourages the mixing of uses, as the land in various places suits the variety of urban uses equally. The only issue will be to ensure that the uses are compatible. The eventual choice of land uses should take place on a smaller scale and should be implemented on a case-by-case basis. An idea found in the literature is to allow most uses in an area, if the land is suitable, and only disallow the uses that would not be compatible, such as noxious industries. The main aim for future developments should be to discourage motor vehicle travel and make more pedestrian movement possible. The study area, and South Africa as a whole, have other problems that discourage pedestrian movement outside the scope of this study, but making destinations closer to homes can only facilitate a move away from fossil-fuelled vehicles. With Potchefstroom experiencing the highest population growth, the city will experience the greatest pressure to expand its boundaries, but should rather focus on densifying the current urban area, and place social housing closer to services and economic opportunities. Large parts of Potchefstroom are dedicated to the university

and housing for its students. Therefore, student apartments are a great way of densifying around the university and should encourage students to live closer to campus by promoting lower cost housing in the area, rather than pushing students to the suburbs and peripheries for affordable housing.

Last, Ikageng was identified as an area of great vulnerability that should be attended to. Large parts of Ikageng have been built on dolomite land, which could lead to sinkholes that could cost lives and cause the destruction of homes. The area is also situated next to a waterway that has the potential to cause flooding. The area should be closely monitored to prevent informal housing being set up too close to flood risk areas. The HAND model can be used along with other hydrological studies to determine the safest distance from waterways for future site identification. The HAND model is only an indication of how flood risk should be integrated in land use management and is far from a comprehensive flood risk report.

### **8.3 Recommendations for future research**

As mentioned, research on LUCIS is in short supply in South Africa and is a resource that can be used by any municipality to guide its spatial layout. Therefore, more research needs to be conducted to determine sufficient criteria for LUCIS analysis. The criteria used in this study were compiled from international articles and the limited research done on the subject in South Africa. Criteria should be changed according to context, but certain criteria can remain constant, such as proximity to infrastructure and services. However, the importance certain criteria carry in South Africa will differ from the rest of the world due to socio-economic and cultural differences. This means that expert judgements will need to be gathered until enough research is published to use case-based research for urban land use criteria. The inclusion of public interest would also provide a beneficial perspective on urban land use criteria. By combining expert and public judgments, a better understanding of value can be gathered. Therefore, future studies should experiment with the use of public knowledge alongside expert judgements.

The lack of up-to-date spatial data and the inaccessibility of such data also hampered the research. Research on spatial elements, especially in urban environments, needs to be done more frequently on smaller scales to better understand the spatial situation in local areas. Without sufficient recent data, the conclusions drawn from LUCIS analysis could be inaccurate and negatively influence the formulation of future spatial development goals.

The usefulness of the HAND model is demonstrated in this research. By only requiring the DEM of an area, the process can be implemented in even the remotest of areas. However, when detailed flood reports can be implemented, it would increase disaster risk mitigation in terms of

land use placement. Where possible, the HAND model should be combined with land cover, precipitation data, and soil permeability data in order to increase its accuracy in the modelling of flood risk. Research on these geophysical features should also be done more extensively in South Africa to allow for these criteria in flood risk modelling. The data used in the future should ideally be of higher resolution. The data used in this study did not allow for resolutions of lower cell size. The more the detail can be seen in the LUCIS analysis, the greater its usefulness for land use management.

#### **8.4 Summary**

The study used various objectives to guide the research method in order to reach the aim of creating a spatial planning framework which can be used to guide future developments. The final chapter looked at what was achieved by the research and how the results can be used in future legislation, spatial planning and research. The need for integrating disaster risk and spatial planning has been highlighted. The use of the LUCIS results as a framework for spatial planning in the study area was discussed and how such an analysis can be used in most of the country. Finally, the need for more research in the methods used was emphasised and how this research should focus on creating more up-to-date databanks of spatial data which can be used for such research. The aim of the study as mentioned was to create a framework which can be used to guide spatial planning in the study area. With the use of the suitability maps, conflict maps and flood risk maps spatial plans can be created which look to use land in the most efficient manner.

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## **ANNEXURE A (INFORMED CONSENT FORM)**

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**SUBJECT GROUP URBAN AND REGIONAL PLANNING**

**FACULTY OF NATURAL AND AGRICULTURAL SCIENCE**

### ***Consent to participate in the research study***

The Faculty of Health Sciences Ethics Office of the North-West University is acknowledged for the use of their document with minor adjustments made by the North-West University Education, Management and Economic Sciences, Law, Theology, Engineering and Natural Sciences Research Ethics Committee (NWU-EMELTEN-REC).

**TITLE OF THE RESEARCH STUDY: Identifying suitable land uses and possible conflicts through LUCIS analysis in the JB Marks and City of Matlosana municipalities**

**STUDY SUPERVISOR: Dr Menini Gibbens**

**POST GRADUATE STUDENT: Jan-Frans Lötz**

**ADDRESS: 15 Bach Avenue, Potchefstroom**

**CONTACT NUMBER: 0847797011**

You are invited to take part in a research study that forms part of my Master's Degree in Urban and Regional Planning at the North-West University. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is important that you are confident that you clearly understand what this research is about and how you might be involved. Further, your participation is **entirely voluntary**, and you are free to decline to participate. If you decline, this will not affect you

negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the Faculty of Natural and Agricultural Sciences Ethics Committee (FNASREC), (NWU - 01377 - 22 - A9) and will be conducted according to the ethical guidelines and principles of Ethics in Health Research: Principles, Processes and Structures (DoH, 2015) and other international ethical guidelines applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

### **What is this research study all about?**

*The study will involve participants completing an online survey regarding different variables and their importance to land use planning. The study area focuses on the Potchefstroom and Klerksdorp region. The data gathered from the surveys will be used to create land use suitability maps for agricultural, urban, and conservation land uses. These maps will, in turn, be used to identify possible land use conflicts.*

*This survey will be conducted via an email link that will be sent to participants. 8-10 participants will be included in this study.*

### **Why have you been invited to participate?**

*You have been invited to be part of this research because you are an urban planner with professional knowledge regarding land use planning.*

*You will unfortunately not be able to take part in this research if you are not a professional urban planner.*

### **What will be expected of you?**

*You will be expected to rank the various variables according to their importance for different land uses.*

### **Will you gain anything from taking part in this research?**

*There will be no direct gains for you in the study.*

### **Are there risks involved in you taking part in this research and what will be done to prevent them?**

*There are no risks involved in taking part in this study.*

**How will we protect your confidentiality and who will see your data?**

*Anonymity of your data will be ensured, as the surveys will be done anonymously and at no point will you be required to give any personal information along with your response. After the conclusion of the study, the individual responses will be deleted.*

**What will happen with the data or samples?**

*The individual responses will only be used to create an average answer that can be used in this study. These averages are the only data that will form part of this and any future studies.*

**Will you be paid to take part in this study and are there any costs for you?**

You will not be paid for participating in this study. Your participation will not cost you anything and will be done by email.

**Is there anything else that you should know or do?**

You can contact Jan-Frans Lötzt at 0847797011 if you have any further questions or concerns.

You will receive a copy of this information and consent form for your own purposes.

Declaration by participant

By signing below, I ..... agree to take part in the research study titled ***Identifying suitable land uses and possible conflicts through LUCIS analysis in the JB Marks and City of Matlosana municipalities.***

I declare that:

- I have read this information/it was explained to me by a trusted person in a language with which I am fluent and comfortable.
- The research was clearly explained to me.
- I have had a chance to ask questions to both the person receiving the consent from me and the researcher, and all my questions have been answered.

- I understand that taking part in this study is **voluntary** and I have not been pressured to take part.
- I may choose to leave the study at any time and will not be treated negatively if I do so.
- I may be asked to leave the study before it has finished, if the researcher feels it is in the best interest of the study, or if I do not follow the agreed-to study plan.

Signed at (*place*) ..... on (*date*) ..... 20....

.....

Signature of participant

### Declaration by person obtaining consent

I, Jan-Frans Lötzt declare that:

- I clearly and in detail explained the information in this document to  
.....
- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) ..... on (*date*) ..... 20....

.....

Signature of person obtaining consent

### Declaration by researcher

I Jan-Frans Lötzt declare that:

- I explained the information in this document to .....
- I did/did not use an interpreter
- I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.
- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) ..... on (*date*) ..... 20....

.....

**Signature of researcher**

## ANNEXURE B (QUESTIONNAIRES)

### Questionnaire 1

Please rank the variables according to their importance regarding different land uses

**Please rank the following variables according to their importance to residential land use placement.**

- |              |   |
|--------------|---|
| <b>No.1</b>  | Distance to social services (Schools, health centres, recreational centres) |
| <b>No.2</b>  | Distance to existing bulk services (Power, potable water, sewage)           |
| <b>No.3</b>  | Distance from pollution (Factories, sewage, landfill, mining)               |
| <b>No.4</b>  | Geophysical structure (soil type, slope)                                    |
| <b>No.5</b>  | Environmental conservation  |
| <b>No.6</b>  | Proximity to roadways   |
| <b>No.7</b>  | Distance from other residential areas                                       |
| <b>No.8</b>  | Distance from railway   |
| <b>No.9</b>  | Risk of sinkhole formation  |
| <b>No.10</b> | Distance from city centre   |
| <b>No.11</b> | Distance from industrial area   |

**Please rank the following variables according to their importance to commercial land use placement.**

**No.1**

Distance from residential areas

**No.2**

Geophysical structure (soil type, slope)

**No.3**

Proximity to roadways

**No.4**

Distance to existing bulk services (Power, potable water, sewage)

**No.5**

Distance from pollution (Factories, sewage, landfill, mining)

**No.6**

Environmental conservation

**No.7**

Distance from industrial area

**No.8**

Risk of sinkhole formation

**No.9**

Distance from city centre. local nodes and activity corridors

**No.10**

Distance to health centres

**Please rank the following variables according to their importance to industrial land use placement.**

- No.1** Proximity to roadways
- No.2** Geophysical structure (soil type, slope)
- No.3** Risk of sinkhole formation
- No.4** Distance to existing bulk services (Power, potable water, sewage)
- No.5** Environmental conservation
- No.6** Distance from industrial area
- No.7** Distance from residential areas
- No.8** Distance from city centre. local nodes and activity corridors
- No.9** Distance from landfills
- No.10** Proximity to roadways

## Questionnaire 2

Please rank the variables according to their importance regarding different land uses

### Please rank the following variables according to their importance to residential land use placement.

- |       |   |
|-------|---|
| No.1  | Risk of sinkhole formation  |
| No.2  | Distance from pollution (Factories, sewage, landfill, mining)               |
| No.3  | Environmental conservation  |
| No.4  | Distance from city centre   |
| No.5  | Distance from industrial area   |
| No.6  | Distance to social services (Schools, health centres, recreational centres) |
| No.7  | Distance to existing bulk services (Power, potable water, sewage)           |
| No.8  | Proximity to roadways   |
| No.9  | Distance from railway   |
| No.10 | Distance from other residential areas                                       |
| No.11 | Geophysical structure (soil type, slope)                                    |

#### Please give a short reasoning for your ranking decisions in the previous question.

First safety of the people, which includes flooding, then economic opportunities, where will they work, then social facilities. You will built new roads and install whatever services are required.

**Please rank the following variables according to their importance to commercial land use placement.**

**No.1**

Risk of sinkhole formation

**No.2**

Environmental conservation

**No.3**

Distance from pollution (Factories, sewage, landfill, mining)

**No.4**

Distance from city centre. local nodes and activity corridors

**No.5**

Proximity to roadways

**No.6**

Distance from industrial area

**No.7**

Distance to existing bulk services (Power, potable water, sewage)

**No.8**

Distance from residential areas

**No.9**

Geophysical structure (soil type, slope)

**No.10**

Distance to health centres

**Please give a short reasoning for your ranking decisions in the previous question.**

Stay away from undevelopable land first, then safety to staff, then travel distance for staff and goods. People use health centres near home not work.

**Please rank the following variables according to their importance to industrial land use placement.**

<b>No.1</b>	Risk of sinkhole formation
<b>No.2</b>	Environmental conservation
<b>No.3</b>	Distance from industrial area
<b>No.4</b>	Distance to existing bulk services (Power, potable water, sewage)
<b>No.5</b>	Proximity to roadways
<b>No.6</b>	Distance from city centre. local nodes and activity corridors
<b>No.7</b>	Distance from residential areas
<b>No.8</b>	Geophysical structure (soil type, slope)
<b>No.9</b>	Distance to health centres
<b>No.10</b>	Distance from landfills

**Please give a short reasoning for your ranking decisions in the previous question.**

Stay away from undevelopable land, safety for staff, existing industrial areas have infrastructure already in place, then travel distance for goods. Land fills are not essential for operations.

### Questionnaire 3

Please rank the variables according to their importance regarding different land uses

### Please rank the following variables according to their importance to residential land use placement.

- |       |   |
|-------|---|
| No.1  | Distance to existing bulk services (Power, potable water, sewage)           |
| No.2  | Distance to social services (Schools, health centres, recreational centres) |
| No.3  | Proximity to roadways   |
| No.4  | Distance from other residential areas                                       |
| No.5  | Distance from pollution (Factories, sewage, landfill, mining)               |
| No.6  | Distance from city centre   |
| No.7  | Environmental conservation  |
| No.8  | Distance from industrial area   |
| No.9  | Geophysical structure (soil type, slope)                                    |
| No.10 | Environmental conservation  |
| No.11 | Risk of sinkhole formation  |

### Please give a short reasoning for your ranking decisions in the previous question.

Services are the catalyst for development. Without services, land uses cannot exist (cost effectively). Residential land uses depend upon compatible and supporting land uses to maintain every day needs of a residential community making these land uses co-dependant on each other to successfully exist. Movement corridors are then also very important as this is connection between residential areas and services, connection to towns and regions. The rest of the factors are all influencing factors between establishing average or exceptional locations which again drives the success and sustainability of the residential neighbourhood as well as the cost effectiveness of the development of residential areas.

## Please rank the following variables according to their importance to commercial land use placement.

No.1

Distance to existing bulk services (Power, potable water, sewage)

No.2

Distance from city centre. local nodes and activity corridors

No.3

Proximity to roadways

No.4

Distance from residential areas

No.5

Distance from industrial area

No.6

Distance from pollution (Factories, sewage, landfill, mining)

No.7

Geophysical structure (soil type, slope)

No.8

Risk of sinkhole formation

No.9

Environmental conservation

No.10

Distance to health centres

### Please give a short reasoning for your ranking decisions in the previous question.

Commercial again - like most land uses, are dependant upon services. Very important is to have a location that is highly accessible, visible for passing trade and located along routes near corridors. Transportation of goods are a primary function in most commercial land uses and must thus be in close proximity to roadways, especially those that function as corridors.

## Please rank the following variables according to their importance to industrial land use placement.

No.1

Environmental conservation

No.2

Distance to existing bulk services (Power, potable water, sewage)

No.3

Distance from industrial area

No.4

Distance from city centre. local nodes and activity corridors

No.5

Proximity to roadways

No.6

Geophysical structure (soil type, slope)

No.7

Risk of sinkhole formation

No.8

Distance from landfills

No.9

Distance from residential areas

No.10

Distance to health centres

### Please give a short reasoning for your ranking decisions in the previous question.

Industrial land uses are generally seen as the most noxious and disruptive land uses which often causes the majority of a town's pollution - therefore these land uses should be grouped together to discourage fragmented locations of this type of land use; be situated as far as possible from residential neighbourhoods, but close to corridors for increased mobility and accessibility. Obviously by means of elimination you do not want any land use near possible sinkhole formations/dolomite. Environmental conservation should be the nr1 priority when planning for locations of the various land uses, as at the end-user point in the process, cost-effectiveness trumps environmental conservation for these end-users.

## Questionnaire 4

Please rank the variables according to their importance regarding different land uses

**Please rank the following variables according to their importance to residential land use placement.**

- |              |   |
|--------------|---|
| <b>No.1</b>  | Risk of sinkhole formation  |
| <b>No.2</b>  | Distance to existing bulk services (Power, potable water, sewage)           |
| <b>No.3</b>  | Proximity to roadways   |
| <b>No.4</b>  | Distance from pollution (Factories, sewage, landfill, mining)               |
| <b>No.5</b>  | Environmental conservation  |
| <b>No.6</b>  | Geophysical structure (soil type, slope)                                    |
| <b>No.7</b>  | Distance from other residential areas                                       |
| <b>No.8</b>  | Distance to social services (Schools, health centres, recreational centres) |
| <b>No.9</b>  | Distance from industrial area   |
| <b>No.10</b> | Distance from railway   |
| <b>No.11</b> | Distance from city centre   |

**Please rank the following variables according to their importance to commercial land use placement.**

**No.1**

Risk of sinkhole formation

**No.2**

Distance to existing bulk services (Power, potable water, sewage)

1

**No.3**

Proximity to roadways

**No.4**

Geophysical structure (soil type, slope)

**No.5**

Environmental conservation

**No.6**

Distance from city centre. local nodes and activity corridors

**No.7**

Distance from pollution (Factories, sewage, landfill, mining)

**No.8**

Distance from residential areas

**No.9**

Distance from industrial area

**No.10**

Distance to health centres

**Please rank the following variables according to their importance to industrial land use placement.**

**No.1**

Risk of sinkhole formation

**No.2**

Geophysical structure (soil type, slope)

**No.3**

Distance to existing bulk services (Power, potable water, sewage)

**No.4**

Environmental conservation

**No.5**

Proximity to roadways

**No.6**

Distance to health centres

**No.7**

Distance from industrial area

**No.8**

Distance from residential areas

**No.9**

Distance from landfills

**No.10**

Distance from city centre. local nodes and activity corridors

## Questionnaire 5

Please rank the variables according to their importance regarding different land uses

### Please rank the following variables according to their importance to residential land use placement.

- |       |   |
|-------|---|
| No.1  | Geophysical structure (soil type, slope)                                    |
| No.2  | Risk of sinkhole formation  |
| No.3  | Environmental conservation  |
| No.4  | Distance from pollution (Factories, sewage, landfill, mining)               |
| No.5  | Distance to existing bulk services (Power, potable water, sewage)           |
| No.6  | Proximity to roadways   |
| No.7  | Distance to social services (Schools, health centres, recreational centres) |
| No.8  | Distance from railway   |
| No.9  | Distance from industrial area   |
| No.10 | Distance from other residential areas                                       |
| No.11 | Distance from city centre   |

### Please give a short reasoning for your ranking decisions in the previous question.

Safety of life and possessions is key.

Thereafter the environment.

To be close to bulk services and transport opportunities promotes sustainability.

To be close to work opportunities promotes socio-economic viability.

I ranked city centre last, as employment opportunities in industrial and residential areas have better prospects.

## Please rank the following variables according to their importance to commercial land use placement.

No.1

Geophysical structure (soil type, slope)

No.2

Risk of sinkhole formation

No.3

Environmental conservation

No.4

Distance to existing bulk services (Power, potable water, sewage)

No.5

Proximity to roadways

No.6

Distance from city centre. local nodes and activity corridors

No.7

Distance from pollution (Factories, sewage, landfill, mining)

No.8

Distance from industrial area

No.9

Distance from residential areas

No.10

Distance to health centres

### Please give a short reasoning for your ranking decisions in the previous question.

Safety of life and assets is key.

Access to infrastructure and transport ensures viability.

**Please rank the following variables according to their importance to industrial land use placement.**

- No.1** Geophysical structure (soil type, slope)
- No.2** Risk of sinkhole formation
- No.3** Environmental conservation
- No.4** Distance to existing bulk services (Power, potable water, sewage)
- No.5** Proximity to roadways
- No.6** Distance from industrial area
- No.7** Distance from city centre. local nodes and activity corridors
- No.8** Distance from landfills
- No.9** Distance to health centres
- No.10** Distance from residential areas

**Please give a short reasoning for your ranking decisions in the previous question.**

As per previous.

## Questionnaire 6

Please rank the variables according to their importance regarding different land uses

### Please rank the following variables according to their importance to residential land use placement.

- |       |   |
|-------|---|
| No.1  | Distance to existing bulk services (Power, potable water, sewage)           |
| No.2  | Distance to social services (Schools, health centres, recreational centres) |
| No.3  | Distance from industrial area   |
| No.4  | Distance from other residential areas                                       |
| No.5  | Environmental conservation  |
| No.6  | Geophysical structure (soil type, slope)                                    |
| No.7  | Distance from city centre   |
| No.8  | Distance from railway   |
| No.9  | Risk of sinkhole formation  |
| No.10 | Proximity to roadways   |
| No.11 | Distance from pollution (Factories, sewage, landfill, mining)               |

Please give a short reasoning for your ranking decisions in the previous question. Based on Town planning logic

**Please rank the following variables according to their importance to commercial land use placement.**

**No.1**

Distance from residential areas

**No.2**

Proximity to roadways

**No.3**

Distance to existing bulk services (Power, potable water, sewage)

**No.4**

Distance from industrial area

**No.5**

Environmental conservation

**No.6**

Distance from city centre. local nodes and activity corridors

**No.7**

Geophysical structure (soil type, slope)

**No.8**

Distance from pollution (Factories, sewage, landfill, mining)

**No.9**

Distance to health centres

**No.10**

Risk of sinkhole formation

**Please give a short reasoning for your ranking decisions in the previous question.**

Based on Town planning logic

**Please rank the following variables according to their importance to industrial land use placement.**

- No.1** Distance to existing bulk services (Power, potable water, sewage)
- No.2** Proximity to roadways
- No.3** Environmental conservation
- No.4** Geophysical structure (soil type, slope)
- No.5** Distance from city centre. local nodes and activity corridors
- No.6** Distance from landfills
- No.7** Distance from residential areas
- No.8** Distance to health centres
- No.9** Risk of sinkhole formation
- No.10** Distance from industrial area

**Please give a short reasoning for your ranking decisions in the previous question.**

Town Planning principals

## Questionnaire 7

Please rank the variables according to their importance regarding different land uses

### Please rank the following variables according to their importance to residential land use placement.

- |       |   |
|-------|---|
| No.1  | Distance from city centre   |
| No.2  | Proximity to roadways   |
| No.3  | Environmental conservation  |
| No.4  | Distance to social services (Schools, health centres, recreational centres) |
| No.5  | Distance from other residential areas                                       |
| No.6  | Distance to existing bulk services (Power, potable water, sewage)           |
| No.7  | Distance from railway   |
| No.8  | Distance from pollution (Factories, sewage, landfill, mining)               |
| No.9  | Geophysical structure (soil type, slope)                                    |
| No.10 | Distance from industrial area   |
| No.11 | Risk of sinkhole formation  |

#### Please give a short reasoning for your ranking decisions in the previous question.

It should actually focus on restructuring so the question should not be distance from city centre but distance from mixed use nodes, not distance from roadways and railway but distance from public transport.

**Please rank the following variables according to their importance to commercial land use placement.**

**No.1**

Distance from city centre. local nodes and activity corridors

**No.2**

Proximity to roadways

**No.3**

Environmental conservation

**No.4**

Distance to existing bulk services (Power, potable water, sewage)

**No.5**

Distance from industrial area

**No.6**

Geophysical structure (soil type, slope)

**No.7**

Risk of sinkhole formation

**No.8**

Distance from residential areas

**No.9**

Distance from pollution (Factories, sewage, landfill, mining)

**No.10**

Distance to health centres

**Please give a short reasoning for your ranking decisions in the previous question.** has to be located in areas where it can contribute to the restructuring of the city

**Please rank the following variables according to their importance to industrial land use placement.**

- No.1 Environmental conservation
- No.2 Distance to existing bulk services (Power, potable water, sewage)
- No.3 Proximity to roadways
- No.4 Distance from industrial area
- No.5 Distance from residential areas
- No.6 Distance from city centre. local nodes and activity corridors
- No.7 Distance from landfills
- No.8 Distance to health centres
- No.9 Geophysical structure (soil type, slope)
- No.10 Risk of sinkhole formation

**Please give a short reasoning for your ranking decisions in the previous question.** protect sensitive areas from industrial impacts

## Questionnaire 8

Please rank the variables according to their importance regarding different land uses

**Please rank the following variables according to their importance to residential land use placement.**

- |       |   |
|-------|---|
| No.1  | Environmental conservation  |
| No.2  | Geophysical structure (soil type, slope)                                    |
| No.3  | Distance from other residential areas                                       |
| No.4  | Distance to existing bulk services (Power, potable water, sewage)           |
| No.5  | Proximity to roadways   |
| No.6  | Distance from railway   |
| No.7  | Distance to social services (Schools, health centres, recreational centres) |
| No.8  | Distance from city centre   |
| No.9  | Distance from industrial area   |
| No.10 | Distance from pollution (Factories, sewage, landfill, mining)               |
| No.11 | Risk of sinkhole formation  |

**Please rank the following variables according to their importance to commercial land use placement.**

<b>No.1</b>	Distance from industrial area
<b>No.2</b>	Environmental conservation
<b>No.3</b>	Geophysical structure (soil type, slope)
<b>No.4</b>	Risk of sinkhole formation
<b>No.5</b>	Distance to existing bulk services (Power, potable water, sewage)
<b>No.6</b>	Proximity to roadways
<b>No.7</b>	Distance from city centre. local nodes and activity corridors
<b>No.8</b>	Distance to health centres
<b>No.9</b>	Distance from residential areas
<b>No.10</b>	Distance from pollution (Factories, sewage, landfill, mining)

**Please rank the following variables according to their importance to industrial land use placement.**

<b>No.1</b>	Distance from industrial area
<b>No.2</b>	Environmental conservation
<b>No.3</b>	Geophysical structure (soil type, slope)
<b>No.4</b>	Risk of sinkhole formation
<b>No.5</b>	Proximity to roadways
<b>No.6</b>	Distance to existing bulk services (Power, potable water, sewage)
<b>No.7</b>	Distance from city centre. local nodes and activity corridors
<b>No.8</b>	Distance to health centres
<b>No.9</b>	Distance from landfills
<b>No.10</b>	Distance from residential areas

## ANNEXURE C (PROOFREADING)



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### Certificate of Proofreading

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**Identifying suitable land uses and possible conflicts through LUCIS analysis in the JB Marks and City of Matlosana municipalities**

Submitted in fulfilment of the requirements of the Degree *Magister Scientiae* in Urban and Regional Planning at the North-West University.

Primary proofreader: Mirrycke Krüger

Secondary proofreaders: Henriëtte Krüger and Christiaan Krüger

The primary proofreader works on the entire text and gives the final approval. The secondary proofreader provides support and revises track changes.

Yours sincerely

A handwritten signature in black ink, appearing to read 'Mirrycke Krüger'.

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## ANNEXURE D (TURN IT IN REPORT)

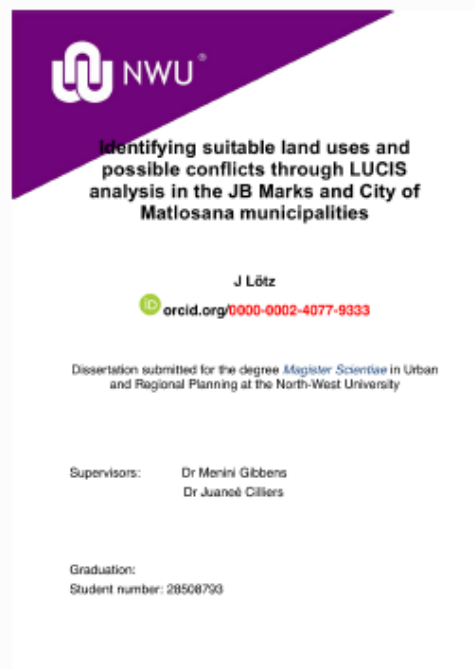


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