The development and use of a land-use suitability model in spatial planning in South Africa

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NOORDWES-UNIVERSITEIT

Expression of thanks

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Abstract

The United Nations (UN, 2006) predicts that 61% of the world population (approximately 4.9 billion people) will be living in urban settlements by the year 2030. It is further anticipated that most of this urbanization will take place in developing countries, and more specifically in Africa. This is most likely due to the fact that most African countries are currently in an urban transition phase, as they are systematically changing from predominantly rural societies to predominantly urban societies. Urban growth is a definite reality and poses a threat to the natural environment around urban areas, and in effect also to urban sustainability. To assist planners and governments in effectively planning for urban growth and to ensure sustainable development, they need optimal decision support systems to aid them in the development of land-use management policies and spatial development plans. It is crucial that these support systems be comprehensive, to encourage sustainable development in a proactive manner. One way to assist planners and governments in this crucial task, is by providing them with land-use suitability and urban growth scenarios, which may assist them in the development of spatial development frameworks (SDF) and policies. Although a great deal of research has been done internationally on urban growth modelling, it is poorly researched in South Africa. This study employs a multiple-criteria approach to analyse land-use conflicts as well as land-use suitability via a Geographical Information System-based weighted overlay procedure. The analysis takes three competing land-uses (urban, agriculture and conservation) into consideration, in an attempt to identify the most suitable land available for each land-use. The results are ultimately used as inputs for urban growth modelling. A successful urban growth scenario was achieved for the city of Potchefstroom, North West, South Africa for the year 2030. The study showed that a fairly uncomplicated approach to urban growth modelling is possible with readily available data in South Africa and that such an approach has value for spatial planning purposes.

Uittreksel

Die Verenigde Nasies (UN, 2006) voorspel dat 61% van die wêreld se bevolking (ongeveer 4.9 biljoen mense) teen 2030 in stedelike nedersettings gaan woon. Daar word verder aangedui dat meeste van hierdie verstedeliking in ontwikkelende lande en meer spesifiek in Afrika gaan plaasvind. Die laasgenoemde is heel waarskynlik as gevolg van die feit dat meeste lande in Afrika huidiglik in 'n stedelike oorgangsfase is aangesien hul stelselmatig van oorheersend landelike samelewings na oorheersend stedelike samelewings verander. Stedelike groei is 'n realiteit en 'n verskynsel wat 'n bedreiging vir natuurlike omgewings rondom stedelike areas, en in effek ook vir stedelike volhoubaarheid, inhou. Om volhoubare ontwikkeling te verseker en effektief vir hierdie groei te beplan, benodig beplanners en owerhede optimale besluitneming-ondersteuningstelsels tydens die ontwikkeling en implementering van grond gebruik beleide en ruimtelike ontwikkelings planne. Hierdie ondersteuningstelsels moet omvattend van aard wees om sodoende volhoubare ontwikkeling op 'n pro-aktiewe wyse aan te moedig. Een wyse waarop beplanners en owerhede bygestaan kan word in hierdie komplekse en belangrike taak is deur hulle te voorsien van grond-gebruik geskiktheid en stedelike groei scenario's wat hul mag onderskraag in die ontwikkeling van ruimtelike ontwikkelings raamwerke (SDF) en beleide. Ten spyte van baie internasionale navorsing op die gebied van stedelike groei modellering is dit nog min nagevors in Suid-Afrika. Hierdie studie implementeer 'n Geografiese Inligting Stelsel-gebaseerde, multi-kriteria benadering om grond gebruik konflikte te analiseer en 'n grond gebruik geskiktheid analise uit te voer. Hierdie analises neem drie kompeterende grondgebruike (stedelik, landbou en bewaring) in ag in 'n poging om deur middel van superponering die mees geskikte grond vir elk te identifiseer en toe te eien. Die resultate van die analises is uiteindelik gebruik as basis datastelle vir stedelike groei modellering met behulp van GIS. 'n Suksesvolle stedelike groei scenario is vir 2030 vir Potchefstroom in die Noord Wes provinsie ontwikkel. Die studie het getoon dat 'n taamlik eenvoudige en deursigtige benadering tot stedelike groei modellering moontlik is met beskikbare data in Suid Afrika en dat dit 'n bydrae kan lewer in die opstel van ruimtelike ontwikkeling planne.

Preface

The article format[1] is used for this dissertation and the text consists of the following chapters[2]:

Chapter 1: Introduction

This is an adapted version of the original research proposal.

Chapter 2: Planning Theory

Chapter 2 comprise an examination of the planning theory relevant to the study. The chapter commences with a discussion on the development of central places, followed by an in-depth examination of various different models of urban structure. Throughout the chapter, special attention is paid towards the outward or horizontal development of urban areas in the form of urban sprawl, and reasons for urban sprawl is discussed in relation to the situation as it manifests in South Africa.

Chapter 3: Planning with Nature

Chapter 3 deals with the issue of sustainable development. Having discussed the realities of urban development and urban sprawl in Chapter 2, the effects thereof on the natural environment is discussed, along with methods that can be used to support planners in planning for environmental sustainability. One of the core concepts that are discussed is urban ecology, which has potential for use in spatial planning.

Chapter 4: Policy and Legislation

In Chapter 4, policy and legislation relevant to the study is discussed. The chapter concentrates on the concept of Spatial Development Frameworks (SDFs) and its application in spatial planning in South Africa.

Chapter 5: Spatial Modelling

The final literature chapter deals with the Geographical Information System (GIS) concepts crucial to spatial modelling. The focus falls on multi-criteria analysis (MCA) and the spatial application thereof in the form of land-use suitability analysis. The different methods of land-use suitability modelling are furthermore discussed and examined.

Chapter 6: Article one

"A GIS-based approach for visualizing urban growth"

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[1] See Section 2.2. of the Manual for Post Graduate Studies (www.nwu.ac.za/library/manualpostgrad.pdf) as well as Rule A 13.7. of the North West University (www.nwu.ac.za/opencms/export/NWU/html/gov-man/policy/a-rules-NWU-2007-09-01.pdf)

[2] Please note that the list of references for each chapter is presented separately at the end of each chapter, and not as a whole as is the standard method. This is in accordance with the requirements indicated in footnote 1

The first article explains the technical aspects with regard to modelling land-use suitability and eventually urban growth. A thorough explanation of the methodology is made and the analysis results are verified against current land-uses. Some recommendations with regard to land-use suitability and urban growth modelling are made for consideration in future research.

Chapter 7: Article two

"Land-use suitability modelling as a framework for spatial planning in Tlokwe Local Municipality, North-West Province, South Africa"

The second article investigates the use and value of land-use suitability, and urban growth scenarios (Article 1 results) for spatial planning, and more specifically SDF development. The analysis results are compared to the existing SDF for Potchefstroom and disparities are identified and examined. The results are further used to delineate a new urban edge as well as to identify priority development nodes, which can be used in future SDFs.

Chapter 8: Synthesis and Conclusion

Chapter 8 summarizes the findings of the study and provides some concluding remarks and recommendations.

Chapter 1

Introduction

"If you are failing to plan,
you are planning to fail"

- Tariq Siddique

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Chapter 1: Introduction

1.1. Problem statement and substantiation

Over time issues related to the state of the environment have begun to play an increasingly more important role in the global arena of politics and civil society. It is of the utmost importance that these issues associated with sustainable development be recognized and embraced whilst current planning methods be improved or altered in such a way as to contribute to the protection of the natural environment. As Marcus and Detwyler (1972:3) points out:

> "...cities are nodes of man's greatest impact on nature, the places where he has most altered the essential resources of land, air, organisms and water. The city is the quintessence of man's capacity to inaugurate and control changes in his habitat. Through urbanization man has created new ecosystems within which the interactions of man, his works, and nature are complex. This complexity – and the importance of our understanding of it – grows as cities burgeon in the modern world."

Urban areas are the most important habitat for humans, but according to Collins *et al.* (2000:424-425) are also the least understood. In an effort to better understand the urban system and the way it evolves and function it must be thoroughly examined as a whole (Wu *et al.,* 2003:100). It should further be aimed to develop urban environments into sustainable areas through sustainable development, which according to Asafu-Adjaye (2000:28) can be achieved by, maximizing economic and social development in urban areas while at the same time minimizing adverse environmental impacts.

Land-use patterns are the most clearly visible result of human interaction with the biophysical environment. These land-use types include residential, commercial, industrial and agricultural uses (Koomen *et al.,* 2007:1). Changes in land-use are normally correlated with urban sprawl, which impact soil, biotic diversity, water and the atmosphere (Sala *et al.*, 2000:1770-1771; Lambin *et al.,* 2001:262). This in turn directly relates it to environmental issues of global relevance, which affect the ability of biological systems to support human needs (Vitousek *et al.*, 1997:498-500; Schneider & Pontius Jr, 2001:83; Wu *et al.,* 2003:101-102; Koomen *et al.,* 2007:2).

Land-use change is driven by the interaction in space and time between biophysical and human dimensions (Veldkamp & Verburg, 2004:1) and is a key factor in the development of the human and physical environment (Koomen *et al.,* 2007:1). The challenge for planners is to steer land-use developments through a wide range of interventions that either constrains certain developments or promote them. This could be done by developing policies and spatial development plans with assistance of land-use models that can simulate the causes, and effects of land-use change (Koomen *et al.,* 2007:2).

Another challenge is the complexity of land-use systems, which calls for multidisciplinary analyses (Veldkamp & Lambin, 2001:2). Initial efforts aimed at modelling land-use change have focused primarily on biophysical attributes (e.g. altitude, slope or soil type). It is however required that data on a wide range of socio-economic drivers (multidisciplinary) be incorporated into the modelling process for better results (Veldkamp & Lambin, 2001:2; Musters *et al.*, 1998). The effective incorporation of social, political and economic factors is however hampered by lack of spatially explicit data and by methodological difficulties in linking natural and social data (Veldkamp & Lambin, 2001:2).

However, regardless of the aforementioned difficulties, modelling can still play a vital role in understanding the processes at work in land-use change and although, by definition, any model falls short of incorporating all aspects of reality in simulations, it can still provide various valuable scenarios to assist in decision-making processes (Veldkamp & Lambin, 2001:1; Koomen *et al.,* 2007:2). In recent research, a range of land-use models have been developed and tested in an attempt to meet land-use management needs (Serneels & Lambin, 2001:65; Veldkamp & Lambin, 2001:1) and is regarded as an important technique for the projection of alternative pathways into the future (Lambin *et al.*, 2001:262).

The main goal of the models is to broaden the user's view of the future and although it does not necessarily predict how land-use will change, it still gives a realistic representation of how it might change (Koomen *et al.,* 2007:3). These modelling and simulation approaches could further be defined as planning-support systems (PSS), which offer an effective way of integrating social, economic, and environmental datasets, enabling a number of holistic spatial planning scenarios to be generated and evaluated by local planners.

It can thus be concluded that planning processes must move towards integrated planning models which act as planning-support systems that embraces a triple bottom line approach towards sustainable development by incorporating social, economic and environmental considerations.

The following research questions could be asked:

- What is the effectiveness and relevance of a multidisciplinary, environmental sensitive land-use modelling approach in spatial planning? and
- What is the value of such an approach as a support tool in the development of spatial development plans and strategies?

1.2. Research aims and objectives

The general aim of this study is to test and examine the use of land-use modelling and development-suitability modelling in spatial- and forward planning. An attempt will be made to combine land-use modelling projections with ecological and socio-economic data as to project possible scenarios for future development in 2030. The end result will be a set of maps that indicate a sustainable-development-suitability (maximizing economic and social development while minimizing environmental impacts) scenario for the study area. It is hoped that such an approach could assist planners in the design of development plans as well as the making of informed decisions that steer development. The following objectives can be highlighted:

- Design and implement a multidisciplinary, environmental sensitive land-use suitability model for Potchefstroom in the Tlokwe Local Municipality, North-West, South Africa.
- Combine the above results with urban growth statistics to develop an urban growth scenario for 2030.
- Compare the results with existing spatial plans for Potchefstroom.

1.3. Basic hypothesis/central theoretical statement

The application and implementation of land-use change modeling combined with development-suitability modeling (multidisciplinary approach towards the identification of developable land) can act as a scientific spatial planning support system in the South African context.

1.4. Format of study and research methods

The article format[1] will be used for this study and will comprise of the following:

1.4.1. Literature study

A literature study will be undertaken wherein the different fields of the study will be examined. A thorough examination will be made on planning theory and the reasons for urban development and outward growth. Specific attention will be paid towards the effects of urban development on the natural environment and the ways in which planners can contribute to the protection of the environment through spatial or forward planning. The concepts of sustainable development will be discussed in accordance with South African planning policy and legislation and with special reference to Spatial Development Frameworks (SDFs). The literature study will conclude with an examination on spatial modelling tools and its possible applications in spatial planning.

[1] See Section 2.2. of the Manual for Post Graduate Studies (www.nwu.ac.za/library/manualpostgrad.pdf) as well as Rule A 13.7. of the North West University (www.nwu.ac.za/opencms/export/NWU/html/gov-man/policy/a-rules-NWU-2007-09-01.pdf)

1.4.2. Article 1: A GIS-based approach for visualising urban growth

The aim of this article will be to address the technical and methodological detail related to the study. The article will discuss the methodology used to combine land-use suitability analysis with ecological and socio-economic data to project possible scenarios for future development in 2030. The end result will be a set of maps that indicate a sustainable-development-suitability (maximizing economic and social development while minimizing environmental impacts) scenario for the study area.

1.4.3. Article 2: Land-use suitability modelling as a framework for spatial planning in Tlokwe Local Municipality, North-West, South Africa.

In this article the results presented in Article 1 will be compared to existing spatial and strategic plans for the area. The possible use and value of a pro-active (environmentally) approach towards spatial planning will be discussed. It is hoped that this research will present new insights into the use of advanced GIS techniques in multi-disciplinary spatial- and strategic planning in South Africa.

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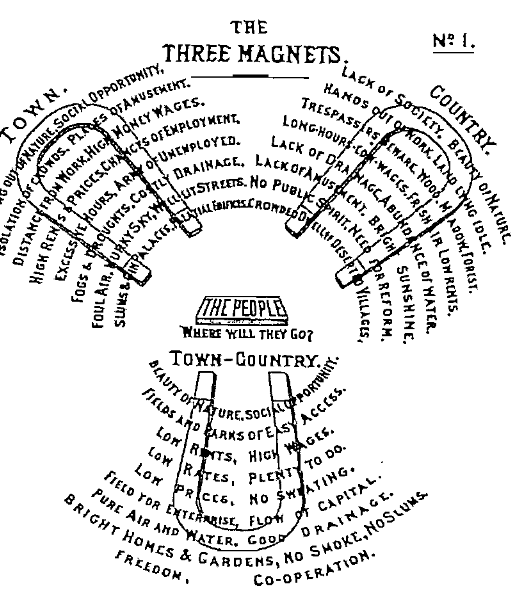
Chapter 2

Planning Theory



THE THREE MAGNETS

"Observe always that everything is the result of change, and get used to thinking that there is nothing Nature loves so well as to change existing forms and make new ones of them"

- Marcus Aurelius

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Chapter 2: Planning Theory

2.1. Introduction

Whenever a study of an urban nature is conducted, it is crucial that the theoretical concepts of urban structure and development be thoroughly investigated. In this chapter the ways in which urban areas develop, organize and change will be examined. To accomplish this, a variety of spatial development theories, that explain the patterns of spatial development and change over time, will be discussed. The following issues will be analysed:

- The development of central and non-central places;
- The fundamental forces that influence all forms of human settlement/development;
- Urban structure models;
- Urban sprawl; and lastly
- The urban development situation in South Africa.

2.2. The Development of Central Places.

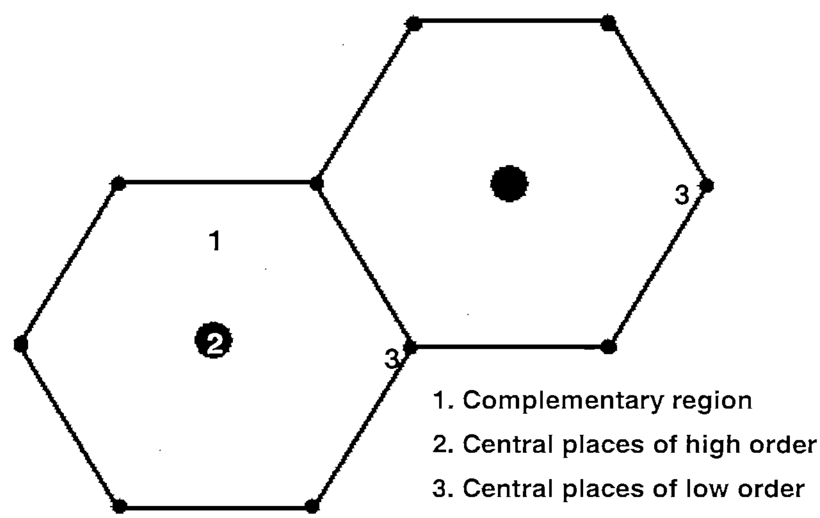
Over the last century there has been a great deal of debate concerning the phenomenon and characteristics of spatial development. One of the most renowned theories that emerged from this debate was the central place theory which, according to Isard (1975:311), provides much needed insight into the process in which hierarchical urban systems emerge. Arguably the most notable pioneer of this school of thought is Walter Christaller (Johnson, 1967:94), who first published his theory on central place development in 1933 (Christaller, 1966:2). The essence of his theory is that all settlements (excluding mining centres) act as central places, providing one or more services to their surrounding areas (Steyn & Barnard, 1976:230). These settlements vary in their importance, or order, according to the number and type of other settlements dependent upon them, and according to the number and type of services, or functions, they provide (Johnson, 1967:95). Although Christaller's work was built upon earlier ideas and studies (von Thünen, 1966; Weber, 1909), it is generally regarded as the predecessor of all subsequent attempts to understand the nature of order in central place systems (Beavon, 1975:1).

Christaller commences by stating that some sort of spatial force governs the distribution of all central places within space and that centralization forms the main building block for his theory. He talks about a centralistic order, where development crystallizes around a nucleus (Christaller, 1966:14). From this it is clear that centrality forms the main theme of Christallers theory. According to Beavon (1975:4), Christaller introduced four descriptive terminologies to help explain his theory. The terminologies can be defined in the following manner (Figure 2.1):

- ***Complementary region***: The region that is served by the central place;
- ***Central activities***: The activities that influence surrounding areas;

- ***Central places of high order*:** Central places whose central activities influence extends over a large area, and
- ***Central places of low order*:** Central places whose central activities influence extends over a much smaller area.

Figure 2.1 Christaller's descriptive terminologies



Source: Adapted from Christaller (1966:32)

Christaller (1966:27-43) stated that, for a central place to develop, the supply of basic goods and services to a complementary region should be regarded as the point of departure. He said that a central place's central activities should meet the demand of its complementary region. The extent to which these activities influence the complementary region, will determine if the central place is one of high order or one of low order. According to Christaller (1966:16):

> "...the chief profession – or characteristic – of a town is to be the centre of a region". He goes further by saying that "...because this chief characteristic does not apply only to those settlements which we usually call towns – it applies also, for example, to most market spots – because there are, on the other hand, towns which do not, or only in a very small measure, show this characteristic, we shall call those settlements which are mainly centres of regions, central settlements." Central places of high order can thus be defined as "...those places that have central functions that extend over a larger region, in which other central places of less importance exist. Those, which have only local central importance for the immediate vicinity, are called, correspondingly, central places of lower and of the lowest order. Smaller places

which usually have no central importance and which exercise fewer central functions, are called auxiliary central places."

Christaller stated that every place has a certain importance and that this importance is derived from the centrality of the place and the central goods and services which it delivers to the complementary region (Christaller, 1966:17-18). According to Fujita *et al.* (1999:3) and Waugh (2002:408), Christaller made a number of assumptions whilst developing his theory. These assumptions included the following:

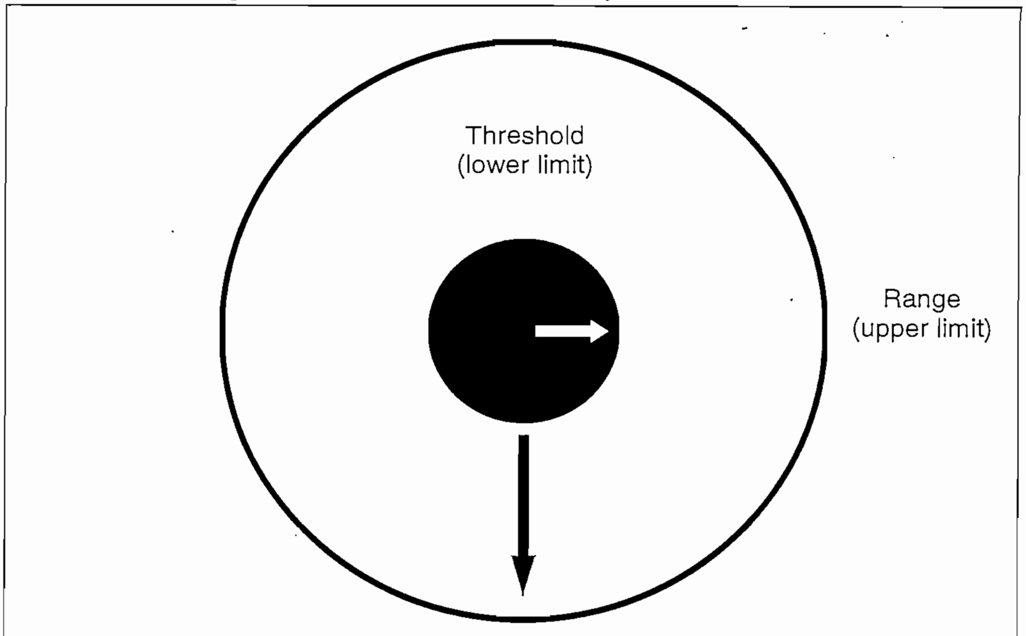
- All areas have an isotropic (flat) surface;
- Population are evenly distributed through all areas;
- Resources are evenly distributed throughout all areas;
- All areas have similar purchasing power of consumers and consumers will patronize the nearest market;
- All areas have transportation costs equal in all directions and proportional to distance; and
- A perfectly balanced competition exists.

Christaller's theory consists of two basic concepts; they are *threshold* and *range* (Steyn & Barnard, 1976:230; Waugh, 2002:407). Christaller (1966:22) explains *threshold* as the minimum population that is required to bring about the provision of certain goods or services, and *range* as the average maximum distance people will travel to purchase goods and services.

The range of the goods or the range of services, determines the size of a settlement's market area, which is the area inhabited by most of the people who use its services (Johnson, 1967:98). Thus, the higher the order of a central place, the larger its range will be. Steyn and Barnard (1976:230), state that the range of a particular service from an urban centre will have an upper limit. This upper limit is determined by the competition it experiences from other centres that offer the exact same service. Johnson (1967:98) further states that the range also has a lower limit which is controlled by the threshold required to allow it to function. Therefore, places with only lower-order functions will have a very limited market area, and their residents will need to travel further to higher-order central places in order to obtain higher-order services or goods.

From these two concepts the lower and upper limits of a central place's goods or services can be determined (Figure 2.2). By using the upper and lower limits, it is possible to see how the hierarchy of central places are arranged in an imaginary area (Johnson, 1967:98; Beavon, 1975:8).

Figure 2.2 The range and threshold of a commodity



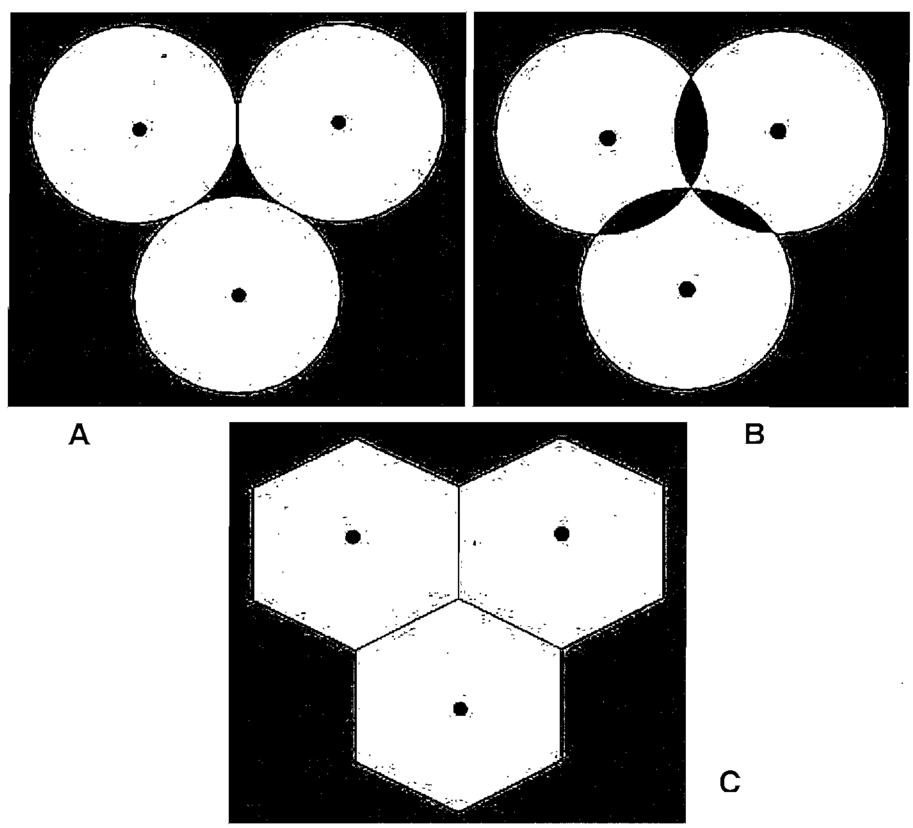
Source: Adapted from Beavon (1975:8)

Taking into consideration Christaller's assumption that all areas are isotropic (Van der Merwe, 1989:100) and that all transport are equal in all directions, Waugh (2002:408) observed in his explanation of Christallers model that each central place will have a circular area of influence (complementary region). This implicates that all distances from the central place to its boundary will be the same (as seen in Figure 2.3a). This however led to the problem that unserviced areas would be left open between circles (Van der Merwe, 1989:101) as also seen in Figure 2.3a. To overcome this problem, Christaller overlapped the circles in such a way that no gaps existed (Figure 2.3b). This, however, violated the assumptions of his model and, in order to overcome the problem, Christaller modified the circles to become hexagons (Van der Merwe, 1989:101), which resulted in no spaces being left open or overlapping (Figure 2.3c).

Since Christaller published his work in 1933, several attempts have been made to refine his ideas. One of the most interesting attempts was the scheme proposed in 1939 by another German named August Lösch (Johnson, 1967:96). In contrast with Christaller, who used supply as his point of departure, Lösch used the demand of the complimentary region as his point of departure (Van der Merwe, 1989:105). Furthermore he also used hexagonal service areas as the basic units in the theoretical landscape, but with the difference that he allowed for various hexagonal systems to coexist. These approaches lead to a continuum of various-sized towns and cities existing in the theoretical landscape (Johnson, 1967:96). Lösch set out to explain how economic activities are arranged within an economic space by using his general settlement theory. In order to do this, he made (similar to Christaller) a number of assumptions, which were that (Smith, 2002:265):

- Natural resources are distributed proportional over space;
- The agricultural population is proportionally distributed and has the same taste and technical knowledge, and
- Enterprise possibilities are equal.

Figure 2.3 Complementary regions of central places.



Source: Waugh (2002:408)

Lösch expanded on Christaller's theory and stated that central places already exist in accordance with an organizing principle and that it is not necessary for one to be created (Lösch, 1954:93; Isard, 1975:312). He further used economic forces to describe the economic region and aimed to represent reality more accurately. He considered it unlikely that settlements would be distributed more or less concentrically around places of the next higher order. Instead, the highest-order settlements, such as large cities, would restrict the nearby development of high- and middle-order settlements because the cities would provide all the required functions, and more. In a Löschian landscape small, low-order central places are found close to very large settlements, such as metropolitan centres, whereas high- and middle-order settlements will only be found a substantial distance away. Even then they are more likely to be clustered in certain directions rather than distributed evenly around the metropolitan centre (Lösch, 1954:93-95; Steyn & Barnard, 1976:214-216; Waugh, 2002:409).

Even though Christaller and Lösch used different approaches whilst developing their theories of central place, they came to more or less the same conclusions on how central places develop. Although their frameworks present many interesting spatial phenomena, it must be accepted that it has certain limitations, such as the natural environment, overlapping of hinterlands and the discouragements of small settlement growth by large settlements (Johnson, 1967:98), and won't always be effective and applicable in the real world.

Having examined the theories and views on the development of central places, progression can be made towards the development of urban structures. Because this study focuses more intently on changes and reasons for changes (environmentalism, urban sprawl, etc.) in the urban structure, more attention will be paid towards just that. The nature of this study is more specifically concerned with the changes occurring on the periphery of the city than in the city itself.

2.3. Forces That Influence Urban Morphology

Before examining the theories that explain the evolution and transformation of the urban structure, the forces that are responsible for these changes have to be discussed. It is a given fact that the urban environment is constantly growing and changing and it has been doing so ever since the very beginning of settlements, thousands of years ago. Lately though, the importance of these changes have become more and more relevant to governing bodies, developers and the general public. As Bollens and Schmandt (1965:2) states:

> "...we are [currently] in a rising tide of interest in metropolitan developments and problems [...] Meeting metropolitan developments in one form or another are daily events for most of us. They have become part of our way of life, although we do not always readily recognize all of them as being of a metropolitan nature."

There are certain forces at work that influence urban morphology and consequently cause the changes observed in towns and cities. Urban morphology is concerned with the physical qualities of the urban environment (Herbert, 1972:64) that shape the structure of the city, and has since the 1970's been considered an important perspective to the study of the city (Herbert, 1972:66). The forces that influence urban morphology include demand and supply, political policies, economic growth, social development of a society, economic growth of a society and industrial development (Long *et al.*, 2007:355-362). They differ in their effects from urban area to urban area, thus making it difficult to predict how urban areas will develop and change.

In Section 2.4 some of the most renowned theoretical models that have been developed in an effort to understand the effects of the prior mentioned forces on the urban morphology are examined.

2.4. Models of Urban Structure.

Urban areas are constantly changing and evolving and these changes within urban areas can be observed almost on an everyday basis. Waugh (cited by Hoogendoorn, 2006:10) stated that spatial patterns, which may show differences and similarities in land use and/or social groupings within a city, reflect how various urban areas have evolved economically and socially in response to changing conditions over a period of time.

The above mentioned resulted in several models, describing and explaining urban structure. According to Chapin and Kaiser (1979:28-31) there are three systems that are of particular relevance to spatial urban structure; they are:

- Activity systems (the way man and his institutions such as households, firms etc. interact on a daily basis);
- Land development systems (processes that change space in a way that it can facilitate different activities); and
- Environmental systems (natural environment).

Chapin and Kaiser (1979:31) further identified two types of frameworks that have to be consulted when discussing urban structure. One is the descriptive framework (representing the way things are in urban areas) and the other the explanatory framework (asking why things are the way they are in urban areas). Both these frameworks will be discussed in this section.

There are many definitions used to describe the concept "urban" (see Mayer, 1969:3-12), but for the purpose of this study urban will be defined as a built-up area that is heavily populated, provides basic services to its surroundings, have feasible economic activities and functions as a system consisting of various elements (Bollens & Schmandt, 1965:6-10).

2.4.1. Descriptive Frameworks

The three so-called classic models of urban land-use (Section 2.4.1.1) have had a considerable impact upon the literature of urban studies (Herbert, 1972:70) and will subsequently be discussed, followed by six modifications of these classic models (Section 2.4.1.2). In doing this, a better understanding on the evolution of urban structure will be gained. The three classic models, that will be discussed, are:

- Burgess Concentric zone model;
- Hoyt's Sector model; and
- Harris and Ullman's Multiple nuclei model

These three models are, most likely, the most renowned models when it comes to urban structure studies, and thus are the natural starting point for this discussion.

2.4.1.1. Classic Descriptive Models

2.4.1.1 (a) Concentric zone model – Burgess (1923)

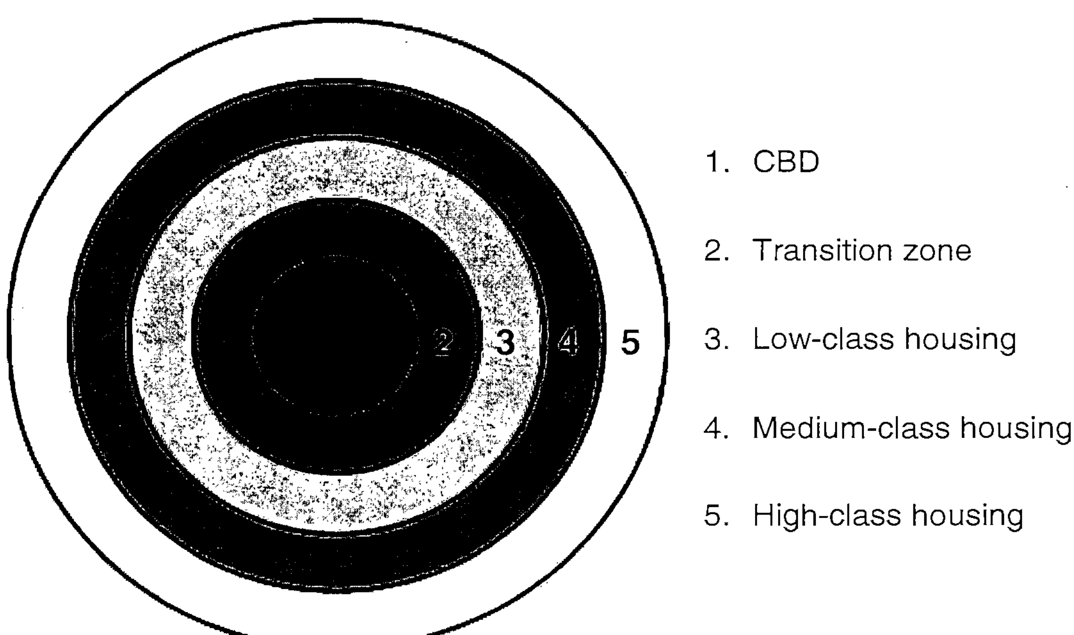
In 1923 Burgess suggested a concentric zone model (Figure 2.4) that was based upon the outward expansion and the socio-economic groupings of inhabitants of the city of Chicago (Johnson, 1967:163; Waugh, 2002:420). The formulation of the model was based on empirical studies conducted in Chicago, which had the advantage of being situated on a level lacustrine landscape with very few topographic anomalies (Mayer, 1969:27). It is important to realise that the model was proposed as an ideal type, and not necessarily as a representation of reality (Pacione, 2005:140). It aimed to explain the effect of market forces upon land-use arrangements (Chaplin & Kaiser, 1979:32) and attempted to provide a descriptive framework for the spatial organisation of urban land-uses (Herbert, 1972:70). The model is based upon the notion that the development of a city takes place outwards from its central business district (CBD) towards the periphery, in the form of a series of concentric circles (Johnson, 1967:163). Burgess made the following assumptions whilst developing the model (Waugh, 2002:420):

- The city was built upon flat land, which meant that equal advantages were available in all directions (he removed morphological features such as rivers and mountains);
- Transport was equal (cheap, fast, etc) in all directions from the core, thus it was not of much significance to him;
- He stated that land values were the highest in the core of the city and rapidly decreased away from the city, resulting in a zoning pattern for urban functions and land use;
- Older buildings were found in the centre of the town, with newer buildings appearing further away from the core;
- Cities contained a variety of well-defined socio-economic and ethnic areas;
- Poorer people lived closer to the centre of the city, because they could not afford transportation or expensive housing; and
- Concentrations of heavy industry did not occur.

By using these assumptions Burgess developed his concentric zone model (Figure 2.4). The five zones he proposed consist of the following (Chaplin & Kaiser; 1979:33-34; Waugh, 2002:420; Pacione, 2005:143):

1. **Central business district** (CBD). This area contains the major shops and offices of the city. It is the centre for services such as entertainment and commerce, and is accessible because most transport routes meet here. Although the CBD is the smallest area in the city, it has the highest rent due to the high numbers of activities in the area.
2. **Transition zone.** This is where older houses is deteriorating into slum property or 'invaded' by light industry. Inhabitants of this area tend to be poorer than in other areas and property tends to be run-down. There are also a variety of land-uses visible.
3. **Low-class housing.** Housing for people who 'escaped' the transition zone and others (labourers and factory workers) who need to live close to factories in order to reduce travel costs occupy this area. Housing in this zone is usually high-density.
4. **Medium-class housing.** The housing in this zone is of higher quality and in some cases on bigger stands. In most cases private housing, as well as apartment blocks, are represented here. The inhabitants are mostly white-collar workers and middle-class families, and housing is usually lower-density.
5. **High-class housing.** This area has very high property values with big, low-density houses and stands that are separated from the CBD.

Figure 2.4. The Burgess concentric zone model



Source: Adapted from Waugh (2002:420)

Burgess' model shows some relevance in explaining the functional areas of the city, but it is mostly oversimplified and does not accurately represent reality (Van der Merwe, 1989:141). It must be remembered though that Burgess' model can't be interpreted too literally because it was always intended as a very broad generalization (Johnson, 1967:165). However, even though it is mainly a generalized description of urban structure it also intends to serve, to some extent, as a mechanistic framework for understanding urban growth and change (Herbert, 1972:70). It is further not clear what Burgess' views on the urban fringe of the city were. He only states that low density, high-income housing are found on the edge of the city, but does not elaborate on what happens behind that.

2.4.1.1 (b) Sector model – Hoyt (1939)

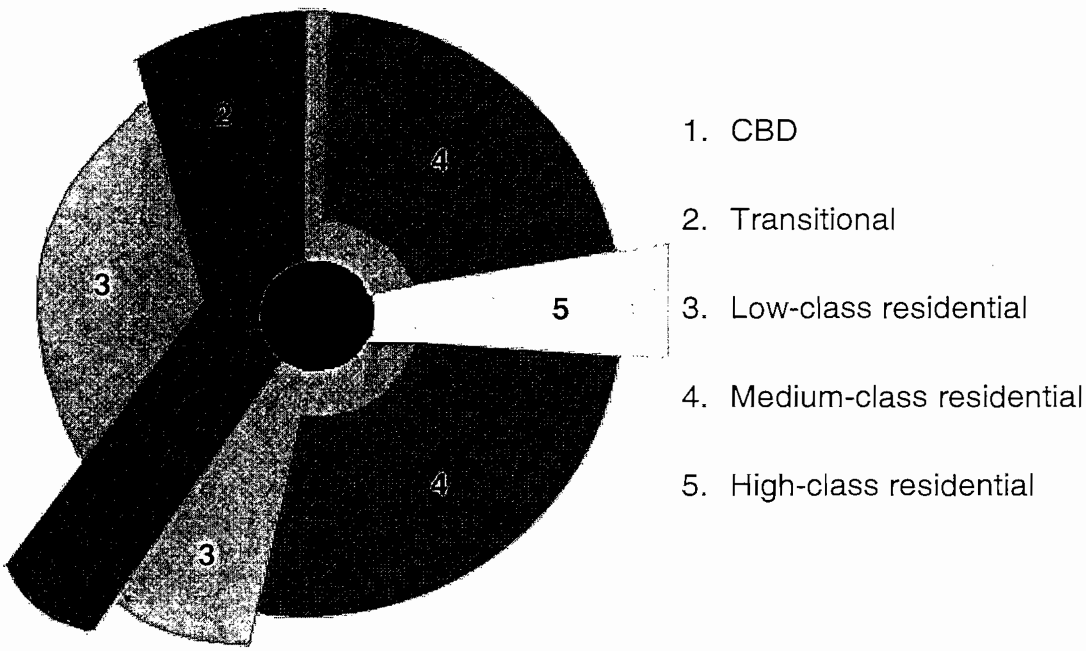
About a decade after the dawn of the concentric zone model Hoyt presented a sector model which was based upon Burgess' work. This sector model (Figure 2.5) is generally regarded as the second of the classic models of urban spatial form (Herbert, 1972:72) and stated that mixed land-uses would develop away from the CBD and towards the periphery in the form of sectors (Herbert, 1972:72; Chapin & Kaiser, 1979:35; Pacione, 2005:144). It further stated that these developments would be directional (Van der Merwe, 1989:141-142) and focussed along major transport routes (Mayer, 1969:32), which is in direct contrast with the development of concentric zones as suggested by Burgess (Johnson, 1967:166). Hoyt made the same basic assumptions as Burgess, with the addition of three new factors (Chaplin & Kaiser, 1979:35; Waugh, 2002:422):

- Wealthy people chose the best sites, thus competition is based on the ability to pay;
- Wealthy residents could afford private cars or public transport and so lived further from industry and nearer to main roads; and
- Similar land-uses attracted other similar land-uses, concentrating a function in a particular area and repelling others. This process led to a 'sector' development.

According to Waugh (2002:422) and Pacione (2005:144) Hoyt suggested that areas of the highest rent tend to be along main transport routes. He also claimed that once an area had developed a distinctive land-use, or function, it tended to retain that land-use as the city extended outwards, e.g. if an area north of the CBD was one of low-class housing in the 19th century and the CBD was one of low-class housing, then the northern suburbs of the late 20th century would also be likely to consist of low-class estates (Waugh, 2002:422).

Hoyt's model does not aim to replace the concentric zone model, but rather aims to extend and refine it by adding the concept of direction to that of distance from the city centre. The fact that Hoyt acknowledges the importance of transport to the functioning of the city is most certainly an improvement on the Burgess theory (Johnson, 1967:166). According to Hoyt's, model the periphery of an urban area will also develop in sectors, with different land-uses as they originated from the centre. This is best recognized when examining Hoyt's views on residential development. It can be deduced from his model that once an area of high-income housing has been established, the most suitable sites for further high-income housing will be on the outer edge of those areas (Johnson, 1967:166).

Figure 2.5 The Hoyt sector model



Source: Adapted from Waugh (2002:422)

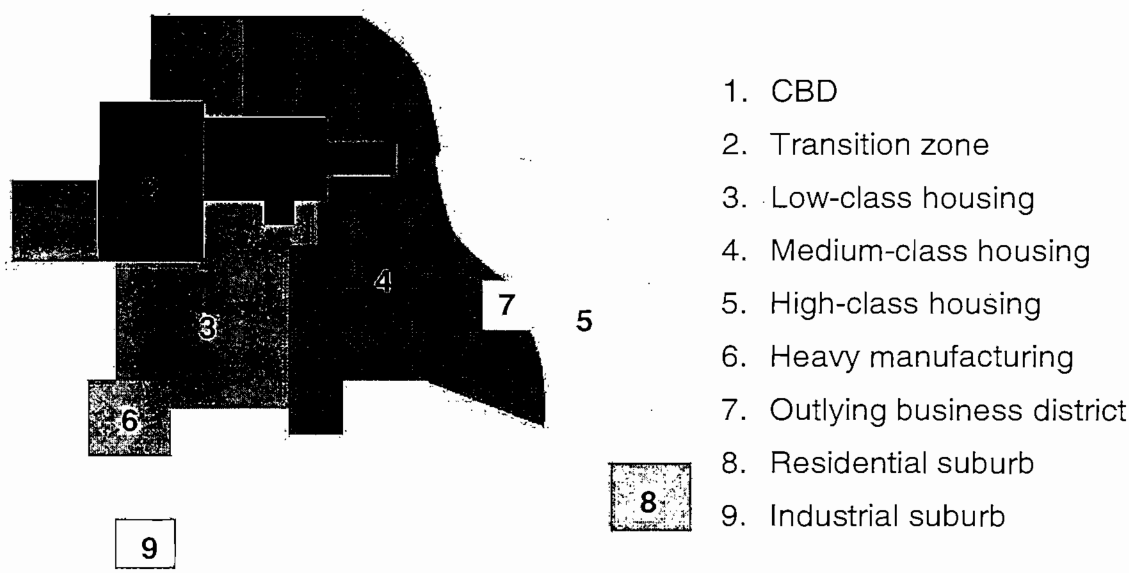
Although Hoyt suggested that residential development might be expected to expand along established lines of travel, he also believed that real-estate speculators could bend this direction of development through skilful promotion (Johnson, 1967:170). Hoyt's model furthermore has some relevance to the phenomenon of segregation (both voluntary and involuntary), visible in many cities around the world, and more specifically in South Africa under the apartheid regime (Mayer, 1969:32).

2.4.1.1 (c) Multiple nuclei model–Harris and Ullman (1945)

Harris and Ullman set out to produce a more realistic model than those of Burgess and Hoyt and eventually developed one that was much more complex and to some degree less clear than its predecessors (Johnson, 1967:170). Harris and Ulmans's multiple nuclei model (Figure 2.6) is generally regarded as the third and last of the classic models of urban spatial structure (Herbert, 1972:72). The main distinctive quality of the multiple nuclei model is that it abandoned the idea of the CBD as the sole focal point of the city, and replaced it with a number of integrated discrete nuclei (including the CBD) around which land-uses develop (Johnson, 1967:170; Herbert, 1972:72; Chapin & Kaiser, 1979:36; Pacione, 2005:145). They made the following assumptions before formulating their model (Waugh, 2002:423):

- Modern cities have a more complex structure than that suggested in Burgess' and Hoyt's models;
- Cities do not grow from one CBD but from several independent nuclei;
- Each nucleus acts as a growth point with its own unique main function within the city;
- In time, there will be outward growth from each nucleus until they merge as one large urban centre; and
- If the city becomes too large and congested, some functions may be dispersed into new nuclei.

Figure 2.6. The Harris and Ullman multiple nuclei model



Source: Adapted from Waugh (2002:423)

Harris and Ullman stated that multiple nuclei developed as a response to the need for maximum accessibility to a centre, to keep certain types of land-uses apart, for differences in land value and, more recently, to decentralize (Chapin & Kaiser, 1979:37). The multiple nuclei idea acknowledged the effects that economic and social forces, as well as the attributes of specific sites, have on the development of land-uses (Johnson, 1967:171). Harris and Ullman further stated that no one model could be applied for all cities because social, cultural and industrial circumstances would differ from city to city (Pacione, 2005:145). According to the multiple nuclei model, nodes will develop on the edges of the periphery and beyond, which will lead to development and outward growth of the city.

Burgess and Hoyt both assumed that a typical city will develop around one centre (Johnson, 1967:172), and even though Harris and Ullman acknowledged the significance of other nodes, the CBD was still portrayed as the highest-order node in their model (Van der Merwe, 1989:142). In modern cities, however, the distribution of major shopping centres and distant residential nodes provides a more complicated framework for urban structure (Johnson, 1967:172; Mayer, 1969:33). In attempts to deal with this reality of urban structure, the classic models have been modified several times. Six of these alternative/modified models will be discussed. They are:

- Mann's model of the urban structure;
- Kearsley's modified Burgess model;
- Vance's urban-realms model;
- White's model of the 21st century city;
- Davies' apartheid city model; and
- Simons modernized apartheid city model.

2.4.1.2. Modified Descriptive Models

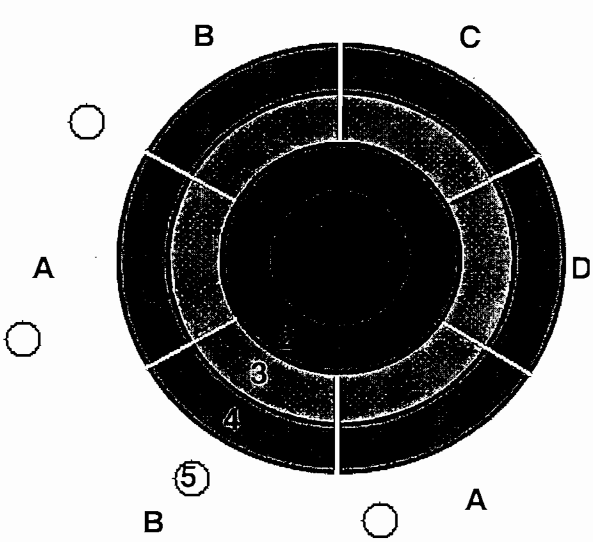
2.4.1.2 (a) Mann's model of the urban structure (1965)

Mann aimed to apply the Burgess and Hoyt models to three industrial towns in Britain. The model that he presented combined the concentric ideas of Burgess and the sector ideas of Hoyt, and can be seen in Figure 2.7 (Johnson, 1967:169; Waugh, 2002:422; Pacione, 2005:147). He took elements such as air pollution, wind factors and industrial development into consideration while developing his model, and allowed for commuting from distinct villages to the CBD (Johnson, 1967:169). Waugh (2002:423) summarized Mann's conclusions as follows:

- The twilight zone was not concentric to the CBD but lay to one side of the city, which allowed more wealthy residential areas elsewhere;
- Heavy industry was found in sectors along main lines of communication;
- Low-class housing should be called the 'zone of older housing' (classification should be made by age and not just socially);
- Higher-class housing was usually found away from smoke and industry; and
- Local government played a role in slum clearance and gentrification (phenomenon in which low-cost, physically deteriorated neighbourhoods undergo physical renovation and an increase in property values). This lead to large council estates, which took the working class/low income groups to the edge of the city.

Mann described development in much the same way as Burgess, with the difference of identifying nodes of development alongside the periphery within high- and middle-class sectors.

Figure 2.7. Mann's model of the urban structure



1. CBD
2. Transitional zone
3. Pre-1918 residential areas
4. Post-1918 residential areas
5. Commuting-distance 'villages'

A. Middle-class sector
B. Lower middle-class sector
C. Working-class sector and municipal housing
D. Industry and lower-working class sector

Source: Adapted from Waugh (2002:423)

2.4.1.2 (b) Kearsley's modified Burgess model (1983)

Kearsley (1983:10-13) aimed to extend Mann's model of urban structure by taking contemporary dimensions of urbanization, such as level of government involvement in urban development, slum clearance, sub-urbanization, decentralization of economic activities, gentrification and ghetto isolation into consideration. The model is illustrated in Figure 2.8 and shows the new towns, council estates and satellite estates which he proposed would develop due to the influence of the above mentioned factors (Pacione, 2005:147).

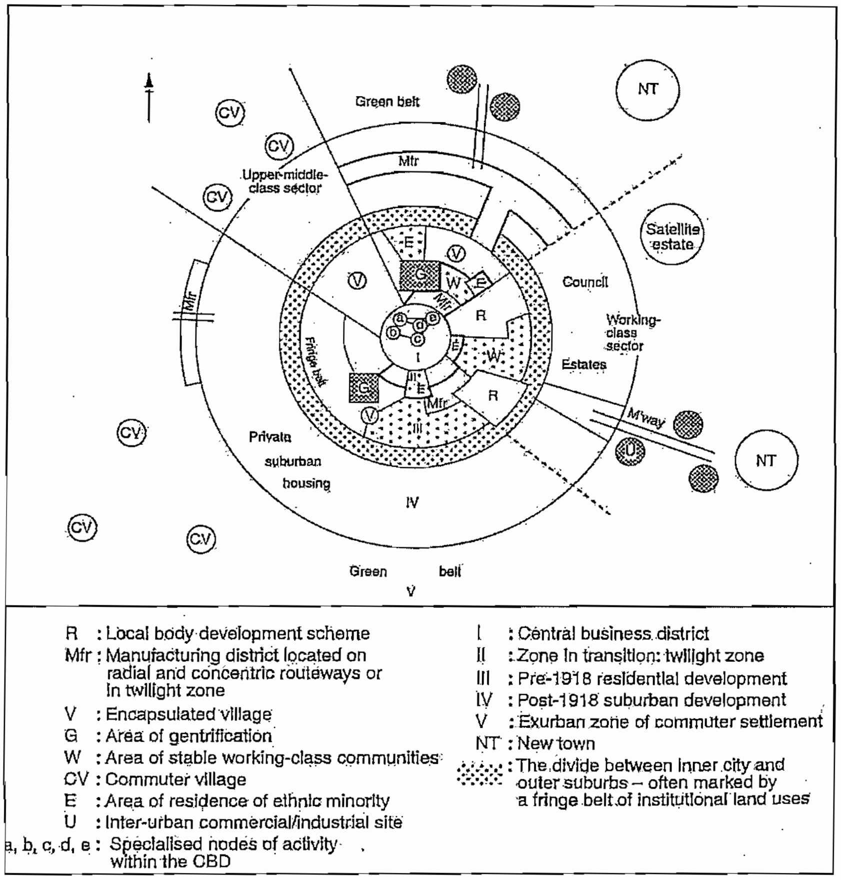
2.4.1.2 (c) Vance's urban-realms model (1964)

Vance (1964) proposed an extension on the multiple-nuclei model (Pacione, 2005:147), proposing that self-sufficient urban areas, each focussing on a downtown, independent from the traditional downtown, would emerge (Figure 2.9). Vance (1964:78) referred to these newly developed areas as 'urban realms' which he defined as natural functions of the growth of cities. He stated that the character of each urban realm is shaped by five criteria (Lang & Nelson, 2007:6):

- The topographical terrain;
- The size of the metropolis;
- The economic activity in each realm;
- Accessibility of each realm; and
- Inter-accessibility between realms.

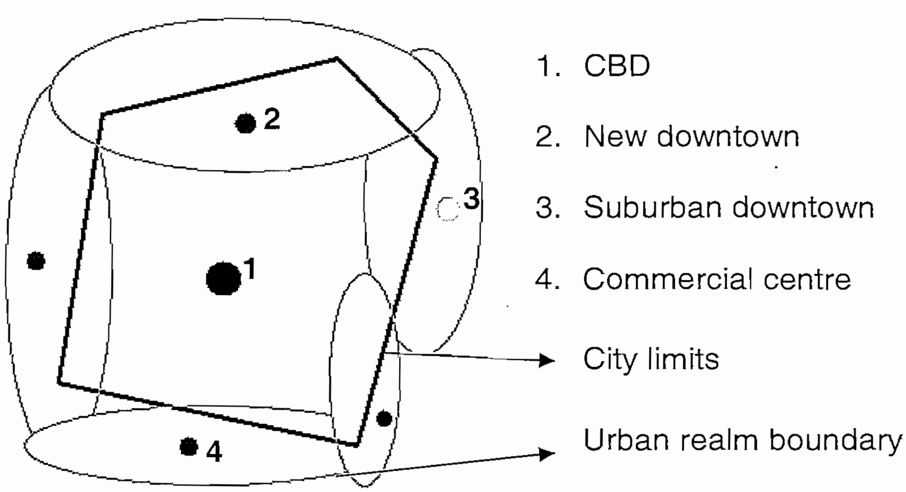
Vance's model proposes that development will continue outwards from other nuclei than just the CBD. These developments will extend the periphery and lead to horizontal growth.

Figure 2.8 Kearsley's modified model of urban land use



Source: Pacione (2005:148)

Figure 2.9. Vance's urban realms model

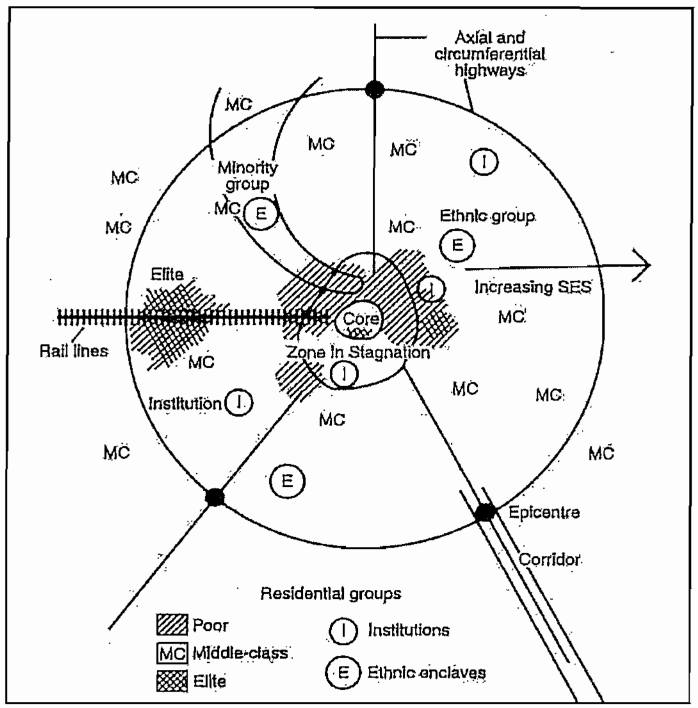


Source: Adapted from Pacione (2005:149)

2.4.1.2 (d) White's model of the twenty-first-century city (1987)

In 1987, White (1987:236-242) proposed a revision of the Burgess model that aimed to better define the twenty-first-century city. He took new trends such as industrial development, social change, the automobile etc. into consideration whilst revising the model (Pacione, 2005:148).

Figure 2.10. White's model of the twenty-first-century city



Source: Pacione (2005:149)

White's model comprises seven elements (White, 1987:236-240; Pacione, 2005:148-149):

- **Core.** The CBD remains the focus of the metropolis and although its functions have changed over the years, it still houses the main financial institutions, government buildings and corporate headquarters (according to White). Most retailing has moved away from the CBD though.
- **Zone of stagnation.** White stated that Burgess' zone of transition would never realize because the CBD will grow vertically rather than spatially outward, thus meaning that the 'transition zone' will never develop.
- **Pockets of poverty and minorities.** These zones comprise of the underclass members of the society such as homeless people, drug addicts, dysfunctional families etc. and their surroundings reflect their status.

- **Elite enclaves.** Wealthy people have the best choice of where they would like to live and have the choice to part themselves from the problems of the metropolis. The elite mostly live on the periphery of the city and in estates outside the city.
- **The diffused middle class.** These areas occupy the largest area of the metropolis and differ in appearance from old to new and size and shape.
- **Industrial anchors and public sector control.** The location of these entities affects zoning within and the form of the metropolis.
- **Epicentres and corridors.** A distinguishing feature of the 21st century city is the emergence of epicentres, located on major access corridors.

White's model has reference to horizontal growth and i.e. urban sprawl. This is due to his perception that the wealthy and to some degree the middle class will move away from the CBD and toward the periphery and beyond.

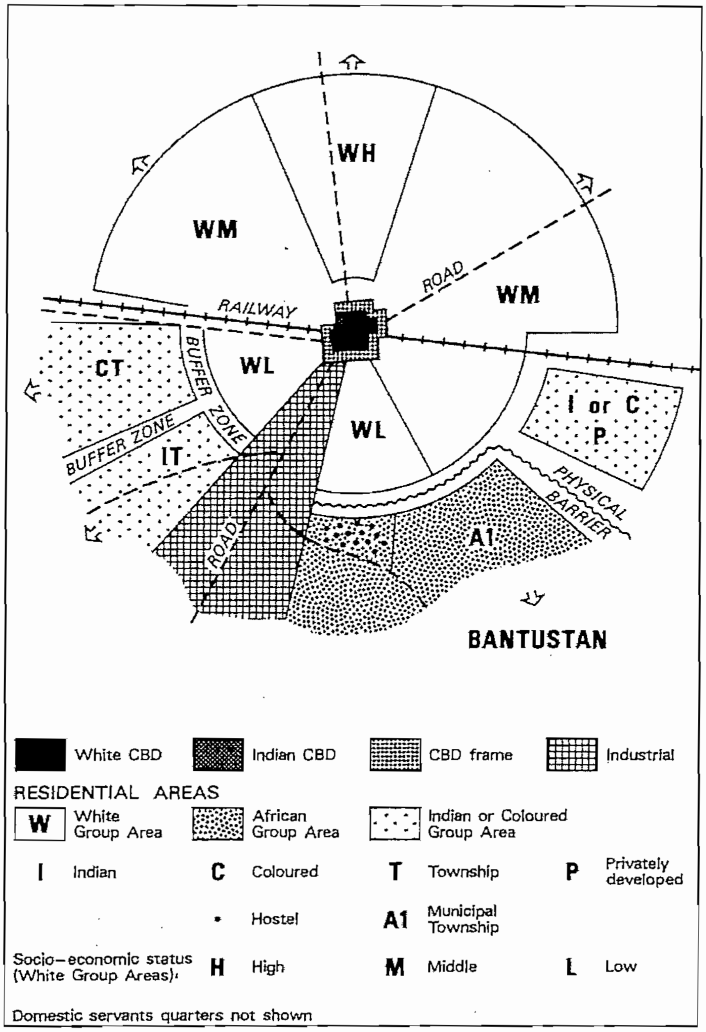
2.4.1.2 (e) Davies' apartheid city model (1981)

In 1981 Davies developed the apartheid city model, which was preceded by his segregation model (*Davies,* 1981:59-72), and had strong resemblances to Hoyt's sector model (Pacione, 2005:472). According to Simon (1989:191) the apartheid city, as found in South Africa, is unique and incomparable to other cities around the world. The apartheid city was the result of the 1950 Group Areas Act, which sought to separate various racial groups in South Africa into distinct areas (Christopher, 1984:77). Everyone in South Africa was classified into a particular racial group, which was again assigned to a specific residential area reserved for that group (Christopher, 1984:77). Davies's model describes these areas and the way in which they were allocated. The model describes the following areas (Christopher, 1984:77; Simon, 1989:191-192):

- A white CBD, reserved for white business owners;
- An Indian CBD, which was an exception and usually located closer to the Indian residential zone;
- White residential areas of low, medium and high income situated around the CBD;
- An Industrial zone, which developed in the direction of non-white residential areas and, in many cases served as a buffer zone between white and non-white residential areas;
- An African residential area or township. These areas where usually separated from white residential areas by means of a physical barrier (like an industrial area);
- Indian and Coloured residential areas, which was adjacent to African residential areas.

To achieve the above various forced removals were conducted, were residents were forced from their homes and moved to new residential areas. The apartheid city model proposed controlled outward growth toward the periphery of the city, much in the same manner as Hoyt.

Figure 2.11. The apartheid city model



Source: Simon (1989:192)

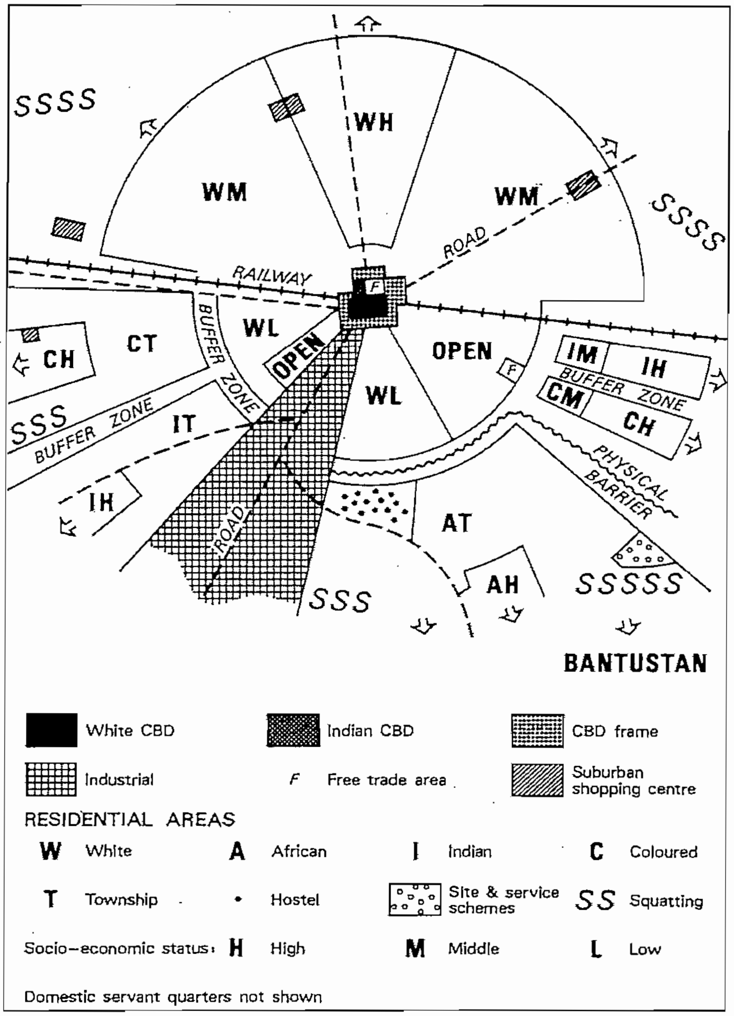
2.4.1.2 (f) Simon's modernized apartheid city model (1989)

In 1989 David Simon proposed a modification of Davies' apartheid city model. Simon's model addressed the changes that were occurring in South African cities due to changing political environments, which was mainly caused by international pressure and sanctions (Simon, 1989:191). The changes that had the biggest effect on the spatial development of towns and cities in South Africa, were (Simon, 1989:194-196):

- The development of 'Open' business districts. These business areas were open for the use of all racial groups and in some cases included the CBD.
- The establishment of free trade areas outside the CBD.

These changes had to effect that new shopping centres developed in white residential areas and initiated the decentralization of business and commercial land-uses. At this time squatter camps also started to appear around town and cities.

Figure 2.12. The modernized apartheid city model



Source: Simon (1989:193)

The classical models, together with the more recent modifications, prove that the structure of the city is ever evolving and changing. One of these changes that can clearly be observed from the models, is the movement of development away from the CBD and towards the periphery of the city. These developments have rapidly increased in South Africa during the past decade (after the demise of apartheid) and have had a huge influence on spatial planning and land-use management, which is the issue with which this study deals. Chapin and Kaiser (1979:37) state that the described theoretical explanations of the patterning of urban land-uses serve a useful purpose in describing the effects of economic forces on the urban form, but also state that explanatory frameworks should be consulted in order to get a better understanding of the forces at work in urban areas.

2.4.2. Explanatory Framework

Chapin and Kaiser (1979:38) states that explanatory frameworks are concerned with defining particular processes, behaviours and other phenomena as they exist in reality – much as descriptive frameworks aim to do – but are also concerned with why these phenomena or processes come to exist and how they might change over time and space.

The explanatory frameworks that will be discussed derive from economic theory and aims to relate theory with real-world situations by looking at the urban development processes as an economic phenomenon. The theories with the most relevance to this study and which will be discussed briefly are:

- The land value model or bid-rent theory; and
- Theory of land-use.

2.4.2.1. The land value model or bid-rent theory

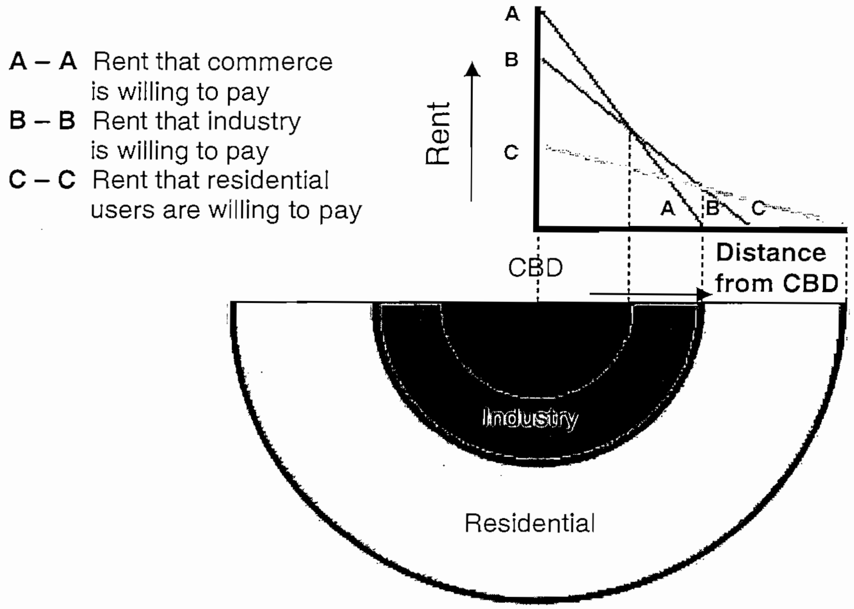
According to Waugh (2002:425) this model is the urban equivalent of von Thünen's rural land-use model. The theory is based upon the assumption that the highest bidder in the free market will obtain the use of a certain piece of land. Figure 2.13 illustrates the competition between three land use types within different parts of a city. According to this model the most expensive land is within the CBD of the city, because of factors such as accessibility and shortage of space. It is very important to perceive that residential areas tend to move further away from the city centre. This phenomenon can explain why peripheral areas develop and satellite suburbs appear. Land further away from the CBD is cheaper and is used to develop residential areas away from industries and noise, but at the same time, the more accessible land is, the higher its cost. Thus land located near main transport routes will have higher value and is more likely to be used for development (Waugh, 2002:425; Pacione, 2005:146).

The model implies that development will occur along main transport routes, thus causing development to sprawl outwards towards the periphery of the city in the form of horizontal growth and ribbon development. These principles will be taken into consideration when formulating and testing a new approach to spatial development.

2.4.2.2. Alonso's theory of land-use

In 1960 Alonso developed a classic model that presented the interaction between land values and land uses. This model will be discussed due to its relevance to outward spatial development. Alonso's model has several stages, beginning with the case of an individual household and ending with urban firms.

Figure 2.13 Bid-rent curves



Source: Adapted from Waugh (2002:425)

He explains his theory by focusing on an individual that enters the market, wishing to buy land, and faces the double decision of how large the parcel should be and how far away from the city centre. The city in Alonso's theory is much like the model of Burgess's city with only one CBD and no zoning restrictions. He also assumes that the buyers have perfect knowledge on the cost of land and transportation (Waugh, 2002:392). In his model the individual has enough money to spend on three entities: land; transportation; and composite goods. By combining these three elements, the individual can decide on a location to buy. It is assumed in this model that land value decreases further away from the city, while transportation costs increases further from the city centre (Pacione, 2005:146). It is assumed that the unit cost of composite goods stays the same.

In the second stage of his theory Alonso derives bid price curves (as in the bid-rent theory, taking the other two elements into account as well) for the individual as to find his/her individual equilibrium (the place where the three elements are at its optimum for the individual). The bid price curve shows the different prices the individual will be able to pay for land at different distances from the CBD, whilst still enjoying feeble satisfaction (Waugh, 2002:392). The bid price curves are unique to each individual and an individual will choose his location where the highest level of satisfaction is associated with the best price. In the last stage of his theory, Alonso achieved a theoretical equilibrium for the whole market. He states that the most central location in the city will go to the individual with the steepest bid price curve. The individual with the second steepest bid price curve will get the next site outward from the city and so on (Chapin & Kaiser, 1979:39-41).

This model thus explains the process by which individuals bid for land and how the owner sells it to the highest bidder. This model implies that land uses will be decided manually on the basis of who buys land where.

Through the evaluation of the above-discussed models it has been determined that the urban structure tends to develop outward towards cheaper and more open, accessible land. In the next section reasons for this phenomenon will be discussed.

2.5. Urban Sprawl

Having discussed the ways in which urban areas change and evolve according to various models, an even deeper examination can be made on the reasons for these changes, as well as ways in which they materialize. According to research done by Clark (1989:16) in Britain, rural areas started to grow faster than urban areas since the sixties. This was mainly due to the development of new towns on the periphery of cities. It is thus clear that the phenomenon of urban growth is nothing new and presents itself all around the world at different times and stages of development. There are many reasons mentioned for the development of rural areas (Clark, 1989:14-42). For the sake of relevance focus will only be on urban *sprawl and envir*onmentalism. According to Miceli and Sirmans (2007:4) urban sprawl is a term that has been used to describe a wide variety of undesirable aspects of urban growth such as traffic congestion, excessively large cities, etc. To date, consensus has not been reached on the underlying causes or reasons for urban sprawl. There are various opinions that seek to explain why urban sprawl occurs; some of these opinions are discussed below.

- Miceli and Sirmans (2007:5) argue that the so-called 'hold out problem' indirectly causes urban sprawl in that people own a parcel of land on the edge of the city but holds it back in order to cause the value/price to rise. This leads to developers buying land further away from the city where it is cheaper which leads to high income housing outside the city, which is in effect urban sprawl.
- Henderson (1985:180) and Nechyba and Walsh (2004:179) state that urban sprawl occurs when people move outward toward lower density areas as transportation costs fall and income rise.
- Martinuzzi *et al.* (2007:296) says that every urban system is unique and so is the way in which urban sprawl occurs. He thus says that there are no specific universal reasons for urban sprawl.
- Wu and Plantinga (2003:289) argue that the nature of people to live close to open space causes urban sprawl. They talk about a concept they dubbed "leapfrog development" that occurs when open space surrounds an urban area and development continues behind it. This phenomenon is visible in South Africa where expensive farmlands (plots) surround the city which causes development to move further away from the city to cheaper land.
- Lastly, Wu (2006:528) states that some economists argue that sprawl is the result of an "orderly market process" that allocates land between urban and agricultural uses.

From the above it is clear that urban sprawl is a phenomenon that is widely discussed but poorly understood; it means different things to different people. There are many, quite diverse, definitions for and opinions on urban sprawl, but none which explains the phenomenon in such a way that consensus can be reached between experts. According to Sudhira *et al.* (2004:30) some researchers define urban sprawl as the "spatial expansion of cities" others as "the lack of continuity in expansion" or as "chopped-up, spread out, segregated, low-density, auto-dependent development". Sudira *et al* (2004:33) state that urban sprawl threatens sustainable urban development, but also says that most researchers agree that it is a fragmented pattern of land development.

Galster *et al.* (2001:682) further elaborate on the concept, and group urban sprawl into six general categories:

1. Sprawl can be defined by an **observable example** in the real world. It can often be observed how urban areas develop outward instead of inward.
2. Sprawl can be defined as an **aesthetic verdict** about a general urban development pattern. Some groups argue that sprawl is the result of bad planning and that it is an unwanted phenomenon.
3. Sprawl can be defined as a case of an **externality**, such as high dependence on the automobile, isolation of the poor in the inner city, spatial mismatch between jobs and housing or loss of environmental qualities. This definition states that certain phenomena cause's urban sprawl. It does not aim to explain what sprawl is, but what it does.
4. Sprawl can be defined as the consequence or **effect** of some independent variable such as fragmented local government control, poor planning, or exclusionary zoning. The way an urban area is managed through policy or legislation etc. affects the way in which sprawl occurs.
5. Sprawl can be defined as one or more **existing patterns of development** such as low-density development, leapfrogging, etc. There are different forms of urban sprawl visible, such as ribbon development along metropolitan roads.
6. Sprawl can be defined as a **process of development** that takes place as an urban area expands outward. It is said that an area may develop outward as a phenomenon of urban sprawl and later in time concentrate in such a way that it becomes part of the town again.

Another view that can shed some light on the reasons for urban sprawl is Berry's reasons for decentralization. According to Blumenfeld (1972:44) decentralization refers to the movement of people and economic activities within an urban area, while deconcentration refers to movement of people and economic activities in a country as a whole. In South Africa, however, deconcentration refers to movement within large urbanised areas, while decentralization refers to movement elsewhere in the country. For the sake of this study, deconcentration will be defined as the movement of people and economic activities within an urban area.

Deconcentration is a phenomenon that is set into motion by various forces (Section 2.3) at work in the urban space. Berry (1976:19-21) provides the following reasons for deconcentration, which can easily be placed in context with South Africa:

- ***The love of newness***. The average person doesn't stay in one place for more than ten years before they move.
  This is mainly due to the desire for a first world lifestyle and also the fact that newer houses on the periphery of cities lures people to move out of older houses towards newer ones. Surely most people, if given the opportunity, will choose to move towards a new and better home, thus making the concept universal.
- ***Nearness to nature***. Some people want to live nearer to nature rather than be surrounded by high buildings and the pollution of a city.
  This has been a common trend in South Africa where people tend to move away from the city towards nature estates.
- ***Freedom to move***. It is human nature to constantly be on the move. Better job opportunities often cause people to move.
  Since the fall of Apartheid in South Africa, previously disadvantaged people for instance were able to move towards city centres while privileged people started to move away from the city. It is every person's right to move freely.
- ***Individualism***. Every person is an individual and makes individual choices based on their own likes, dislikes and situations.
  Thus people don't want to live in an area where everything is uniform; everyone wants to have a little haven of choice, which in many cases leads to deconcentration.
- ***Violence***. Violence in urban areas leads to movement of people to residential areas further away from city centres or areas where violence is low.
  The violence phenomenon also leads to the development of the "defensive city" or "concentration camp" (Berry, 1976:20). In South Africa this phenomenon can be observed in the form of gated communities and "country estates".
- ***The melting pot***. Berry describes the melting pot as the situation where people of different races, backgrounds, education, belief, etc. co-exist together in a residential area. He states that people will tend to move toward areas where they are surrounded by their own type of people rather than integrate.
  In South Africa for instance a couple of projects were launched with the aim of integrating different types of people; it is still unclear how successful these projects were or will be.

Geyer and Kontuly (1993:169-172) further present a theory which describes how urban areas evolve, and sketches two scenarios (environmentalism and productionism) from which further reasons for urban sprawl could be derived. Although their theory was focused on a regional scale, it can also be made applicable on the development of individual urban areas. The two scenarios presented by Geyer and Kontuly (1993:169-172) are:

- **Environmentalism.** It is the process where privileged people tend to move away from the built-up urban areas in search of open space to live in. This causes deconcentration and urban growth and could clearly be linked to Berry's reasons for decentralization.
- **Productionism.** This is the counter-process of environmentalism in which disadvantaged people move towards the city centres in search of jobs and in doing so takes the places of people that moved out, causing the city to continue expanding. These two processes thus form a cycle, which leads to urban growth and eventually urban sprawl.

These definitions and opinions on urban sprawl raise the question of what urban sprawl really is, how far the frog of development has to leap and how broad the development has to be for it to be classified as urban sprawl. Having discussed the theories on how cities first materialized and forces (migration, deconcentration, productionism and environmentalism), which cause them to grow and change into the different and unique urban structures that they are, the situation as it manifest within South Africa will be discussed.

2.7. The Situation in South Africa

Mears (2004:16) states that migration in South Africa historically consisted of two main components, namely a natural process based on socio-economic mobility of the white population group, and secondly, a regulated process of migration of the black people. The level of urbanization of white people in South Africa has decreased since the 1990's, while the rest of the population's level of urbanization has kept on growing. This is thought to be mainly due to the fall of Apartheid, which implied that people of other races were allowed to live in previously white urban areas. During this time white people started deconcentrating, causing the overall white urbanization number to fall (Kok *et al.*, 2003:33-36; Mears, 2004:16). According to Kok *et al.* (2003:35) most of the urbanization after Apartheid has gone towards the four major metropolitan conurbations (Gauteng, Durban functional region, greater Cape Town and Port Elizabeth-Uitenhage), a phenomenon he refers to as metropolization.

Anecdotal evidence suggests that the wealthier segment of the population in South Africa started to deconcentrate while the poorer ones concentrated. The above-mentioned phenomena could be viewed as environmentalism and productionism as explained by Geyer and Kontuly (1993:169-172). From the discussed urban structure models it is clear that the migration of privileged people usually occurs outwards towards the periphery of the city and towards the open natural areas adjacent to it. This phenomena is visible in many urban areas in South Africa and can be ascribed to most of Berry's (1976:19-21) reasons for deconcentration.

2.8. The Urban Future

Leven (1979:21) states that the new metropolis will be determined mainly by the spatial requirements for consumption of goods and services and that those elements such as transport, communication, illegal immigration rates and birth rates won't have a relevant effect. He goes on by saying that the cities of the 21st century will grow to the extent where they all have the same population size and that giant metropolises will disappear and smaller ones will appear. Burtons's (1979:207-208) statement that the automobile has a perceivable influence on the way the city evolves, also has to be taken into consideration, for the automobile shapes the way in which cities develop and are redeveloped to accommodate them.

Alonso (1964:227-229) makes an interesting point when he states that poorer people live on land with higher value than people that are privileged. He says this is because wealthier people used to live close to the CBD but as the houses became older they moved toward the only available space in the city, which was the periphery. Poorer people then moved into the old abandoned houses, which meant they lived on the land with higher value. In effect this means that wealthier people are responsible for the growth of the city. They move towards the fringes of the city and live in estates and suburbs leaving behind old housing that will have to be renewed in time. Wingo (1962:228-229) confirms the above when he states that the urban core is uniformly losing population to residential areas, shopping centres and industries on the urban fringe. It is thus clear that the future of urban areas lies in horizontal growth and peripheral development.

2.9. Conclusion

Urban growth is a certain reality which mainly materializes in South African towns and cities in the form of horizontal development (urban sprawl) and fragmented development (leap-frogging). From the discussed literature it is clear that urban areas will almost indefinitely continue to evolve and change. Although the factors and reasons for change may start to differ over time, some of the physical manifestations will almost certainly remain unchanged. One of these is the outward or horizontal development of urban areas or i.e. urban sprawl. From the discussed models it is clear that outward development will always occur for a variety of reasons. In South Africa this phenomenon is visible in most towns and cities and has to be confined by means of strict policies and planning regulations. It is important to guide the horizontal development of urban areas for the sake of sustainable development, which will subsequently be discussed.

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Chapter 3

Planning with Nature

"Man in space is enabled to look upon the distant earth, a celestial orb, a revolving sphere. He sees it to be green, from the verdure on the land, algae greening the oceans, a green celestial fruit. Looking closely at earth he perceives blotches, black, brown, grey and from these extend dynamic tentacles upon the green epidermis. These blotches he recognizes as the cities and works of man and asks, 'is man but a planetary disease?' "

– Loren Eiseley

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Chapter 3: Planning with Nature

3.1. Introduction

According to the United Nations (2006) more than half the globe's population (roughly 3.3 billion) is currently living in urban settlements and it is further anticipated that this total may rise to 61% (roughly 4.9 billion) as early as 2030 (Cohen, 2006:68). This increase in urbanised population will indisputably have urban growth to effect, which has a direct influence and effect on the ecology of natural landscapes surrounding towns and cities. It is crucial that these effects be considered when planning and developing, as to protect areas of critical or scarce biodiversity for future generations (Diamond, 2005:65). To enable a city to grow and function effectively, productive ecosystems outside its borders, to produce food, water and other renewable resources, that are consumed within the city, are required (Folke *et al.*, 1997:167-171). These demands of the city on nature can be described as a city's ecological footprint (Alberti *et al.*, 2003:1170; Venetoulis & Talberth, 2005:2) and can comprise anything from 100 to 300 times the geographical area of an urban region (Rees & Wackernagel, 1996:234; Alberti *et al.,* 2003:1172). Urban sprawl furthermore directly influences land-cover, which among other things controls biodiversity (Alberti *et al.*, 2003:1171). It is clear from this that urbanisation has an extensive effect on its surroundings, with harsh impacts on the natural environment, which is the cities source of life (McHarg, 1969:19). Taking the above into consideration it can be concluded that environmental protection, which includes nature conservation, must be vastly improved in and around urban areas (Cilliers *et al.,* 2004:49). The broad concepts of sustainable development and urban ecology, which addresses these issues, will subsequently be discussed.

3.2. Sustainable development

The background of sustainable development will now be discussed with particular reference to the application of sustainable development in urban areas.

3.2.1. Introduction

The term 'sustainable development' was first coined by the International Union for Conservation of Nature and Natural Resources in their *World Conservation Strategy* of 1980 (Dresner, 2002:30). The *World Conservation Strategy* was aimed at government policy makers, conservationists and developers (Mitcham, 1995:316), and foreshadowed many of the ideas that would later emerge in *Our Common Future* (better known as the Brundtland report). Since the launch of *Our Common Future* by the, United Nations' (UN) initiated, World Commission on Environment and Development in 1987 (WCED, 1987), sustainability has become a very important issue in international politics (Deelstra, 1998:17). The Commission, which was headed by Gro Harlem Brundtland, proposed a new approach towards managing the environment and development by integrating two strains of thought: the need for socio-economic development and the need to limit its harmful impacts on the physical environment (WCED, 1987:48 – 57;

Deelstra, 1998:17). This integration evolved the concept of sustainable development which was redefined (Dresner, 2002:31) by the Brundtland Report (WCED, 1987:54) as

> "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The Commission's conception, however, of what sustainable development would be, was more complex than the simple one-sentence definition presented above (Dresner, 2002:32). They expanded by stating the following (WCED, 1987:54-55):

> "The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth...Sustainable development is not a fixed state of harmony but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs."

This new definition proposed by the Brundtland Commission came at a point in history when awareness was growing that, unless humanity adapted its use of natural resources, the global implications for future generations could be dire and catastrophic (Brundtland, 2007:12; Mitcham, 1995:315-316). However, the message portrayed by *Our Common Future* was not one of doom or defeat, but one of hope, which stated that man, had the capability to save the fragile relationship between itself and the biosphere via sustainable development (Brundtland, 2007:12).

The aims set forth by *Our Common Future* were however general in nature and aimed at a global scale (Deelstra, 1998:17), and for them to be effectively implemented on local scales, they had to be translated into action plans for local communities. Many such attempts were made internationally through initiatives such as the *Sustainable Cities and Towns Project* in Europe (Brundtland, 2007:17), but more had to be done. This realization along with the impact of the Brundtland Report (Mitcham, 1995:316), lead to the first Earth Summit (the United Nations Conference on Environment and Development) held at Rio de Janeiro, Brazil in 1992, where many governments and international agencies pledged their support for sustainable development (Dresner, 2002:1-2).

3.2.2. Agenda 21

A total of 172 governments participated in the 1992 Earth Summit Conference, and 108 of these governments were represented by their heads of state. The Summit intended to focus global concern on the emerging environmental and development crisis (Dresner, 2002:38), and was the pinnacle of a long endeavour of planning and negotiations among all Member States of the United Nations (UN), which eventually led to the adoption of Agenda 21 (UN, 1997). Agenda 21 is a global policy framework guiding governments around the world in the implementation of sustainable development (Schwabe, 2002:13; Dresner, 2002:41) via a set of developmental and environmental objectives (UN, 1992:3). The 21 in Agenda 21 refers to earth's development in the twenty-first century (Deelstra, 1998:20), and thus aim to guide that development in a sustainable manner (Urquhart & Atkinson, 2000:13). According to Paragraph 1.3 of Agenda 21 this can be achieved by addressing current problems and preparing the world for challenges yet to come (UN, 1992:3). At this stage it is important to realize that Agenda 21 is voluntary and only a framework, and that it is the responsibility of national governments to formulate their own national strategies, plans, policies and processes to ensure that sustainable development is implemented in their respective countries (Schwabe, 2002:13). It is proposed that the following objectives be kept in mind during the development of these strategies, policies and plans:

- Ensure the integration of environmental and development issues by means of reviewing existing economic and environmental policies at all scales of government;
- Ensure the integration of environmental and development issues at all levels of government by means of strengthening institutional structures;
- Involve concerned individuals, groups and organizations at all levels of decision-making by means of improving facilitation mechanisms; and
- Establish domestically determined procedures for the integration of environmental and development issues in decision-making (UN, 1992:64).

Agenda 21 highlight the role of citizens and non-governmental organizations (NGO's) in a bottom-up approach towards sustainable development, and thus emphasizes the use and development of human resources (Dresner, 2002:41). Marx (2003:18) states that the goals set by Agenda 21 can only be successfully achieved if all sectors of government and society effectively participate in the mission towards sustainable development. Since the Earth Summit in 1992 South Africa has actively participated in global sustainability, by publishing a report entitled 'Building the foundation for sustainable development in South Africa', which described the state of the environment in South Africa; highlighted challenges to sustainable development; and provided an action plan for the implementation of sustainable development in the country (Schwabe, 2002:14). Even though South Africa does not have a strategy solely dedicated to sustainable development, it has, since 1994, incorporated the concept into all new policies (Schwabe, 2002:14-15) and has started a process to establish a Agenda 21 steering committee

(Urquhart & Atkinson, 2000:25), stressing the country's commitment towards the concept. South Africa's commitment is further emphasized through plans developed by local authorities in relation to Agenda 21 (Urquhart & Atkinson, 2000:25). Some of these local authorities include the Durban metropolitan area, Cape Town metro, Pretoria metro, Johannesburg metro, Kimberley, Garies and Marabastad (Marx, 2003:84-95). In present South Africa, Agenda 21 principles are widely included in Integrated Development Planning (IDP) processes (discussed in Chapter 4) at local levels throughout the country (Urquhart & Atkinson, 2000:30).

Throughout Agenda 21 this importance of the role that local governments play in the implementation of the policy framework is stressed (Marx, 2003:12-15; Urquhart & Atkinson, 2000:13). Local governments are seen as the most effective way of implementing Agenda 21 and in Chapter 28 of Agenda 21 (UN, 1992:285-286) it is stated that they should undertake this task via the development of a Local Agenda 21 (LA21) that reflects their individual needs and circumstances. LA21 is the process used around the globe, to implement Agenda 21 at local government levels (Marx, 2003:84; Urquhart & Atkinson, 2000:13), and is a long-term , strategic process aimed at helping local communities and local councils deal with the issues related to sustainable development (Urquhart & Atkinson, 2000:14).

During the Earth Summit +10 held in Johannesburg, South Africa in August 2002, it was decided that the LA21 process had to be followed up by a Local Action 21 process (Marx, 2003:15), which was aimed at assisting in the execution of the principles set forth by LA21 (Marx, 2003:18). Leaders and representatives of local governments across the world adopted the so-called *Johannesburg Call,* which stated that they commit themselves to developing realistic and practical Action Plans which would be implemented via Local Action 21 (ICLEI, 2002:9). Local Action 21 was launched as a *motto* for the next decade of LA21, and served as a *mandate* to local authorities around the world to join in the *movement* from agenda to action, in the implementation of sustainable development (ICLEI, 2002:1). According to the International Council of Local Environmental Initiatives (ICLEI, 2002:1-9), the movement from LA21 towards Local Action 21 would bring forth the following three advances in sustainable development planning and management at a local scale:

- It would advance the creation of sustainable communities and cities;
- It would reduce the environmental degradation and the depletion of world resources caused by cities; and
- It would introduce new management instruments, which would assist in the implementation, monitoring and improvement of municipal sustainability management.

Local Action 21 would further support ongoing efforts such as the Habitat Agenda, which is aimed towards the development of sustainable cities around the world.

3.2.3. Sustainable cities

According to Schwabe (2002:13), Agenda 21 covers a wide range of social themes, such as combating poverty; demographic dynamics and sustainability; promoting education; public awareness and training; protecting and promoting human health and promoting sustainable human settlement development. Achieving the goal of sustainable human settlements is definitely not an easy task. This is among other things due to the complexity of effectively merging sustainability into densely populated built-up areas (see Portney, 2003). In 1996, four years after Agenda 21, the Habitat II conference (also known as the City Summit) was held in Vancouver, Canada. The summit was intended to help shape the way forward for urban management into the twenty-first century (McAuslan, 2003:106). It was from this summit that a new international policy towards sustainable cities emerged.

The Habitat Agenda saw the light in 1996 following the second Habitat conference and, although it was adopted by 171 countries (UNCHS, 1996), it received very little initial response in comparison with the Rio Summit and Agenda 21 (McAuclan, 2003:106-107). Nonetheless the Agenda addressed two main themes (UNCHS, 1996:1):

- Adequate shelter for all; and
- Sustainable human settlements.

The latter will subsequently be discussed in greater detail, due to its applicability to the study at hand. The Habitat Agenda is committed to the goal of developing societies that are efficient in their use of resources with regard to the environment, while at the same time focusing on economic and social development (UNCHS, 1996:12-13). To achieve the above, the Agenda commits to the following objectives with regard to the development of sustainable human settlements (UNCHS, 1996:13-15):

- Generating a suitable environment for economic development, social development and environmental protection;
- Integrating urban planning and management with regard to housing, transport, employment, opportunities and environmental management;
- Promoting the protection of fragile ecosystems via better and wiser use of productive land in and around human settlements;
- Promoting education with regard to sustainability; and
- Promote the sustainable use of coastal areas.

It is clear from the above that sustainable human settlements will only be achieved if towns and cities can become economically buoyant, socially vibrant and environmentally sound (Figure 3.1), with full respect for cultural, religious and natural heritage (UNCHS, 1996:43). To achieve this is no easy task and the Habitat Agenda, in accordance with Agenda 21, acknowledges the important role that local authorities

(Figure 3.1) have to play in achieving the above (UNCHS, 1996:44). The three elements of sustainable human settlements development will subsequently be discussed.

3.2.3.1. Social Development

The Habitat Agenda states that social development will be achieved through the eradication of poverty and the creation of productive employment conditions (UNCHS, 1996:48). Poverty is one of the biggest threats to sustainability and is in many cases the cause of negative phenomena, such as crime and hunger. In order to wipe out poverty, policies aimed at creating equal and fair employment opportunities, improving access to resources, promoting rural development, developing human resources and promoting strategies for meeting the basic needs of all, are crucial (UNCHS, 1996:48). The Habitat Agenda further highlight the following actions that should be taken with regard to social development (UNCHS, 1996:48-56):

- Promote the provision of basic services in human settlements;
- Promote social integration and eliminate all forms of discrimination;
- Promote the gender sensitive planning and management of human settlements;
- Develop the potential of young people and prepare them for the responsibilities of the development of human settlements;
- Promote disability-sensitive planning and management;
- Promote the continuing progress of indigenous people;
- Reduce violence and crime; and
- Take measures to protect vulnerable and disadvantaged people.

The execution of these actions is crucial if social development is to be achieved. Social development then marks the first of three (Figure 3.1) equally important fundamentals of sustainable human settlement development.

3.2.3.2. Improving Urban Economies

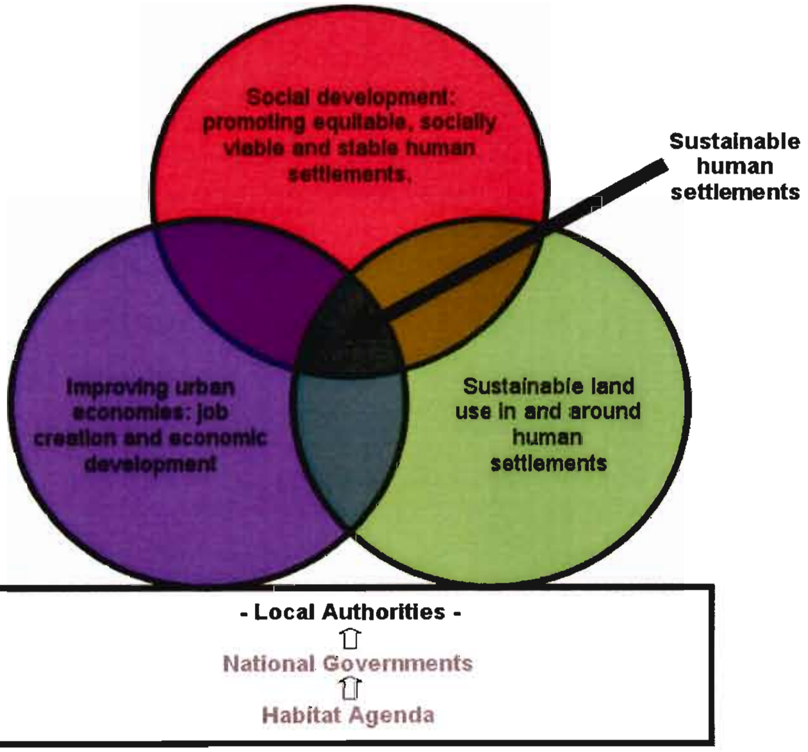
The improvement of urban economies is crucial if economic transformation and development are to be achieved. According to the United Nations (UNCHS, 1996:69), cities currently generate more than half the world's economic activity and are the primary providers of services. A large percentage of the world's population depends on cities for their income and servicing their basic needs. The Habitat Agenda states that many new jobs will have to be created in urban areas to deal with the current trends of urbanization. This is especially relevant in the developing world (UNCHS, 1996:69). The Agenda proposes the following actions with regard to improving urban economies (UNCHS, 1996:69-27):

- Implement financial policies aimed at establishing an effective financial base for urban development;

- Implement policies aimed at providing opportunities for productive employment and private investment;
- Facilitate the extension and improvement of the informal sector via training, policies and integration with other sectors; and
- Promote global competitiveness by strengthening urban economies via improved education, job training and sound financial practises.

The improvement of urban economies is vital to sustainable development, and is often, along with social development, the first priorities, leaving sustainable land-use in the background. The former is especially the case in developing countries where issues such as the eradication of poverty, redistribution of wealth, and wealth creation are the main concerns (Drewes & Cilliers, 2004:16).

Figure 3.1. Sustainable development in human settlements according to the Habitat Agenda



Source: Adapted from Bell & Morse (2003:4)

3.2.3.3. Sustainable Land-use and Environmental Sustainability

Land is critical to all human activity. Horizontal urban expansion and urban growth intensify the competing land demand for housing, industry, commerce, infrastructure, transport, agriculture, open space and conservation (UNCHS, 1996:45). This competing demand makes land-use planning and management a very complex issue to deal with. The Habitat Agenda (UNCHS, 1996:45) states that one of the basic steps to be undertaken in achieving sustainable human settlements, is bringing urban development into harmony with the natural environment. This can be done via innovative methods of urban planning and policies. The Habitat Agenda recommends the integration of Agenda 21 principles into policy and planning approaches (UNCHS, 1996:45). It further states that green spaces and natural vegetation cover within and around urban areas are vital for biological balances, as well as economic development. The Habitat Agenda proposes some actions that should be executed for the sake of sustainable land-use (UNCHS, 1996:46-62):

- Establish legal frameworks to facilitate the implementation of sustainable development plans;
- Strengthen capacities in integrated environmental management;
- Raise awareness of environmental issues;
- Implement plans and policies, addressing goals set forth by Agenda 21;
- Include the protection of biodiversity into sustainable development planning processes; and
- Encourage the establishment of green belts in and around urban areas.

To successfully reach the goal of sustainable human settlements, all three the discussed elements have to be addressed at equal importance. It is only once they are in harmony that sustainable human settlements will arise (Figure 3.1).

3.3. Urban Ecology

To ensure the achievement of sustainable developmental goals, ecological knowledge needs to be considered in urban and spatial planning (Niemelä, 1999a:120). This task is not an easy one, but can be achieved via interdisciplinary research and collaboration in, among others, the fields of urban planning and urban ecology. Urban ecology can assist planners and policy makers in integrating environmental and development issues, protecting critical biodiversity areas, and achieving sustainable land-use in and around urban areas. Urban ecology should be seen as a planning tool, assisting planners in achieving sustainable development.

3.3.1. What is urban ecology?

According to Breuste (1998:v) urban ecology has evolved from a scientific branch of Biology towards an interdisciplinary research field with definite applications in urban and regional planning. This type of interdisciplinary research and collaboration is fundamental in the task of preventing environmental degradation and biodiversity loss in human settlements around the world. Urban ecology refers to ecological research done in cities and towns (Niemelä, 1999b:58), but in order to fully understand the term, the separate words 'urban' and 'ecology' first need to be discussed (Niemelä, 1999a:120). There are numerous definitions for the term 'urban' (Sukopp, 1998:3; Niemelä, 1999b:58; McIntyre *et al.*, 2000:10; Nilon *et al.*, 2003:1-2; Cilliers *et al.*, 2004:50), but in the context of natural science it refers to a human community with a high density of people, living in an built-up area consisting of dwellings and other constructions (Niemelä, 1999a:120). As with 'urban', 'ecology' can also be defined in many different ways ranging from the scientific usage of the word to its normative usage (Sukopp, 1998:3; Niemelä, 1999a:121; Niemelä, 1999b:58). In the light of natural science, it is seen as the science of the relationships between living creatures and communities, as well as their relationship to the environment (Sukopp, 1998:3), while in the normative sense it can be defined as political activities related to ecological and environmental issues (Niemelä, 1999a:121). The fact that both 'urban' and 'ecology' have a variety of different meanings makes urban ecology a very diverse and complex concept, with different dimensions (Niemelä, 1999a:121) which will subsequently be discussed.

3.3.2. Different perspectives

According to Sukopp (1998:3; 2008:79) the term urban ecology can be used in two ways. In the natural sciences it is used to describe the study of the relationships between living creatures and communities and their relationships to the natural environment within an urban area (Sukopp, 1998:3; Sukopp 2008:79). Urban ecology as a natural science is a fairly young field since urban areas were for a very long time not thought worth studying with regard to ecology (Sukopp, 1998:3). This view started to change when intensive research on ecological aspects started almost 35 years ago (Sukopp, 1998:4). Since then many books and papers have been published on the subject. The second and more common usage is the normative usage where it is used to describe urban development and design programmes, at the political and planning level (Sukopp, 1998:3; Cilliers, 2007:4; Pickett *et al.*, 2008:101), with aims to reduce the environmental impacts of urban regions (Deelstra, 1998:19-21). According to Pickett *et al.* (2008:101) the planning perspective of urban ecology claims ecological justification for specific planning approaches and goals. Although environmentally sound urban planning is not yet well developed, serious efforts are made around the world to improve and apply it (Deelstra, 1998:18). Pickett *et al.* (2008:111) propose the integration of the above two perspectives on urban ecology and state that social and biophysical processes should be dealt with on an equal footing. All the above relates to the definition offered by Marzluff *et al.* (2008:vii) when they describe urban ecology as:

> "...an emerging, interdisciplinary field that aims to understand how human and ecological processes can coexist in human-dominated systems and help societies with their efforts to become more sustainable."

These efforts of society to become more sustainable are directly linked to urban planning and the use of ecological data in planning processes. It is this integration into planning that makes urban ecology an applied science (Niemelä, 1999a:121).

3.3.3. The role of urban ecology in spatial planning

From the preceding definitions and perspectives it is clear that urban ecology is a very complex field with deep roots in various disciplines such as sociology, geography, urban planning, landscape architecture and ecology (Marzluff *et al.*, 2008:vii). Due to this complexity, an interdisciplinary approach is crucial for the studying and understanding of urban ecological systems. Such an interdisciplinary approach has the potential to advance sustainable development by allowing social (planners) and biological (ecologists) scientists to effectively integrate information in towns and cities (Alberti *et al.*, 2003:1178; Sukopp, 2008:79). According to Alberti *et al.* (2003:1178) this can only be achieved if urban ecology's scientific community makes scientific results relevant to policy, by actively participating in policy developing processes. This is however no easy task and, according to Niemelä (1999a:127), three broad issues need to be addressed before ecological knowledge can be effectively incorporated into planning.

The first is to determine what kind of nature exists in urban areas. This is a challenge due to the lack of detailed ecological information in an easily accessible format for many cities around the world, including South African cities (Cilliers *et al.*, 2004:58). One way to overcome this challenge and capture and present the required data in an accessible format is by means of a process known as biotope mapping. Biotope mapping was first used in Europe in projects that focused on the conservation of nature in and around cities (Drewes & Cilliers, 2004:17; Pickett *et al.*, 2008:110), and has since been used routinely for planning purposes in countries such as Germany and Sweden (Löfvenhaft *et al.*, 2002:224). A biotope refers to an environmental area that is characterised by certain conditions and populated by certain biota (Löfvenhaft *et al.*, 2002:225). Biotope mapping is the process of identifying and specifying these areas on a map (Niemelä, 1999a:127; Mansuroglu *et al.*, 2006:176), which can later be used for urban planning purposes. Sukopp and Weiler (cited by Mansuroglu *et al.*, 2006:176) distinguish between two different methods of biotope mapping, which is, selective mapping, where only biotopes worthy of protection are mapped, and comprehensive mapping, where all biotopes are mapped. Knowledge about processes affecting urban ecosystems in comparison to rural ecosystems needs to be obtained and is, according to Niemelä, (1999a:127), the second issue that needs to be addressed. This knowledge will improve our understanding of urban ecosystems and will assist planners and governments in their task of planning for environmental sustainability. The final issue that needs to be addressed is the development of, ecological knowledge based, ecosystem-specific management schemes for urban nature (Niemelä, 1999a:127).

It is thus clear that ecology alone is not sufficient in providing the complex information that urban planners need, and that the collaboration of natural and social scientists in an interdisciplinary manner needs to be encouraged (Niemelä, 1999a:127-128). This is fundamental in the task of planning for sustainable development.

3.4. Sustainable development: the South African situation

In order to successfully achieve sustainable development, and more specifically sustainable human settlement development, it has to be promoted at a national level, whilst involving local authorities. South Africa has attempted to do this by Linking Local Agenda 21 and the Habitat Agenda via an interim national multi-stakeholder committee. The committee's aim is to promote the implementation of Local Agenda 21 and Habitat principles in South Africa (Urquhart & Atkinson, 2000:25). According to Schoeman (2006:6) South Africa has further acknowledged the concept of sustainable development in various legal and policy documents, some of which are (Drewes & Cilliers, 2004:16; Pekelharing, 2008:51):

- The Reconstruction and Development Plan (1994);
- The Urban Development Strategy (1995);
- The Development Facilitation Act (Act 76 of 1995);
- The Rural Development Strategy (1997);
- The National Environmental Management Act (Act 107 of 1998);
- The Green Paper on Development Planning (1999); and
- The White Paper on Spatial Planning and Land-use (2001).

South Africa has adopted an integrated approach towards sustainable development, which is evident from the majority of policies introduced by the first democratic government of South Africa (Pekelharing, 2008:51). It is important to realise that a program or plan doesn't necessarily have to have a Local Agenda 21 or Habitat Agenda label to conform to principles related to sustainable development and, according to Urquhart and Atkinson (2000:24-25), there are many processes and projects underway in South Africa which do not necessarily call themselves "Local Agenda 21" or "Habitat Agenda", but still implement the core values depicted by the Agendas (Urquhart & Atkinson, 2000:25). One of these is the Integrated Development Planning (IDP) process, which is enforced by the Municipal Systems Act (Act 32 of 2001) in all local municipalities in South Africa (Urquhart & Atkinson, 2000:23-24). The IDP aims to strategically align sustainable development as an element of integrated planning on all spheres of government (Retief, 2007:11; Pekelharing, 2008:55) and will thoroughly be discussed in Chapter 4.

3.5. Conclusion

Sustainability and sustainable development is a very important topic in current international politics. Although the South African government has made an excellent effort to integrate the concepts of sustainability into policy and legislation, the effective implementation thereof on ground level is still relatively poor. The important role that local governments have to play (as emphasised in Agenda 21 and the Habitat Agenda) in achieving sustainable development should not be overlooked. It is vital that further efforts be made to achieve sustainable development on local governmental levels. To achieve this, the importance of integrated environmental management, by means of integrating social and environmental data, has to be realized. In other words, planners, ecologists and economists should work together in an integrated manner to reach the different sustainable development goals, such as economic development and environmental protection. Hence, the importance and value of detailed ecological data for spatial planning purposes have to be accepted and invested in. Only once accurate environmental data focused on protecting critical biodiversity areas, detailed agricultural data indicating prime agricultural land, and economical indicators are included into planning processes, will sustainable urban settlements be visible on ground level.

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Chapter 4

Policy and Legislation

"A hundred years after we are gone and forgotten, those who never heard of us will be living with the results of our actions"

- Oliver Wendell Homes

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Chapter 4: Policy and Legislation

4.1. Introduction

Integrated development planning is still quite a young science in South Africa, but is steadily growing in its application and success (Binns & Nel, 2002:931). The Integrated Development Plan (IDP) provides local governments with a holistic, integrated and participatory strategic plan, to guide them in development orientated tasks within their municipalities (Pekelharing, 2008:54). One of the core elements of an IDP is the Spatial Development Framework (SDF) which provides development direction, co-ordinates initiatives and identifies key development areas within a local or provincial municipality (Maxim, 2008:6). SDFs further provide a link between integrated development planning and land-use management, and if integrated with environmental considerations, could potentially make a significant contribution to sustainable development (Retief, 2007:11). Because this study focuses on spatial planning in South Africa, and more specifically SDFs, the policy and legislation relevant to SDFs will be discussed, subsequent to a short overview on planning law in South Africa.

4.2. The history of planning law

According to Van Wyk (1999:85) the first reference to planning law in South Africa can be traced back to 1652 when Jan van Riebeeck and the Dutch settlers arrived in the Cape of Good Hope. The Dutch apparently accepted that the land on which they sat foot belonged to no one, and implemented a land registration system, which made use of title deeds to facilitate the allocation of land. These title deeds provided for the inclusion of certain restrictive conditions to help mange the utilization of land and erven, though the restrictions weren't enforced by any law, they were unanimously regarded as official (Van Wyk, 1999:85). However, the biggest influence on planning regulations in South Africa was most likely the 18th century industrial revolution, which was responsible for the transpiring of large-scale urbanization all around the Western world. This unforeseen increase in urbanization had a massive effect on development in early industrialized countries such as England, and due to the lack of zoning and management plans, mixed land-uses emerged with industries and houses, in some cases, developing next to each other (Van Wyk, 1999:82). These uncontrolled and unplanned developments led to the manifestation of the first planning legislation and regulations, which attempted to direct urban development in England (Van Wyk, 1999:82). In the years that followed, England's planning legislation and regulations developed quite fast and were soon being implemented in British colonies, such as South Africa (Van Wyk, 1999:85). Ever since then, planning law started to evolve and grow into a specialist field that is of immense importance nowadays.

4.3. The situation in South African planning law

Since the fall of Apartheid in 1994, South Africa has undergone an exceedingly dynamic transformation in the planning field as well as the legislative field. These changes are mostly due to, respectively, the political changes that transpired, and rapid increases in urban development that took place. To enable

South Africa to effectively cope with these changes, new legislations and policies with regard to planning, had to be developed. Some of the new guiding systems that emerged, were the Development Facilitation Act (1995) and the White Paper on Spatial Planning and Land Use Management (2001). According to Abrahams (2005:1-4) and Van Wyk (1999:81), the central characteristic of South African planning law is the regulation of land-use. Van Wyk (1998:1-5) defines planning law as:

> "...that area of the law which provides for the creation, implementation and management of a sustainable planning process", she continues by stating that "...planning law is concerned with the determination of principles and devices underpinning land development as well as the management and regulation of land-use in different spheres of government."

In South Africa, planning law is responsible for guiding and managing development on all levels of government through policy, regulations and legislation that steer procedures such as spatial initiatives, township establishment and rezoning.

Before discussing the policies and legislations applicable to SDFs, the terms 'policy' and 'legislation' will first be defined. Legislation can be described as a system of rules or regulations intending to order society by means of enforcement through various government institutions (Kleyn & Viljoen, 1998:12), while policy can be defined as a set of enforcing guidelines developed in accordance with legislation to assist various roll players in the implementation of legislation (Torjman, 2005:2). At this stage it is important to distinguish between two concepts relevant to legislation, they are Acts and Bills. An Act is a document describing and enforcing a Law, but before an Act is promulgated it is known as a Bill. It is only once the Bill has gone through various legal steps and has been accepted in Parliament that it is promulgated to an Act. With this in mind the examination of policy and legislation relevant to SDFs can commence.

4.4. Legislation

The investigation will commence with a discussion of the applicable legislation.

4.4.1. The constitution of the Republic of South Africa, Act 109 of 1996

The most important single piece of legislation in South Africa is the Constitution (Act 108 of 1996). The broad purpose of the Constitution as described in the preamble is to (RSA, 1996b:3):

- "Heal the divisions of the past and establish a society based on democratic values, social justice and fundamental human rights;
- Lay the foundations for a democratic and open society in which government is based on the will of the people and in which every citizen is equally protected by law;
- Improve the quality of life of all citizens and free the potential of each person; and lastly

- Build a united and democratic South Africa able to take its rightful place as a sovereign state in the family of nations."

All laws are subject to the Constitution, which bluntly means that no law may be in any conflict whatsoever with it or its principles (Van Wyk, 1999:99). This has to effect that all development functions in South Africa have to be executed in accordance with it (Scheepers, 2000:36). According to Scheepers (2000:36) the 1996 Constitution is the first of its kind in that it is development orientated and more specifically sustainable development orientated. The latter is clear from Section 24(b)(iiii) which states that (RSA, 1996b:8)

> "...everyone has the right to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

The Constitution indicates that local authorities have a very definite developmental role to play in achieving the above (Binns & Nel, 2000:924) and states in Section 153 (RSA, 1996b:52) that municipalities must structure and manage its administration, budgeting and planning processes as to promote social and economic development while at the same time participating in national as well as provincial development programmes. According to the White Paper on Local Government of 1998, IDPs are crucial tools in assisting local governments in achieving these development outcomes as specified in the Constitution (DPLG, 2000:17). The success of any IDP thus depends on the extent to which it has assisted the local government to execute the following goals as described in Section 152(1) of the Constitution (RSA, 1996b:51):

a) "Provide democratic and accountable government for local communities;
b) Ensure the provision of services to communities in a sustainable manner;
c) Promote social and economic development;
d) Promote a safe and healthy environment; and
e) Encourage the involvement of communities and community organizations in the matters of local government."

It is thus clear that the Constitution plays a very crucial role in the manner in which development and development planning is conducted.

4.4.2. The Development Facilitation Act (Act 67 of 1995)

The Development Facilitation Act of 1995 (DFA) was introduced to speed up the implementation of RDP projects and other projects related to land development within South Africa (Scheepers, 2000:62, RSA, 1995:1), and is possibly the most significant piece of land legislation to date (Van Wyk, 1999:141). According to Binns and Nel (2002:925) the act provides general principles for land development and conflict resolutions, and is principally aimed at encouraging efficient and integrated land development in urban as well as rural areas. In Section 10B of the LGTA (209/1993) it is stated that IDPs must give effect to the general principles contained in Chapter 1 of the DFA. These principles state that IDPs should (RSA, 1995:8-9):

- "Promote the integration of the social, economic, institutional and physical aspects of land development;
- Promote integrated land development in rural and urban areas in support of each other;
- Promote the availability of residential and employment opportunities, in close proximity to or integrated with each other;
- Optimise the use of existing resources including such resources relating to agriculture, land, minerals, bulk infrastructure, roads, transportation and social facilities;
- Promote a diverse combination of land uses, also at the level of individual erven or subdivisions of land;
- Discourage the phenomenon of "urban sprawl" in urban areas, and contribute to the development of more compact towns and cities;
- Contribute to the correction of the historically distorted spatial patterns of settlement in the Republic, and to the optimum use of existing infrastructure in excess of current needs; and
- Encourage environmentally sustainable land development practices and processes."

The DFA aims to steer all development in South Africa into the same direction via the principles presented in Sections 2 – 4, and presents a brand new route for development in post-apartheid South Africa. The fact that the DFA discourages urban sprawl and promotes sustainable development, indicates that it (along with The National Environmental Management Act) supports the views established by Agenda 21.

4.4.3. The National Environmental Management Act (Act 107 of 1998)

The National Environmental Management Act of 1998 provides all relevant parties with environmental management principles for application in decision making on matters, affecting or concerning the environment (Van Wyk, 1998:244; RSA, 1998b:1). NEMA directs all provinces in South Africa to prepare an environmental implementation and management plan via Chapter 3 of the Act (1998/107). The purpose of these plans is to align all plans and policies that affect the environment, or are tasked with protecting it, in such a manner that the duplication of procedures is avoided and consistency is promoted (RSA, 1998b:11). In Section 16(4)(b) NEMA states that municipalities should adhere (RSA, 1998:14):

- "...to the relevant environmental implementation and management plans, and the principles contained in Section 2 [of NEMA] in the preparation of any policy, program or plan, including the establishment of integrated development plans and land development objectives."

As a result of the above, all IDPs must adhere to the principles as portrayed in Section 2 of NEMA which among others things call for development to be sustainable (RSA, 1998:7). It can thus be held that an IDP should promote sustainable development by ensuring that (RSA, 19987-8):

- "The disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- Pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- The disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimised and remedied;
- The development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;
- A risk-averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and
- Negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimised and remedied."

It is clear that NEMA corresponds with the principles and recommendations made by Agenda 21 with regard to sustainable development, and aims to further it via Section 16(4)(b). It is crucial that NEMA be consulted when planning, as to ensure a sustainable future for all (Scheepers, 2000:81-82).

4.4.4. The Municipal Systems Act (Act 32 of 2000)

The Local Government: Municipal Systems Act of 2000 (LGMSA) aims to provide core principles, mechanisms and processes that are compulsory to enable municipalities to (RSA, 2000:1):

> "...establish a simple and enabling framework for the core processes of planning, performance management, resource mobilization and organizational change which underpin the notion of developmental local government."

The LGMSA is aimed at increasing the effectiveness of local governments in South Africa and, according to Scheepers (2000:45), is utilized whenever issues related to the process of managing affairs in local government are to be dealt with. The LGMSA enforces the implementation of IDPs in South Africa through Section 25 and further urges municipal planning to be development orientated (in accordance with the Constitution). In Section 26 the core components of IDPs are discussed, and it is stated that an IDP must reflect (RSA, 2000:20):

a) "The municipal council's vision for the long term development of the municipality, with special emphasis on the municipality's most critical development and internal transformation needs;
b) An assessment of the existing level of development in the municipality, which must include an identification of communities which do not have access to basic municipal services;
c) The council's development priorities and objectives for its elected term, including its local economic development aims and its internal transformation needs;
d) The council's development strategies, which must be aligned with any national or provincial sectoral plans and planning requirements binding on the municipality in terms of legislation;
e) A spatial development framework, which must include the provision of basic guidelines for a land use management system for the municipality
f) The council's operational strategies;
g) Applicable disaster management plans;
h) A financial plan, which must include a budget projection for at least the next three years; and
i) The key performance indicators and performance targets determined in terms of section 41."

In Section 23 the LGMSA calls for municipal planning with regard to IDPs to be developmental orientated and compliant with Sections 24, 25, 26, 27, 29, 152 and 153 of the Constitution (109/1996), as well as Chapter One of the Development Facilitation Act (67/1995). In effect this calls for IDPs to promote sustainable development via Section 24(e)(iii) of the Constitution (109/1996), which was discussed above. The LGMSA further describes all the processes that have to be followed in the development, adoption and reviewing of IDPs, and stresses the importance of community participation in the whole process. In Section (26)(e) the first official reference to Spatial Development Frameworks (SDFs) are made, as the LGMSA calls for the development of an SDF, which has to include the basic guidelines for a land-use management system for a municipality. In Section 35(2) it is stated that (RSA, 2000:23):

> "...[such] a spatial development framework contained in an integrated development plan prevails over a plan as defined in Section 1 of the Physical Planning Act [of] 1991..."

These plans referred to in the Physical Planning Act (125/1991) are national or regional development plans, and regional or urban structure plans (RSA, 1991:2). The fact that SDFs surpass these plans, stresses their importance to spatial planning in South Africa. Although SDFs are enforced by the LGMSA, the detail prescription of what they should contain are communicated via other policies and regulations still to be discussed.

4.4.5. The Local Government: Municipal Planning and Performance Regulations, 2001

The Local Government: Municipal Planning and Performance Management Regulations of 2001 (MPPMR) was published in the Government Gazette as Notice 796, and provides regulation in the context of the Local Government Municipal Systems Act (32/2000). In Section 2 the focus falls on the detail of IDPs, and a more comprehensive explanation is presented with regard to the requirements of SDFs. In Section 2(4) it is stated that an SDF reflected in a municipality's IDP must (RSA, 2001a:1-2):

- "Give effect to the principles contained in Chapter 1 of the DFA (Act 67 of 1995);
- Set out objectives that reflect the desired spatial form of the municipality;
- Contain strategies and policies, which:
  - Indicate desired patterns of land use within the municipality;
  - Address the spatial reconstruction of the municipality; and
  - Provide strategic guidance in respect of the location and nature of development within the municipality;
- Set out basic guidelines for a land use management system in the municipality;
- Set out a capital investment framework for the municipality's development programs;
- Contain a strategic assessment of the environmental impact of the spatial development framework;
- Identify programs and projects for the development of land within the municipality;
- Be aligned with the spatial development frameworks reflected in the integrated development plans of neighboring municipalities; and
- Provide a visual representation of the desired spatial form of the municipality, which representation-
  - Must indicate where public and private land development and infrastructure investment should take place;
  - Must indicate desired or undesired utilization of space in a particular area;
  - May delineate the urban edge;
  - Must identify areas where strategic intervention is required; and
  - Must indicate areas where priority spending is required."

The Municipal Planning and Performance Management Regulations is a crucial element in the IDP and SDF development process and provide local authorities with the necessary guidelines to successfully develop and implement an IDP.

4.4.6. Land Use Management Bill, 2006/2008

The Land Use Management Bill (LUMB) was first published for commentary in the Government Gazette in July 2001. Since then, updated versions of the bill have appeared in 2006 as well as in 2008. The 2008 version of the bill received some negative commentary with regards to the consultation process that was followed, as well as some conflicting constitutional issues that appeared (see Parliamentary Monitoring Group, 2008). The 2008 LUMB proposes some severe changes to the 2006 bill. These changes still have to be commended on by various stakeholders, and for that reason the 2006, as well as the 2008 bill, will be discussed in conjunction with each other and with special reference to SDFs. The main objective of the LUMB is to establish a uniform, effective and integrated procedure for land use management in South Africa. According to the LUMB 2006 this will be achieved by means of (RSA, 2006:2):

- Establishing principles for land development and land-use management;
- Providing for land-use schemes;
- Establishing land-use- and appeal tribunals; and
- Repealing certain laws.

The 2008 LUMB expands on these means and states that in addition to the above, imbalances of the past have to be addressed to ensure the equity of matters related to land-use management (RSA, 2008:2). The LUMB 2006 calls for intergovernmental support in the development of SDFs, and states that the Minister and Premier should be involved in the processes with regard to the adoption and alignment of SDFs in local governments (RSA, 2006:12-14). The LUMB 2008 indicates nothing with regard to intergovernmental support in the SDF process, but concurs that SDFs have to be aligned to other plans and policies, as stated in the Municipal Systems Act of 2000 (RSA, 2008:17). The 2006 LUMB further states in Section 17(7) that SDFs should reflect the current state of affairs in the municipality and provide a conceptual framework for desired spatial growth (RSA, 2006:15). It also states that all land-use applications within a municipality must, amongst other things, be consistent with the SDF (RSA, 2006:16).

Although the LUMB has not been promulgated, it provides valuable insight into the direction that government is going with regard to land-use management. The relevance of the discussed policies and legislation to SDFs will now be summarized.

4.5. Policy

Having discussed the relevant legislation, the applicable policies will now be discussed.

4.5.1. The White Paper on Local Government (1998)

The White Paper on Local Government, 1998 (WPLG) elaborates on the role of local governments with regard to development (Binns & Nel, 2002:922). It states that (RSA, 1998a:23):

"...the central responsibility of municipalities [is] to work together with local communities, to find sustainable ways to meet their needs and improve the quality of their lives"

The WPLG defines the development roles (with regard to the Constitution) that local municipalities have to play in the IDP process (DPLG, 2000:3), and further provides valuable guidance with regard to the preparation of IDPs. According to the Department of Provincial and Local Government (2000:4), the WPLG strengthens the case for IDPs as a key tool in developmental local government. The WPLG describes the main steps, crucial to producing an IDP as (RSA, 1998a:29-30):

- Assessing the current social, economic and environmental reality in the municipal area (*status quo*);
- Determining the needs of the community through close consultation;
- Developing a vision for development in the area;
- Assessing available resources, skills and capacities;
- Prioritizing of the order of urgency and long-term importance of determined needs;
- Developing integrated frameworks and goals to meet these needs;
- Formulating strategies to achieve the goals within specific time frames;
- Implementation of projects and programs to achieve key goals; and
- Utilizing monitoring tools to measure impact and performance.

The WPLG further states that municipalities should not attempt to produce a detailed IDP in the first year of the project, but recommend that the IDPs should be viewed as incremental plans (RSA, 1998a:30). The WPLG strongly discourages the outsourcing of IDP development to private consultants, and states that the development should be managed within the municipalities, in such a way that the strategic planning capacity of the municipality is enhanced (RSA, 1998a:30).

4.5.2. The White Paper on Spatial Planning and Land-use Management, 2001

The White Paper on Spatial Planning and Land-Use Management of 2001 (WPSPLM) was compiled by the Department of Agriculture and Land Affairs with the aims to rationalize the existing overabundance of planning legislation in South Africa, and provide for a uniform, efficient and effective framework for spatial planning and land-use management in urban as well as rural contexts (RSA, 2001b:3-4). The WPSPLM builds on the earlier published Green Paper on Development and Planning of 1999, as well as on the concept of IDP as set forth in the Municipal Systems Act (23/2000). The WPSPLG proposes five elements essential to a new approach in spatial planning and land-use management, which will now be discussed (RSA, 2001b:3-4):

- **Principles and norms**, aimed at achieving sustainability, equality, fairness, integration and good governance in spatial planning and land-use management. All decisions made by planning authorities with regard to spatial planning (IDPs & SDFs) of land development (rezonings) have to be in accord with these principles;

- **Land use regulators**, which will make decisions with regard to spatial planning and land-use management. These regulators include municipalities, land-use tribunals and appeal tribunals, with the Minister acting as national land use regulator in cases where national planning principles and norms were neglected.
- **IDP-based local planning**, such as SDFs. The WPSPLM states that integrated development planning is a crucial step towards sustainable and equitable growth and development, and states that SDFs forms a core component in this regard.
- **Uniform procedures** to guide the appropriate land use regulator in decisions on proposed developments. The WPSPLM proposes one set of such procedures for the whole country, thereby eliminating the current situation where different procedures apply in different provinces, and even within a province in different previous apartheid race zones; and
- **National spatial planning frameworks** to achieve more integrated and coordinated spending of public funds.

The WPSPLM states that an SDF should operate as an indicative plan within an IDP and spells out the minimum elements required in an SDF. According to the WPSPLM, an SDF has four basic components (RSA, 2001b:18). They are:

- "Policy for land use and development;
- Guidelines for land use management;
- A capital expenditure framework, showing where the municipality intends spending its capital budget; and
- A strategic environmental assessment."

The WPSPLG states that the primary purpose of a SDF is to present the local government's spatial development goals, in a manner which is comprehensive and comprehensible, as well as guide and inform decisions relating to land-use (RSA, 2001b:19). In this regard a SDF must guide and inform on the following (RSA, 2001b:19):

- "Directions of growth;
- Major movement routes;
- Special development areas for targeted management to redress past imbalances;
- Conservation of both the built and natural environment;
- Areas in which particular types of land use should be encouraged, and others discouraged; and
- Areas in which the intensity of land development could be either increased or reduced."

The WPSPLG states that an SDF should be viewed as a strategic and flexible forward planning tool, which assists local governments in decisions on land development.

4.6. Relevance of policy and legislation to SDFs

As stated earlier, SDFs form a core part of the IDP process in South Africa. Thus, to fully understand the SDF and its role in spatial planning, the history and role of the IDP have to be discussed. The development of IDPs became a legal requirement for local governments in November 1996 (DPLG, 2000:3) in terms of the Second Amended Local Government Transition Act, 1996 (LGTA). The Second Amended LGTA, 1996 (which is the Second Amendment Act to the LGTA of 1993) specifically describes the role of the IDP in the municipal planning process (Binns & Nel, 2002:924) and calls for the insertion of PART VIA into the original LGTA of 1993, in such a manner that Section 10B states that an (RSA, 1996a:3):

> "Integrated development plan, means a plan aimed at the integrated development and management of the area of jurisdiction of the municipality concerned in terms of its powers and duties, and which has been compiled having regard to the general principles contained in Chapter 1 of the Development Facilitation Act, 1995 (Act No. 67 of 1995), and, where applicable, having regard to the subject matter of a land development objective contemplated in Chapter 4 of that Act".

According to the Department of Provincial and Local Government (DPLG, 2000:19), the IDP was aimed at integrating development and management within municipal areas, and was thus conceived as a tool to assist municipalities in achieving their development goals, especially with regard to the Reconstruction and Development Program (RDP). However, when the RDP office closed in 1996, the focus of reconstruction and development had completely shifted to the role of IDP in local governments and became a legal requirement as stated above (Binns & Nel, 2002:923). In this regard the IDPs were referred to by the DPLG as (Binns & Nel, 2002:923):

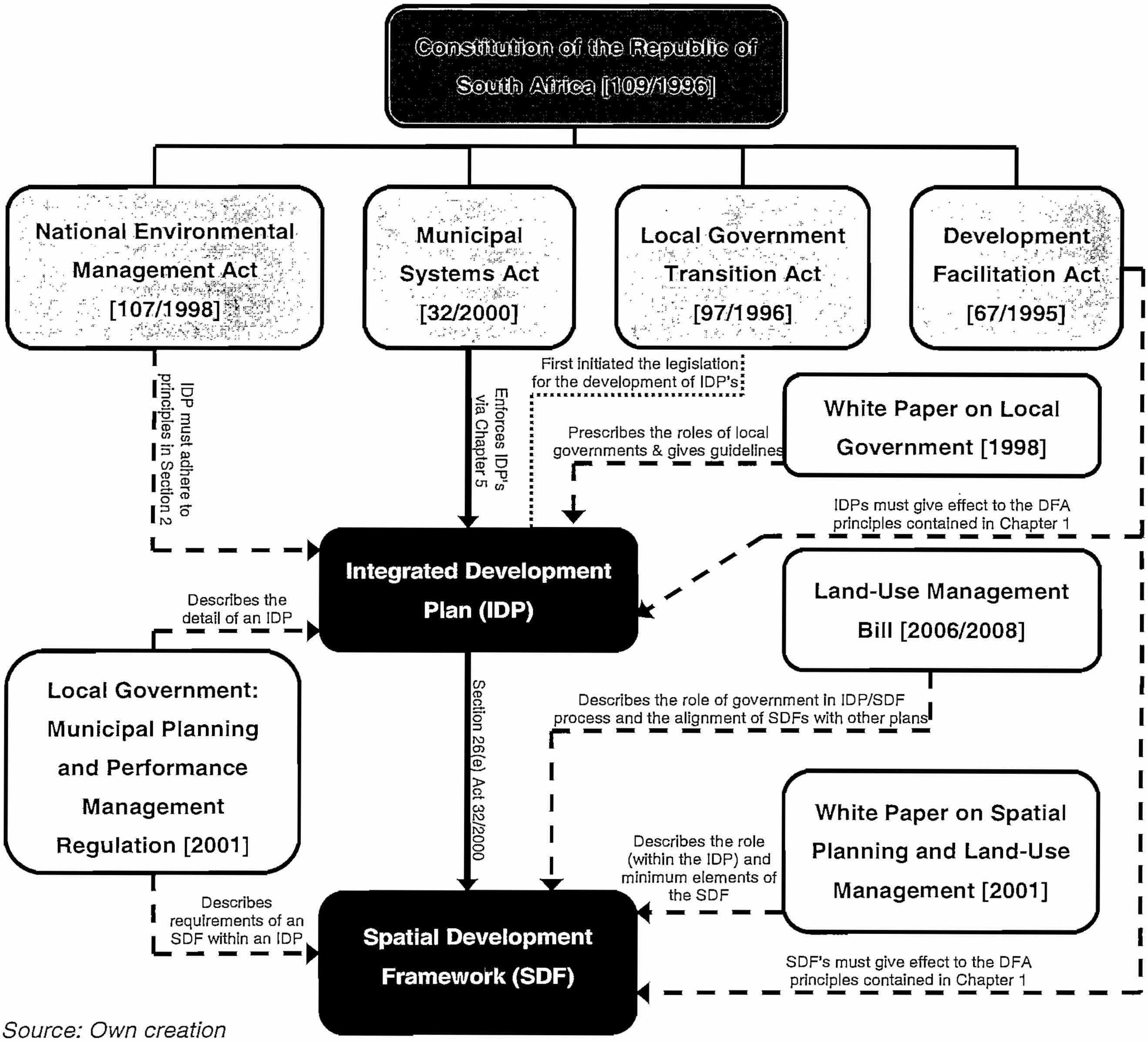
> "...local versions of the Reconstruction and Development Program (RDP), grounded in infrastructural planning and development, upon which rests the crucial linkage between meeting basic needs and fostering more competitive economic activities..."

One of the most lucid definitions of Integrated Development Planning (which correlates with the principles of sustainable development as discussed in Sections 3.2 and 4.4.3) is the one supplied by the Forum for Effective planning and Development (FEPD) when they describe it as (DPLG, 2000:14):

> "...a participatory approach to integrate economic, sectoral, spatial, social, institutional, environmental and fiscal strategies in order to support the optimal allocation of scarce resources between sectors and geographical areas and across the population in a manner that provides sustainable growth, equity and the empowerment of the poor and the marginalised".

The discussed legislation and policy can be presented in a flow diagram as illustrated in Figure 4.1. The figure illustrates were each of the relevant policies and acts fit into the IDP and SDF processes. In Figure 4.1 it can be observed that the Municipal Systems Act of 2000 enforces both the IDP and the SDF and that the SDF is a component of the IDP. The figure illustrates that IDPs must adhere to the principles of the National Environmental Management Act as well as the Development Facilitation Act, and that local governments must fulfil the roles defined for them in the White Paper on Local Government. It can further be observed that SDFs should too give effect to the principles of the Development Facilitation Act and that they should be aligned with other spatial plans as described in the Land Use Management Bill of 2006. The SDF should further meet the requirements as described in the White Paper on Spatial Planning and Land-Use Management and the Municipal Planning and Performance Management Regulations and should fulfil its role within the IDP as described in the aforementioned documents. For a summary of the applicability of each of the discussed policies and acts to SDFs, please see Table 4.1.

Figure 4.1. Legislation and policy related to SDFs



Source: Own creation

Table 4.1. Summary of policy and legislation

Relevant Policy / Legislation	Relevance to SDFs
The Constitution of the Republic of South Africa [109/1996]	All laws are subject to the constitution. All legislation and policy with regard to planning have to concur with its principles. The constitution promotes sustainable development and recognizes the important role that local governments have to play in development planning (IDP/SDF).
Development Facilitation Act [97/1995]	IDPs and SDFs must give effect to the principles contained in Chapter 1 of the act.
The Second Amended Local Government Transition Act [97/1996]	First legislation to enforce the development of IDPs. It further describes the role that the IDP should play in municipal planning processes.
National Environmental Management Act [107/1998]	States that municipalities should adhere to its principles when developing policies and plans, such as IDPs and SDFs. NEMA calls for the promotion of sustainable development when planning or developing.
The Municipal Systems Act [32/2000]	Provides municipalities with core principles, mechanisms and processes to assist them in planning processes. It enforces the implementation of IDPs through Section 25 and discusses the core requirements of IDPs. It enforces the development of SDFs and requires planning to be sustainable development orientated.
White Paper on Spatial Planning and Land Use Management [2001]	States that a SDF should operate as an indicative plan within the IDP. Identifies the four main components of a SDF and discusses the primary purpose and goals of an SDF.
Land Use Management Bill [2006]	Calls for intergovernmental support in the development of SDFs, as well as the alignment of SDFs with other strategic plans and policies.
Land Use Management Bill [2008]	Calls for the alignment of SDFs with other strategic plans and policies.
The White Paper on Local Government [1998]	Elaborates on the roles that local governments have to play in development and planning, and in effect the IDP process. It provides guidelines with regard to the preparation of IDPs.
The Local Government: Municipal Planning and Performance Regulations [2001]	Provides details on IDPs as well as a comprehensive explanation on the requirements of SDFs. It calls for the inclusion of a SEA on the impact of the SDF

Source: Own creation

4.7. Conclusion

From the above, a thorough understanding has been gained regarding the development process and principles with regard to SDFs. The importance of SDFs in spatial planning in South Africa is emphasised in Section 35(2) of the Local Government Municipal Systems Act, which states that SDFs prevails over regional development plans and regional and urban structure plans as defined in the Physical Planning Act of 1991. It is further clear that sustainable development as described in the Constitution, the National Environmental Management Act and the Development Facilitation Act, forms a core element in integrated development planning as well as spatial development frameworks, but the reality is that it is rarely achieved effectively. This is mainly due to the difficulty of effectively integrating environmental principles with spatial planning policies and legislation, as well as the lack of capacity in certain municipalities.

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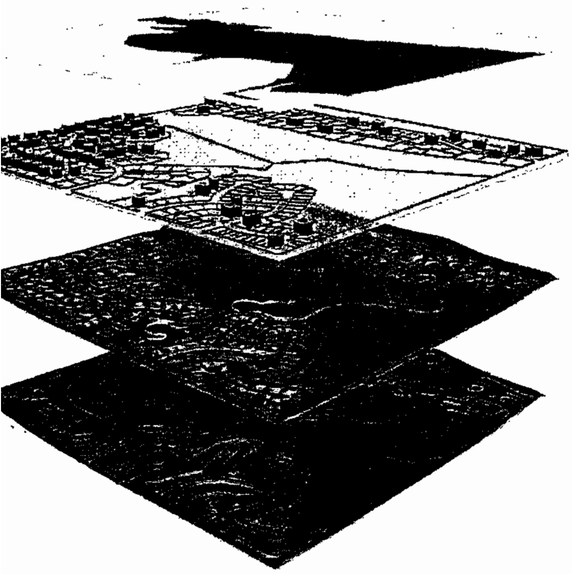
Chapter 5

Spatial Modeling



"The outcome of the city will depend on the race between the automobile and the elevator, and anyone who bets on the elevator is crazy."

- Frank Lloyd Wright

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Chapter 5: Spatial Modelling

5.1. Introduction

Having discussed the theoretical background with regard to planning, sustainable development and spatial development planning, a more technical discussion will be made with regard to GIS analysis. It is hoped that the techniques that will be discussed can assist planners and policy makers in reaching sustainable development goals through spatial planning.

5.2. Multi-criteria analysis and land-use suitability modelling

According to Belton and Steward (2002:1), every decision that's taken in life involves the balancing of different criteria or factors. This balancing of different criteria can take place consciously (knowingly) or unconsciously (unknowingly), and can be referred to as multiple-criteria decision making. Take for instance the process of buying a new car; factors that become relevant in making a decision, are the price, model, fuel consumption, service plan and engine capabilities, and they all have to be compared to eventually make an informed and sensible decision. Due to the complexity of multiple-criteria decision making and its wide application, multi-criteria analysis (MCA) was developed in the 1960's, as a tool to assist decision makers in making comparative assessments (European Commission, 2003:1). Roy (1996:202) defines MCA as a decision aid and a mathematical tool, allowing the evaluation of different alternatives or scenarios according to many criteria (often conflicting), in order to guide the decision maker towards a sensible choice. MCA thus assists decision makers in the organization and synthesizing of large amounts of data, in a way which leads them to feel at ease and confident in the decision they make (Belton & Steward, 2002:2). Spatial multi-criteria decision-making refers to the application of MCA in a spatial context, where the elements involved in the decision making process have specific spatial dimensions (Chakhar & Mousseau, 2007:747). Spatial multi-criteria decision making has been coupled with GIS since the late 1980's (Chakhar & Mosseau, 2007:747), and has been evolving ever since. One of the most common, GIS-based, uses of spatial multi-criteria decision-making, is land-use suitability modelling.

According to Carr and Zwick (2007:46), the first traces of land-use suitability modelling can be traced back as far as the late 19th century, when two landscape-architects superimposed transparent sheets of paper on a window to view multiple site characteristics at the same time. This technique came to be known as sieve mapping, and was later used for site suitability analysis by town planners in Scotland and in England. Since then, references to approaches of land-use suitability modelling can be found in the works of authors such as Mcharg (1969), Beek and Benemma (1972), Pathan *et al.* (1992) and more recently Joerin *et al.* (2001) and Carr & Zwick (2005, 2007). As observed from the prior mentioned works, it is clear that a variety of different methodologies exist for the spatial application of MCA in the form of suitability analysis. Most of the differences are in terms of the type of datasets and format of the datasets that were used. Other differences (which have a bigger influence on the result) are in the differences in overlay techniques that were used. These different methodologies (referred to above) include Boolean logic methods (Malczewski, 1999:32-45; Price, 2008:527-528; Chang, 2008:239), weighted overlay methods (Longley *et al.*, 2005:378; Carvalho *et al.*, 2007:174-175; Esri, 2009) and fuzzy set methods (Malczewski, 1999:47; Carvalho *et al.*, 2007:175-178), but, before discussing these three techniques, an overview of the basic data structures they work with is required.

In GIS-based land-use suitability modelling, there are two types of spatial data structures that can be used in analysis. They are vector data and raster data. Vector data (which is limited in its use for suitability analysis) consists of three types of shapes, which are lines, points and polygons (Figure 5.1). These shapes are used to represent real world elements such as roads, rivers and water bodies (Heywood *et al.*, 2006:78) and are usually used on road maps and topographic maps. Although vector datasets can be used in some types of GIS-based land-use suitability analysis, they are not the most desirable choice. The more preferable data structure is the raster data structure. Raster (or cellular) datasets are used to represent geographic features within a framework of uniform cells (Carr & Zwick, 2007:18). This implies that all data will be represented in the same manner (Figure 5.1), making it easier to compare different types of criteria. Figure 5.1 illustrates the manner in which vector data will be represented in the raster structure. Raster datasets furthermore have different spatial resolutions (Heywood *et al.*, 2006:78). Spatial resolution refers to the size of the cells in the raster dataset. Figure 5.2 illustrates the same feature (road network) being represented at different spatial resolutions in a raster structure. It is clear from Figure 5.2 that, the higher the resolution, the more accurate the data will be, and in effect the analysis. Having discussed the two different data structures, the three overlay techniques can be discussed.

Figure 5.1. Vector and raster data structures.

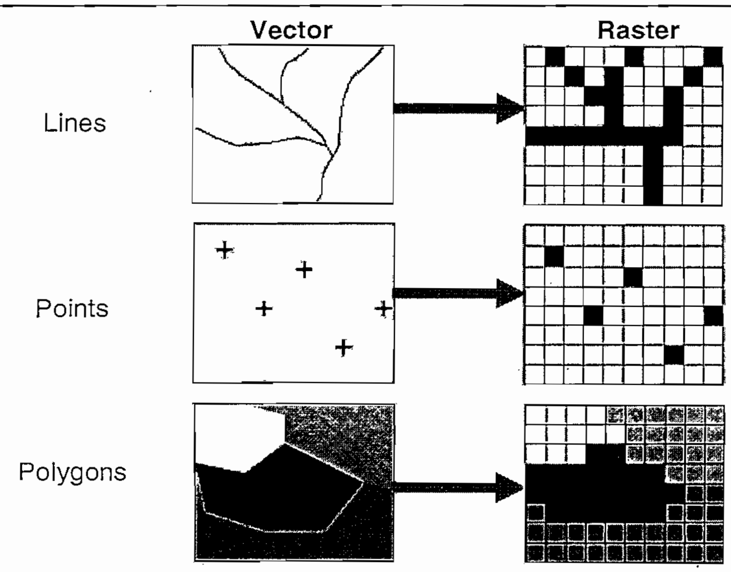

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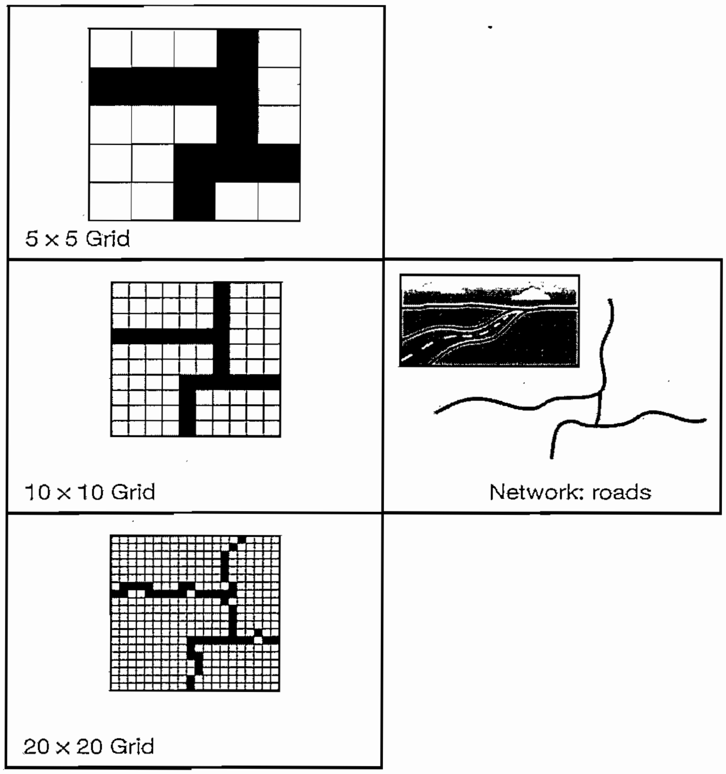
Figure 5.2. Different resolutions in raster data.



Source: Adapted from Heywood et al (2006:79)

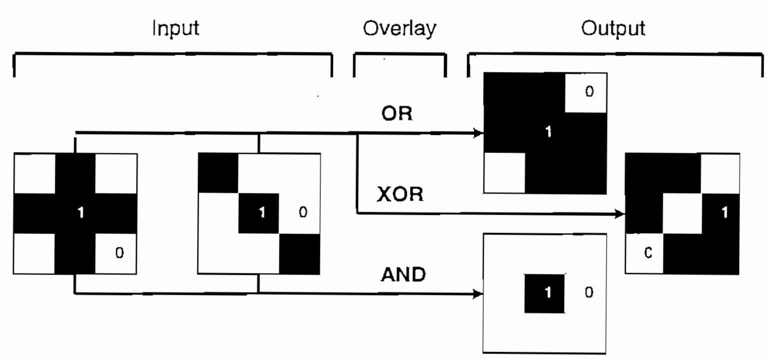
5.2.1. Boolean logic

Boolean logic combines different input layers by using the logical operators AND, OR or XOR (Chang, 2008:239-240) to determine the suitability of a given area for a certain land-use. These operators are based on Boolean algebra, and can only take on two states, which are zero or one (Malczewski, 1999:45). This clear-cut nature (one or zero) of the input data (Gupta *et al.*, 2008:1), leads to the limitation that the result can only be true or false (one for suitable and zero for unsuitable), leaving no room for prioritisation. According to Chang (2008:239), most conventional overlay methods are based on Boolean logic, which can be either vector or raster based (Price, 2008:223,527). Figure 5.3 illustrates how the three Boolean operators can be implemented in a raster based analysis. It will now be discussed accordingly.

When an overlay procedure uses the OR operator, it is referred to as a Union, due to the fact that all cells with a true value (one) will be preserved and included in the end result (Heywood *et al.*, 2006:187; Chang, 2008:239), as seen in Figure 5.3 When the XOR operator is used, all cells with a single true value will be preserved for the final result, while cells with a zero value or more than one true value will be excluded.

This type of overlay is referred to as a Difference (Chang, 2008:239). The final operator is the AND operator (the opposite of the XOR operator), which is almost certainly the most efficient overlay procedure of the three. The AND operator includes only the cells that have more than one true values, while all other cells are excluded from the analysis. This type of overlay is referred to as an Intersect overlay (Heywood *et al.,* 2006:187; Chang, 2008:239). Although Boolean logic overlays are uncomplicated and quite easy to use, it has one rather big limitation, which is that all input datasets are of equal importance when overlaid. This limitation contributes to the exacerbating issue of lack of prioritisation in Boolean overlay procedures.

Figure 5.3. Boolean logic overlay procedure



Source: Own creation

5.2.2. Weighted overlay

The second technique to be discussed is weighted overlay. Weighted overlay makes use of clear-cut datasets, much as Boolean logic does, but with the difference that criteria can vary between values such as one to nine, rather than just zero or one, thus allowing room for prioritisation in the final result. In weighted overlay these datasets are superimposed on to one another as to determine land suitability (Carr & Zwick, 2007:57). Weighted overlay further makes use of weights defined for a dataset to compute a result via the following equation:

$$[R] = \sum_{i=1}^{n} W_i [A]_i$$

where [R] is the result in the form of an output raster, W_i is the weight allocated to a given dataset, $[A]_i$ is the input raster dataset and n is the number of datasets used in the overlay. In Figure 5.4 there are two datasets, consisting of nine cells each, with varying values from one to nine in each dataset. These two datasets are overlaid at weights of importance of 50% each. This will mean that each cell will contribute 50% of its value to the final result, which is indicated in Figure 5.4b. The drawback to this approach is that the final result will be rounded to the nearest whole number, which does affect the accuracy to some degree. One of the main advantages of weighted overlay though, is that it allows the inclusion of expert knowledge in the model. Expert knowledge is obtained via consultation processes with experts and is included in the datasets as in Figure 5.5. Furthermore weighted overlay acknowledges the relative importance of each variable in the analysis with regard to its allocated weight, as well as the relative importance of the classes of each variable according to a given objective (Carvlaho, *et al.*, 2007:175).

Figure 5.4. Weighted overlay

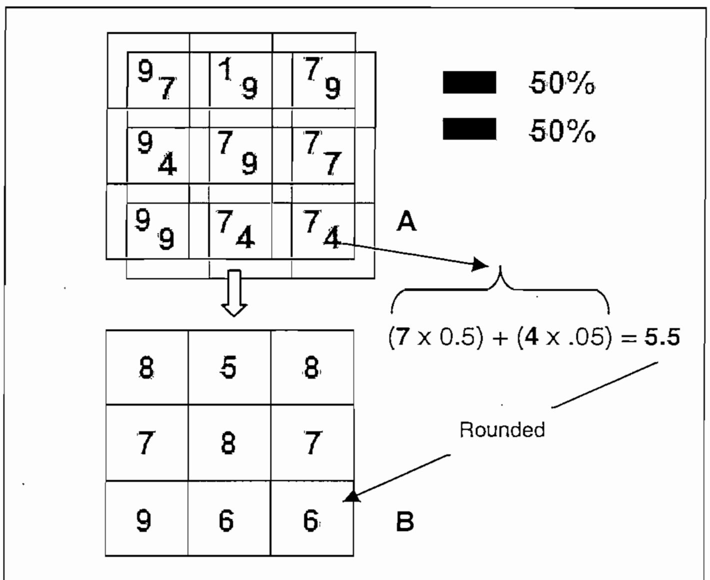


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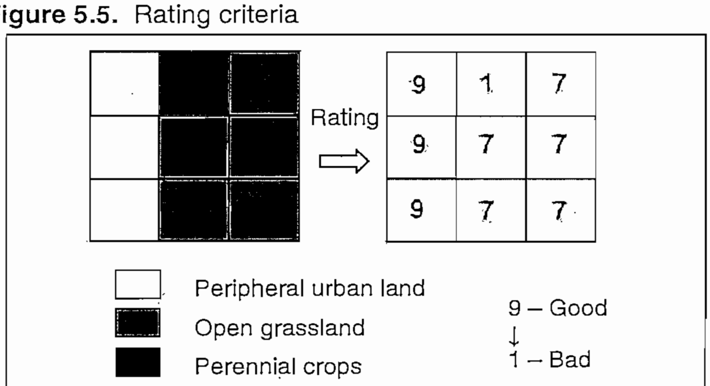
Figure 5.5. Rating criteria



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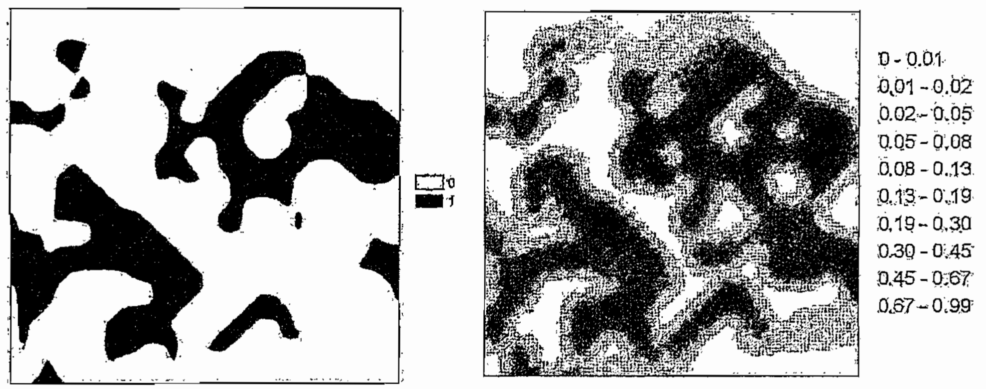
5.2.3. Fuzzy logic

The final technique to be discussed is fuzzy logic. Methods that are based on fuzzy sets are very similar to the methodology of weighted overlay, with the advantage that the combination rules are more flexible (Carvalho *et al.*, 2007:175). Instead of classifying datasets into exact classes, such as one or zero and then allocating weights, data are classified into a continuous scale using fuzzy sets. In fuzzy sets the notion that things must belong to a defined class doesn't apply any more (Gupta *et al.*, 2008:2). Data boundaries are no longer clean and crisp, but rather continuous, therefore dealing with uncertainties, making it possible to deal with sets that cannot be exactly defined (Longley *et al.*, 2005:133). Figure 5.6 illustrates the same phenomena in a Boolean classification and a fuzzy classification. The fuzzy set has the advantage of more accurately representing uncertainty, but poses other difficulties with regard to rating data via expert knowledge (Krivoruchko & Gotway Crawford, 2005:82; Carvalho *et al.*, 2007:172-182).

Figure 5.6. Boolean classification vs. fuzzy classification



Source: Krivoruchko & Gotway Crawford *(2005:85)*

Although these approaches vary in many ways, they fundamentally all rely on the comparison of different qualities of land for the assessment of its utilization.

5.3. Spatial modelling

Another element, crucial for revision when attempting to model urban growth, is that of spatial modelling. Spatial modeling has a wide range of applications, which differ quite a lot. The use of spatial modeling in planning orientated processes, allows planners and decision makers to experiment with different 'what if' scenarios (Longley *et al.,* 2005:366), which have the potential of broadening their idea of what may happen in their area of jurisdiction. Land-use change modelling is an example of such an approach, and is a highly dynamic and diverse field (Veldkamp & Lambin, 2001:4) that aim to predict how and where land-use changes might occur on the earth's surface. However, it is important to realize that no model of a physical system will ever flawlessly replicate reality (Longley *et al.*, 2005:366), but they can help to reduce the uncertainties about the future and potentially play a vital role in understanding the processes at work in urban development (Koomen *et al.*, 2007:2).

Numerous different land-use change modelling approaches have been developed in recent years (Serneels and Lambin, 2001:65), and various authors have discussed the principles of some of these models, as well as the future directions of research on the subject (Briassoulis, 2000; Agarwal *et al.*, 2002; Verburg *et al.*, 2004; Koomen *et al.*, 2007). But as Koomen *et al.* (2007:4) plainly states, almost all existing land-use change modelling and simulation approaches differ immensely in theoretical backgrounds, starting points and range of applications. Some of these models focus on urban growth changes, while others concentrate on deforestation or changes in pasture land. Although the principles of change modelling remain the same, these differences in application, clearly affect the inner workings of the models with regard to data inputs and variables of change.

Although many disparities exist, most of the modelling approaches reviewed in this study, such as Schneider and Pontius (2001), Serneels and Lambin (2001) and Wassenaar *et al.* (2007), to name but a few, also have similarity in that they utilize MCA to arrive at land-use change scenarios. These MCA approaches, used to assist the models in identifying and allocating potential land for future urban growth, are very similar to land-use suitability analysis, but are in many cases somewhat elementary.

Two very important characteristics of any spatial model are most certainly their spatial resolution and temporal resolution (Longley *et al.*, 2005:364-366; Koomen *et al.*, 2007:4). Spatial resolution (Figure 2.15) can be defined as the shortest distance over which change is recorded, while temporal resolution can be defined as the shortest time over which these change can be recorded (Longley *et al.*, 2005:366). The temporal resolution of any given model can place it into one of two different types of models, which is, static models, or dynamic models. A static model represents a system at a single point in time (Longley *et al.,* 2005:369), while in a dynamic model time is broken into a series of discrete steps, as to emulate real physical or social processes. Dynamic models are usually more complicated, due to the fact that a change factor has to be derived via mathematical procedures.

Of the models examined by the author, the Land-Use Conflict Identification Strategy (LUCIS) developed by Margaret Carr and Paul Zwick at the University of Florida's GeoPlan centre (Carr & Zwick, 2007), was selected for emphasis in this study.

5.4. The land-use conflict identification strategy (LUCIS)

As stated above, this study builds on ideas set forth by Carr & Zwick (2005, 2007) in their publications on LUCIS. The conceptual basis for LUCIS stems forth from Eugene P. Odum's classic "Strategy for ecosystem development" (1969), and was developed over a period of 10 years (Carr & Zwick, 2007:10).

Odum (1969:268) proposed four general land-use types (Table 5.1) which had to be maintained in a certain balance to ensure the efficient exchange of energy and materials between them. According to Odum (1969:2), this exchange would assure the mutual benefit between land-types. The four land-types were condensed into three categories for the LUCIS model (Table 5.1) and, according to Carr and Zwick (2007:10), this was done to simplify and enhance the comparison contrast between them. LUCIS utilizes the ArcGIS geoprocessing framework, and more specifically the weighted overlay tool, to analyse suitability of land for the utilization of different land-uses, and to inspect the land-use conflicts that may transpire. One of the most distinct characteristics of LUCIS is that it aims to identify potential land-use conflicts that may arise between urban, agricultural and conservation land-uses. After conflicts have been identified, LUCIS uses the land-use scenario results to allocate land for possible future urban growth. However, it does not specify where which type of urban development may occur.

Table 5.1. Odum's land types vs. LUCIS

Odums's land-use classifications		LUCIS land-use classifications	
Productive	Land that produce food	Agriculture	Land that produce food
Protective	Environmentally significant land	Conservation	Environmentally significant land
Compromise	A combination of productive and protective land		
Urban/Industrial	Built-up land	Urban	Built-up land
Source: Carr & Zwick (2007:11)			

Although the LUCIS model provides great insight into the analysis of land-use conflicts and suitability, it was decided not to use the existing model, but to rather adapt its concept to the South African situation. The main concepts that were used were the three main land-uses LUCIS identified, and the concept of identifying land-use conflicts before allocating land for certain uses.

5.5. Conclusion

From the reviewed literature it is clear that sustainable development is a very complex process, which possesses many challenges for planners, ecologists and governments alike. It is clear that current policy and legislation acknowledges sustainable development in and around cities via integrated development plans and spatial development frameworks, but it also true that it is not often achieved due to the lack of environmental priority. In the next two chapters an attempt will be made to develop an environmentally proactive approach toward spatial planning, by means of land-use suitability modelling. It is hoped that such an approach will better integrate environmental aspects into spatial plans, and provide an urban growth scenario that may assists governments in planning for sustainable town's and cities.

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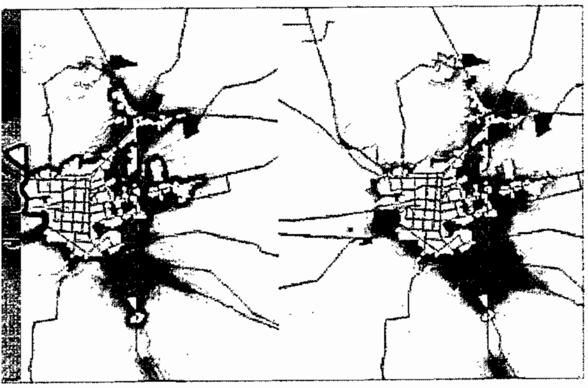
Chapter 6

Article 1



A GIS-AIDED APPROACH FOR VISUALISIN(URBAN GROWTH

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Requirements for Contributors:

The South African Geographical Journal

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THE SOUTH AFRICAN GEOGRAPHICAL JOURNAL

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Authors **must** adhere to the style as laid out here when preparing manuscripts for submission to the *Journal*. Failure to do so will delay refereeing and publication. Note: S.I. units must be used throughout; tables should be appended on separate sheets; a separate list of figure captions must precede the figures; and figures should be appended on separate sheets. Figures must be clear and legible for reproduction at single column width; computer graphics of high quality are only acceptable if the linework and lettering is comparable to conventional productions.

The first page of the typescript should contain the title of the paper and the name(s) and full address(es) of the author(s) in the style shown eg:

RAINFALL AND AGRICULTURE IN THE EASTERN CAPE, 1900-1994

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The second page must repeat the title of the paper, followed by an **abstract** of approximately 100-200 words in which the principal findings of the research should appear.

RAINFALL AND AGRICULTURE IN THE EASTERN CAPE, 1900-1994

Abstract

Climatological records show dramatic variability of rainfall in South Africa as a whole during the twentieth century. In theory, agricultural productivity should match these variations, a proposition that is tested with specific reference to crop yields in the eastern Cape. Strong associations do indeed exist between rainfall patterns and agricultural activity. Other changes, such as variations in farm size and farming technologies, appear to exert little effect.

The introduction (and subsequent text) must be typed in double-spacing. The introduction should not contain any subheadings. Leave a space between paragraphs. References to be cited as shown. List citations in ascending date order, and alphabetically within the same year. One or more publications by an author in the same year must be distinguished by appending letters a, b, c to the citations. Main headings should be in bold type.

Introduction

Throughout the history, human activity on the land has been governed by the availability of water. In all the available historical research, however, little attention has been given to quantitative estimates of the precise relationship between .... Furthermore, in South Africa, data are now available for the first time which allow detailed examination of the effect of changes in farming practices on crop yields. In their discussion the historical geography of agriculture, both Smith (1977) and Andrews (1978) show a keen awareness of the climatological constraints ...

Indent and punctuate particular points as shown, and designate alphabetically. The expression et al. is used when the work of more than two authors of one work is being cited. Use 'n.d.' to show that a work has no publishing date. Footnoted material to be marked with a superscript.

Rainfall Variability in South Africa

The principal rainfall variations in South Africa have been studied only recently (Reed, 1994). Preliminary screening of climatological data in Southern Africa by Deane (1980, 1983b) shows that numerous sites in the eastern Cape are subject to extreme variations (Fig. 1). Data on precipitation at selected mission stations in the nineteenth century show that:

(a) rainfall was heaviest in summer;

(b) rainfall exhibited great variations within decades1; and

(c) yields varied in concert with rainfall, with a lag of several months (Parker et al., n.d.).

These findings differ markedly from those reported in the study undertaken ten years ago during storm conditions (Brown, 1986), but approximate those made by Gill (1989).

Type subheadings in italics, aligned with the left margin of text. Avoid placing subheadings directly after a main heading. Refer to Figures and Tables as shown. Quantities less than ten should be expressed verbally, otherwise numerically.

Agriculture in the Eastern Cape Information pertaining to crop yields at 1 117 Cape farms disclose a strong geographical variation which is best understood in terms of two major regions. The Northern District The two most distinctive features of yields in this part of the country are ... (Figs 2 and 3). Altogether, ten per cent of the crop yields ... Precipitation at each of the stations shows a very pronounced diurnal variation (Table 1). Early morning and early evening patterns are similar excepting at land lying higher than 1 000 m, but at all other times ... The Southern District There are three notable components evident in the eastern zones of the study area (Deane, 1993a). As suggested elsewhere (Francis, 1977, 1978) these accord well with observations that ...

Direct quotations should be cited using double inverted commas and must contain a page(s) reference. Direct quotations which are more than three lines in length should be inset from both margins and typed in single spacing without inverted commas. Avoid ending a paragraph with a long direct quotation

Rainfall-Agriculture Relationships

In her landmark study, Tessig (1965, p.89) proposed that in dry areas especially, regional studies of arable and pastoral activity which failed to attend to climatic constraints were `a charade'. Others have made the same argument (Yelch, 1962; Bore, 1988), although Tedious (1977, pp. 286-287) has noted that:

> Direct links between climate and agriculture are never proven absolutely until the likely mediating affect of human agency can also be ascertained, and this is the true challenge facinginterdisciplinary research science today.

Taking these various opinions into account, and bearing in mind the well known warning given in 1902 by a Government minister, 2 who ...

Equations should be laid out as shown below:

The relationship between rainfall and production of maize may be expressed as follows:

$$P = 1{,}53R + 0{,}86T \qquad (1)$$

where P is production in tonnes ha-1, R is January-March rainfall in mm, and T is a measure of technology levels (Gill, 1989).

Do not introduce new material in the conclusion, and do not use point form in this section. Acknowledgements should follow immediately after the text.

Conclusion

In the eastern Cape during the twentieth century the nature of agricultural activity correlates extremely strongly with patterns of rainfall. On the one hand, ... On the other hand, ... Taking into account the major differences pinpointed in the Cape region, it is reasonable to suppose that...

Acknowledgements

Grateful thanks are due to M.J. Mouse who drew the maps, and to the Dollar Foundation which provided financial support for the research. The conclusions reached are solely those of the authors.

Footnotes should be kept to a minimum and must be collected numerically at the end of the typescript. Use small superscript digits to number the notes, and indent the text of the notes. Notes should be used for archival references and **not** as a device for elaborating the text or making asides.

Notes

[1] Central Archives Depot, Pretoria (CAD), Department of Agriculture (DA) 468 (12/345): Memoranda concerning production of grain in the colonies, March 1976 - December 1993

[2] CAD, DA 469 (47/521): Minister of Lands to Prime Minister, 12 October 1902

[3] Ibid., 9 December 1902.

The reference list

The reference list is **not** a bibliography and must contain only material which is cited in the text. **Complete information should be provided for every reference.** Organise the references alphabetically without numbering. The initials of authors and/or editors must appear behind the surname(s). Use the convention 'Anon.' to refer to unknown authors. Do not use 'et al.' in the reference list. Date of publication must appear as in the examples. Punctuate all material exactly as shown. The only words which are capitalised in the titles of journal articles are proper nouns. The titles of journals should **not** be abbreviated. Book and periodical titles should be italicised. Volume numbers must be included for journals, but part numbers should only be used if the pagination in successive issues is not sequential. The names of book publishers and city/town of publication must be included. Monographs and dissertations/theses to be cited in the style shown. Leave a blank line between references.

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Sample figure and table captions

These should be presented on separate sheets immediately preceding the figures.

Figure Captions

Figure 1: The spatial variation of rainfall off the east coast in the summer of 1949 (from Wetty, 1954).

Figure 2: The geography of crop yields.

Figure 3: Rainfall - crop yield relationships, 1944-1954.

Table Captions

Table 1: Farm size classification in the Cape, 1956-1978 (Source: South Africa (Republic), 1976).

A GIS-AIDED APPROACH FOR VISUALISING URBAN GROWTH

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Abstract

Uncontrolled urban sprawl is a phenomenon posing serious threats to global sustainability. Planners and governments need optimal decision support in deriving and implementing land-use policy and spatial development plans. One way to assist planners and governments in this crucial task, is by providing them with possible urban growth scenarios that may guide them in the development of relevant policies and spatial development plans. Despite considerable international research in urban growth modelling, it is poorly researched in South Africa. This study employs a multiple-criteria approach to analyse land-use conflicts as well as land-use suitability via a GIS-based weighted overlay procedure. These results of the empirical survey are ultimately used as inputs for urban growth modelling. A successful urban growth scenario was achieved for the city of Potchefstroom, South Africa. The study showed that a fairly uncomplicated approach to urban growth modelling is possible with readily available data in South Africa.

Introduction

Current realities such as population growth, urban development and agricultural expansion, threaten to ruin the intricate balance that exists between different land-use types in South Africa. Whenever these phenomena take effect, land-use change will be observed as a direct result of the interaction between human activity and the biophysical environment (Koomen *et al.*, 2007). The effects of these changes on their physical surroundings cannot be ignored (Lambin *et al.*, 2001) and must be examined.

Although numerous studies aimed at investigating these changes, by means of land-use suitability analysis (Joerin *et al.*, 2001; Carr & Zwick, 2005, 2007) and land-use change modelling (Schneider and Pontius, 2001; Serneels and Lambin, 2001; Ritsema van Eck and Koomen, 2008; Wassenaar *et al.*, 2007; Yang and Lo, 2003), have been conducted on a global scale, very few documented studies – with the exception of Van der Merwe's (1997) evaluation of the Cape Town region – have been conducted for the South African situation.

Furthermore, anecdotal evidence suggests that some planners and policy makers are sceptical towards the use of GIS (Geographical Information System) analysis in spatial planning and decision-making processes, even though the process of land-use planning has become ever more complex (Joerin *et al.*, 2001), with principles of sustainable development, such as nature conservation and economic development, opposing each other in the real world (Van Lier, 1998). This scepticism is often due to a misconception or lack of knowledge regarding GIS and its potential for planning purposes.

To address these issues, the testing of a straightforward and transparent multi-disciplined land-use suitability analysis approach, which will ultimately assist in urban growth modelling, should be investigated for South African context in this paper.

The rest of the paper is structured as follows: First, the applicable literature with regard to urban growth, spatial planning, land-use suitability modelling and spatial modelling are reviewed from which the goals are derived. This is followed by a description of the research methods and procedures that were used in this study. Finally the results are discussed, followed by recommendations for future research.

Urban growth

The concept of continued urban growth is not a new one; it is a given fact that the urban environment is constantly growing and changing and it has been so ever since the first human settlements. One of the main factors responsible for urban growth, and in effect urban sprawl, is the phenomenon of urbanization. According to the United Nations (2006), more than half the globe's population (roughly 3.3 billion) is currently living in urban settlements. It is further anticipated that this total may rise to 61% (roughly 4.9 billion) as early as 2030 (Cohen, 2006) and that most of this urban growth will be in developing countries and more specifically in Africa (United Nations, 2007).

The most likely reason for this is that most African countries are currently in an urban transition phase, as they are systematically changing from predominantly rural societies to predominantly urban societies (Fair, 1982; Friedmann & Wuff, 1975). This transition is mainly fuelled by the combination of population growth and economic change (United Nations, 2007). Although South Africa has an urbanization rate of 60%, which is much higher than the World and African average of respectively 50% and 39%, it is still expected to grow in urbanized population by approximately 1% per annum (United Nations, 2007). South Africa's higher than average urbanization rate can be ascribed to its dualistic nature of developed (European influence) and developing (African reality) components, which is evident in almost every town and city in South Africa.

With this knowledge at hand, governments and planners need to plan proactively and be prepared for the potential growth that may transpire. To achieve this it has to be understood that there are certain forces at work that influence urban morphology and consequently cause the spatial changes observed in towns and in cities. These forces include demand, supply, political policies, economic growth, social development of a society, economic growth of a society, and industrial development (Long *et al*, 2007). The fact that these forces differ in their effects from one urban area to the next, has the effect that it is very difficult to predict how urban areas will develop and land-uses might change. One way to assist policy makers and planners in this challenge of managing urban growth in South African towns and cities, is to attempt to predict these changes by means of modelling approaches such as land-use suitability modelling and land-use change modelling.

Spatial planning

Spatial planning in South Africa traditionally distinguished between 'forward planning' and 'development control' (RSA, 2001), which both relate to the application of spatial planning on local governmental levels (Drewes & Cilliers, 2004). Development control refers to the management of land by means of land-use management schemes, while forward planning refers to the strategic earmarking of land for future development (Drewes & Cilliers, 2004). The focus of this research falls on forward planning and more specifically on Spatial Development Frameworks (SDFs), which forms a core part of the Integrated Development Planning (IDP) process in South Africa.

IDPs are plans that aim to integrate sustainable development and management in municipalities (local and district) and are enforced by the Municipal Systems Act of 2000 (32/2000). In Section 26 of the Municipal Systems Act it is stated that an IDP must reflect its formal spatial development goals by means of an SDF (RSA, 2000). Spatial Development Frameworks are the main instruments by which future urban development and growth are managed within municipalities, and according to the White Paper on Spatial Planning and Land-use Management of 2001, must guide and inform on the following (RSA, 2001):

- Directions of growth;
- Major movement routes;
- Special development areas for targeted management to redress past imbalances;
- Conservation of both the built and natural environment;
- Areas in which particular types of land-use should be encouraged and others discouraged; and
- Areas in which the intensity of land development could be either increased or reduced.

The Municipal Systems Act (32/2000) further states that SDFs should indicate desired patterns of land-use within the municipality (RSA, 2000), while at the same time advancing integrated and sustainable development as described in the Development Facilitation Act of 1995 (67/1995). Although White Paper on Spatial Planning and Land-use Management of 2001 encourages the inclusion of a strategic environmental assessment as a component of an SDF (RSA, 2001) it is only voluntary and rarely included. This poses the problem that environmental aspects aren't always effectively integrated into SDFs, which, in effect, constrict the effectiveness of sustainable development.

Multi-criteria analysis and land-use suitability modelling

Roy (1996) defines multi-criteria analysis (MCA) as a decision aid and a mathematical tool allowing the evaluation of different alternatives or scenarios according to many criteria (often conflicting), in order to guide the decision maker towards the optimal choice. Spatial multi-criteria decision-making refers to the application of MCA in a spatial context, where the elements involved in the decision making process have specific spatial dimensions (Chakhar & Mousseau, 2007). Spatial MCA has the ability to improve and accelerate the decision making process (Cebellos-Silva & Lòpez-Blanco, 2003) while at the same time assimilating vast quantities of diverse data.

Land-use suitability modelling is an instance of spatial multi-criteria decision-making and, according to Carr and Zwick (2007), can be traced back as far as the late 19^{th} century. Since then references to approaches of land-use suitability modelling can be found in the works of authors such as McHarg (1969), Beek and Benemma (1972), Pathan *et al.* (1992) and more recently Joerin *et al.* (2001) and Carr & Zwick (2005, 2007). As observed from these works, it is clear that a variety of different methodologies exist for the spatial application of MCA in the form of suitability analysis. These methodologies include, among others, Boolean logic methods (Malczewski, 1999; Price, 2008) and weighted overlay methods (Esri, 2009; Carvalho *et al.*, 2007; Longley *et al.*, 2005).

Boolean logic combines different input layers by using the logical operators AND, OR or XOR (Chang, 2008) to determine the suitability of a given area for a certain land-use. Due to the clear-cut nature (one or zero) of the input data (Gupta *et al.*, 2008), the result can only be true or false (one for suitable and zero for unsuitable) and leave no room for prioritisation. Another limitation of Boolean logic is that all variables are of equal importance when overlaid, further exacerbating the issue of lack of prioritisation. Figure 1 illustrates the implementation of the three Boolean operators on two input datasets of equal importance.

Weighted overlay makes use of clear-cut datasets much as Boolean logic does, but with the difference that criteria can vary between values such as one to nine rather than just zero or one, thus allowing room for prioritisation in the final result. Weighted overlay further makes use of weights defined for a dataset to compute a result via the following equation:

$$[R] = \sum_{i=1}^{n} W_i [A]_i$$

where [R] is the result in the form of an output raster, W_i is the weight allocated to a given dataset, $[A]_i$ is an input raster dataset and n is the number of datasets used in the overlay. One of the main advantages of weighted overlay is that it allows the inclusion of expert knowledge in the model. Furthermore, weighted overlay acknowledges the relative importance of each variable in the analysis with regard to its allocated weight, as well as the relative importance of the classes of each variable according to a given objective (Carvlaho, *et al.*, 2007).

Although land-use suitability modelling approaches vary in many ways, they fundamentally all rely on the comparison of different qualities of land for the assessment of its utilization. For this study a weighted overlay procedure, utilizing clear-cut interval data, was decided upon as the appropriate approach due to its fairly uncomplicated and transparent nature, and because it allows the inclusion of expert knowledge and opinions with relative ease.

Spatial modelling

Another entity crucial for revision when attempting to model urban growth, is that of spatial modelling. The use of spatial modeling in planning orientated processes allows planners and decision makers to experiment with different 'what if' scenarios (Longley *et al.,* 2005), which has the potential of broadening their idea of what may happen in their area of jurisdiction. Land-use change modelling is an example of such an approach and is a highly dynamic and diverse field (Veldkamp & Lambin, 2001) that aim to predict how and where land-use changes might occur. However, it is important to realize that no model of a physical system will ever flawlessly replicate reality (Longley *et al.*, 2005). Even so, they can help to reduce the uncertainties about the future and potentially play a vital role in understanding the processes at work in urban development (Koomen *et al.*, 2007).

Numerous different land-use change modelling approaches have been developed in recent years (Serneels & Lambin, 2001) and various authors have discussed the principles of some of these models as well as the future directions of research on the subject (Agarwal *et al.*, 2002; Briassoulis, 2000; Koomen *et al.,* 2007; Verburg *et al.,* 2004). But as Koomen *et al.* (2007) plainly states, almost all existing land-use change modelling and simulation approaches differ immensely in theoretical backgrounds, starting points and range of applications.

Although many disparities exist, most of the modelling approaches, such as Schneider and Pontius (2001), Serneels and Lambin (2001), and Wassenaar *et al.* (2007), to name but a few, also have similarity in that they utilize MCA to arrive at land-use change scenarios. These MCA approaches used to assist the models in identifying and allocating potential land for future urban growth are very similar to land-use suitability analysis, but are in many cases somewhat elementary.

Two very important characteristics of any model of land-use change are most certainly their spatial resolution and temporal resolution (Koomen *et al.*, 2007; Longley *et al.*, 2005). Spatial resolution can be defined as the shortest distance over which change is recorded while temporal resolution can be defined as the shortest time over which these change can be recorded (Longley *et al.*, 2005). The temporal resolution of any given model can place it into one of two different types of models, which is, static models, or dynamic models. A static model represents a system at a single point in time (Longley *et al.,*

2005) while in a dynamic model time is broken into a series of discrete steps, as to emulate real physical or social processes.

Of the models examined by the authors, the Land-Use Conflict Identification Strategy (LUCIS) developed by Margaret Carr & Paul Zwick at the University of Florida's GeoPlan centre (Carr & Zwick, 2007), was selected for emphasis in this study. It was further decided to implement a model of a static nature, relying on an in-depth land-use suitability analysis as base for predicting urban growth.

The goal with this paper is to demonstrate the possible value of an uncomplicated, easy-to-use and transparent, GIS-based modelling approach in forward planning in South Africa by developing a, environmentally proactive, land-use specific, urban growth scenario for the city of Potchefstroom, North-West Province, South Africa. The approach relies on data that are readily available for most provinces in South Africa in order to predict a possible scenario for future urban growth.

The land-use conflict identification strategy (LUCIS)

As stated earlier, this study builds on ideas set forth by Carr and Zwick (2005, 2007) in their publications on LUCIS. The conceptual basis for LUCIS stems forth from Eugene P. Odum's classic "Strategy for ecosystem development" (1969). LUCIS utilizes the ArcGIS geoprocessing framework, and more specifically the weighted overlay tool, to analyse suitability of land for the utilization of different land-uses and to inspect the land-use conflicts that may transpire. One of the most distinct characteristics of LUCIS is that it aims to identify potential land-use conflicts that may arise between urban, agricultural and conservation land-uses. After conflicts have been identified, LUCIS uses the land-use scenario results to allocate land for possible future urban growth. However it does not specify where which type of urban development may occur. Although the LUCIS model provides great insight into the analysis of land-use conflicts and suitability it was decided not to use the existing model, but to rather adapt its concept to the South African situation.

Study area

The area of study is the city of Potchefstroom, which is situated in the Tlokwe Local Municipality, North-West Province, South Africa (Figure 2). Although the key focus falls on Potchefstroom and its immediate surroundings, the whole local municipality was selected for the study to ensure an adequate buffer zone. Potchefstroom has a population of approximately 140 000 people and a total built-up area of approximately 116 km^2. Over the last 15 years Potchefstroom had shown a total growth rate of roughly 15% (built-up area) and is still expanding at a constant rate.

Data management

While ongoing advances in computer technologies help modellers to develop faster and better models for spatial analysis (Koomen *et al.*, 2007), the input data remain the most important elements of any model. One of the biggest stumbling blocks in data reliability is the problem of scale. In many cases sufficient large-scale data (≤ 1:50 000) are not readily available. Due to a lack of large-scale biodiversity and agricultural data, a multi-scale approach had to be adopted for this study. For this reason the study was divided into two phases, using a scale of 1:250 000 (small scale) for the first phase of the study and a scale of 1:50 000 (large scale) for the second phase. All input datasets were projected to the Africa Albers Equal Area Conic system. The Hartebeesthoek 1994 datum was used and the central meridian, standard parallel one and standard parallel two were set to respectively 24° East, 30° South and 20° South.

Methodology

The following section explains the process and methodology used in the study.

Goals and objectives for modelling

The first step was to define goals and objectives for the study (Table 1). According to Zwick and Carr (2007) goals and objectives should be seen as a hierarchical set of statements that firstly aim to define what is to be accomplished (goal) and secondly, define how each intended accomplishment is to be achieved (objective). The three goals that were identified correspond with the three land-uses (urban, agriculture and conservation) that were originally suggested by Carr & Zwick (2005, 2007) for LUCIS.

Table 1: Goals and objectives as identified for the study.

Goals and Objectives			Explanation
Goal 1			**Identify land suitable for agricultural land-use**
	Objective 1.1		Identify land suitable for cropland land-use
		Sub-objective 1.1.1	*Determine potential yield in terms of CERES maize model*
		Sub-objective 1.1.2	*Identify existing cultivated land*
	Objective 1.2		Identify land suitable for grazing land-use
		Sub-objective 1.2.1	*Identify land grazing-capability*
Goal 2			**Identify land suitable for conservation land-use**
	Objective 2.1		Identify terrestrial critical biodiversity areas
		Sub-objective 2.1.1	*Identify critical biodiversity areas (CBA)*
		Sub-objective 2.1.2	*Identify ecological support areas (ESA)*
	Objective 2.2		Identify aquatic critical biodiversity areas
		Sub-objective 2.2.1	*Identify critical biodiversity areas*
		Sub-objective 2.2.2	*Identify ecological support areas*

Goal 3			**Identify land suitable for urban land-use**
	Objective 3.1		Identify land suitable for residential land-use
		Sub-objective 3.1.1	*Determine land physically suitable for residential land-use*
		Sub-objective 3.1.2	*Determine land economically suitable for residential land-use*
	Objective 3.2		Identify land suitable for commercial and business land-use
		Sub-objective 3.2.1	*Determine land physically suitable for residential land-use*
		Sub-objective 3.2.2	*Determine land economically suitable for residential land-use*
	Objective 3.3		Identify land suitable for industrial land-use
		Sub-objective 3.3.1	*Determine land physically suitable for industrial land-use*
		Sub-objective 3.3.2	*Determine land economically suitable for industrial land-use*
Goal 4			**Analyze possible conflicts between land-uses and derive a suitability layer**
Goal 5			**Develop an urban growth scenario for Potchefstroom in 2030**

The Process

Once the goals and objectives were finalized (Table 1) an analysis process could be obtained. As stated earlier, the study was divided into two phases (Figure 3). Phase One (Goals 1 – 4) is the small-scale (1:250 000) analysis aimed at identifying possible land-use conflicts and generating a land-use suitability scenario for the Tlokwe Local Municipal area, while Phase Two (Goal 5) is the larger-scale analysis aimed at predicting urban growth and developing a land-use allocation scenario for Potchefstroom in the year 2030. Figure 3 illustrates the two phases, which are discussed in more detail below.

Phase one

The purpose of Phase one was to analyze the suitability of land, within Tlokwe Local Municipality, for different land-uses (Table 1) and subsequently analyze the conflicts that could exist between them. This was done by means of the steps depicted in Figure 3. Although a great deal of detailed biodiversity and ecological data (Cilliers *et al.*, 1998,1999,2004; Cilliers & Bredenkamp, 1998,1999a,b,2000) exists for the study area this data was not always spatially explicit, ensuing that this analysis had to be conducted at a smaller scale. Phase one will now be discussed in relation to the steps indicated in Figure 3.

Step 1) Data gathering and reclassification

In order to successfully execute this analysis, adequate reliable data were required. These datasets further had to be reclassified to a generalized scale ranging from zero to five (zero being least suitable and five being most suitable) in order to overlay different types of datasets for analysis. In total, 38 different layers were reclassified for the analysis. All the data layers had to be in an integer format, to make them useable for the weighted overlay analysis. The processes of data gathering, reclassification and rating for the first three goals (Table 1) will subsequently be discussed.

For the agricultural suitability analysis (Goal 1), soil-depth, rainfall and clay content data were obtained from the Agricultural Research Council (2007). These layers were used as inputs for the CERES-Maize model (Du Toit, *et al.*, 1994), which were utilized to develop a potential yield layer for perennial crops, using maize as the indicative crop. In order to generalize the results from the maize model, maize yield averages for the Potchefstroom region as well as optimal slopes for perennial cropland were acquired from the Agricultural Research Council in Potchefstroom (Table 2), and were used to rate the study areas suitability for perennial cropland (Objective 1.1). To identify land with capabilities for intensive grazing (Schoeman *et al.*, 2002) the land capability layer which was also obtained from the Agricultural Research Council (2007) was utilized (Objective 1.2).

Table 2: Maize potential rankings for Potchefstroom

Slope (%)	Yield (tons)	Rating (1 – 5)
0 – 1	> 3	**5**
1 – 2	> 3	**4**
0 – 1	2 – 3	**4**
2 +	> 3	**3**
1 – 2	2 – 3	**3**
0 – 1	< 2	**3**
2 +	2 – 3	**2**
1 - 2	< 2	**2**
2 +	< 2	**1**

Table 3: CBA's and ESA's ratings

Type	Rating (1 – 5)
CBA 1	**5**
CBA 2	**4**
ESA	**3**

For the conservation suitability analysis (Goal 2), land-cover as well as biodiversity data were retrieved from the North West Department of Agriculture, Conservation and Environment (DACE). The North West land-cover dataset is the first of its kind for South Africa and was classified from SPOT#5 satellite imagery (DACE, 2008). The spatial resolution of the land-cover dataset is 10m x 10m and was used as one of the base layers for the North West Province Biodiversity Conservation Assessment (NWBCA), which identifies critical biodiversity areas (CBA's) and ecological support areas (ESA's) for the province (Objectives 2.1 and 2.2). CBA's are terrestrial and aquatic features that are critical for preserving biodiversity and supporting ecosystem functioning (SANBI, 2008), while ESA's are those areas that play an important role in the ecological functioning of CBA's (Desmet *et al.*, 2008). Both these area types were considered important for conservation and were rated accordingly. The ratings that were used (Table 3) were deduced from recommendations in the NWBCA expert report (Desmet *et al.*, 2008).

For the urban suitability analysis (Goal 3), all the required data weren't readily available and various procedures had to be conducted to derive the necessary datasets. New updated road layers were digitised from satellite imagery and a 15m x 15m Digital Elevation Model (DEM) was developed from 5m contours using the ArcGIS Topo-to-Raster tool. These layers, along with other existing ones, such as the land-cover dataset, were used as inputs for further analysis such as cost surface analysis, accessibility analysis, slope analysis and Euclidian distance analysis. Table 4 lists the 20 datasets that were derived as well as their applicability to the different urban objectives. The derived datasets were reclassified into clear-cut intervals to prepare them for the rating procedure.

Table 4: Urban input layers

Layer	Measurement	Application		
		Residential (Objective 3.3)	Commercial (Objective 3.2)	Industrial (Objective 3.3)
Proximity to substations	Meters	•		
Slope	Degrees	•	•	•
Proximity to high-voltage transmission lines	Meters	•	•	•
Proximity to prisons	Meters	•	•	
Proximity to railways	Meters	•	•	•
Proximity to landfills, cemetery and sewerage works	Meters	•	•	
Proximity to industrial areas	Meters	•	•	•
Proximity to existing residential areas	Meters	•		•
Proximity to existing commercial areas	Meters		•	
Accessibility to primary schools	Minutes	•		
Accessibility to secondary schools	Minutes	•		
Accessibility to basic health care	Minutes	•		
Proximity to distribution networks	Meters	•		
Proximity to bulk services	Meters	•	•	•
Proximity to activity corridors	Meters		•	
Proximity to activity spines	Meters		•	
Proximity to neighbourhood nodes	Meters		•	
Proximity to local nodes	Meters		•	
Proximity to public transport terminus	Meters		•	
Proximity to access routes	Meters			•

Step 2) Inputs from professionals for urban layers

After the datasets had been classified, values of importance (ratings for each interval) and weights had to be allocated. Due to a lack of expert reports on urban orientated data, the authors did not allocate any ratings or weights, but rather obtained the inputs of professional planners from various spheres of planning, for which an appropriate scientific acceptable method had to be used. The procedures that were considered were the straight ranking method, group-rating method, modified Delphi method, pair-wise comparison method and the Analytical Hierarchy Process (Carr and Zwick, 2007; Longley, *et al.*, 2005; Okoli & Pawlowski, 2004). An adapted Delphi method was selected due to its practicality, and a questionnaire was developed accordingly.

The questionnaire was presented to eight registered planners representative of local government, provincial government, private sector and academic institutions, who were asked to rate each interval in each dataset on a scale of zero to five (zero being least suitable and five being most suitable). Once the ratings were acquired, the mean as well as the standard deviation of each interval was calculated (233 ratings in total). If the standard deviation were found to be less than one, the mean of the ratings for the applicable interval could be accepted but, if not, it had to be reconsidered via further consultation. Of the 233 ratings, 16 had to be reconsidered while the rest could be used directly.

Step 3) Overlay analysis

Once the values of importance and weights had been finalized the weighted overlay analysis was conducted using the ArcGIS geoprocessing environment. The weighted overlay tool, found in the ArcGIS Spatial Analyst extension, was used to execute the process as illustrated in Figure 4. The first results were the residential preference, commercial preference, industrial preference, cropland potential, grazing potential, terrestrial biodiversity areas and aquatic biodiversity areas layers. From them the agricultural, biodiversity and urban preference layers, shown in Figures 5 – 7, were derived (Goals 1 – 3). The three resulting layers were then overlaid at equal weights of importance to derive the dataset that indicates areas of potential land-use conflicts (Figure 8).

Five levels of conflict could be observed in the potential conflict result. They were: *no conflict*; *major conflict*; *agriculture and urban conflict*; *agriculture and conservation conflict*; and finally *urban and conservation conflict*. *No conflict* is where one of the three land-uses clearly stand out in terms of suitability, thus the areas are optimally suited for that land-use and won't experience any serious conflicts. *Major conflict* on the other hand is where all three the land-uses share equal suitability importance. The remaining three criteria are where two of the three land-uses have conflict for highest suitability.

Step 4) Conflicts analysed

The final step of Phase one was to analyse the conflicts and develop a suitability map accordingly (Goal 4). This was done by means of normalizing the three input layers for each land-use (Figures 5 – 7) and comparing them in the areas of conflict. Every value in each of the original layers was divided through five (highest suitability), thus obtaining a result between zero and one. These values were further compared and cells with the highest values were allocated to the corresponding land-uses. In some cases however, conflicts could not be resolved and were indicated as such.

Figure 9 shows the final land-use suitability allocation layer, indicating each land-use as highly suitable as well as medium suitable. For urban land-use, a long-term possibility is also indicated, although conflict exists between one other land-use. For the areas of major conflict, further analysis will have to be done before deciding on its relevance for a particular land-use.

Phase two

Phase two entails the urban growth analysis at a scale of 1: 50 000 (Figure 3).

Step 1) Data

For the urban growth analysis, the results of the initial urban suitability analysis (Objectives 3.1 – 3.3) indicated in Figure 4, were used. The original results had a spatial resolution of 15m x 15m but were resampled for use in the land-use suitability analysis. Thus the datasets that were crucial for the urban growth analysis were the residential preference layer, industrial preference layer and the commercial preference layer prior to resampling.

Step 2) Mask creation

The next step was to select from the small scale suitability analysis results (Goal 4), the areas around Potchefstroom that had the highest suitability for urban development. This was done by means of isolating the areas indicated as *Urban High* on the small scale analysis (Figure 9) and further removing from those areas all land that were within a 100m buffer from wetlands and rivers (as an alternative to the delineation of a flood line) as well as land situated on dolomite. The result was a mask indicating the most suitable land for urban development in and around Potchefstroom.

Step 3) Future

Next, the most favourable land for residential, commercial/business and industrial use within the derived mask had to be indicated. This was done via overlaying each of the three urban datasets with the derived mask, and extracting the areas established as most suitable for each urban land-use or zoning. The result was a dataset indicating the most preferred land for each urban land-use within the masked area. The final step was to determine how much land would be needed for each urban land-use in 2030 and allocate it accordingly. For this, the Tlokwe local municipality land-use budget (DPLG, 2008) was consulted. Once the required areas were obtained, future urban land could be allocated. This was done by means of manually selecting the most preferred cells for each zoning and allocating it to that use until all the land indicated by the land-use budget for 2030 were allocated.

Step 4*) 2030 growth scenario*

The final result (Goal 5) is a layer indicating an urban growth scenario for the year 2030. The result indicates where residential, business/commercial as well as industrial growth may transpire.

Results

Some interesting results emerged from the analysis and will now be discussed. In the land-use suitability result (Figure 9) the areas to the West and South-West of the Highveld National Park are indicated as highly suitable for conservation use, thus implying that the Highveld National Park could be expanded. Furthermore, high urban suitability is indicated towards the East and North-Eastern parts of town where new urban development is currently most visible.

The urban growth analysis (Figure 10) also presented very interesting results. Due to the fact that the 2006 land-cover dataset were used to mask out developed land, a three year development gap existed that could potentially be indicated by the results as future growth. One very interesting growth possibility that was indicated was the Mooi River shopping mall, which was completed in 2008. The only area of the now existing mall, that is not indicated, is the buffer around the river; this is because the mall was built across the river. The results further indicate the development of a new industrial area alongside the N12 towards Johannesburg, in close proximity to where an actual industrial park is being envisaged.

The residential areas that are indicated for future development make sense because it indicates development in the Dassierand area (North-West of town) where medium-income development may transpire, especially for people moving from Ikageng (which is boxed in by the Highveld National Park) to the more formalized parts of town. This corresponds to the principle of integrated development (RSA, 2000) as stipulated in The Municipal Systems Act of 2000.

For higher income development, the plots to the East of town (where development is currently transpiring at a very high rate) are indicated. Commercial and business areas are indicated alongside the N12 and the Parys Drive, which are two major axis. A further interesting result is the indication of commercial and business land alongside the Mooi River almost exactly where the development of a new hotel is being envisaged.

Conclusions and future research priorities

The results proved to be accurate and clearly illustrate the value that urban growth modelling might have for strategic spatial planning in South Africa. Urban growth modelling can assist planners and policy makers in indicating directions of growth and optimizing land-use allocation, as required by the White Paper on Spatial Planning and Land-use Management of 2001. It was proved that a fairly uncomplicated and transparent approach could be used for urban growth modelling and scenario development with data that are readily available in South Africa. The pro-active nature of the approach, in that it considers critical biodiversity areas and prime agricultural land from the start, gives it the benefit that conflicts between different stakeholders may me minimised, since everyone was taken into consideration from the start. It is important, however, to realise that a scenario such as this is still only a scenario, and cannot be accepted as the whole truth, although, it does present some guidance on what may happen.

For future research, a few factors have to be carefully considered. Problems such as segregated cities with definite mixed densities and differences in transport systems exist in most towns and cities in South Africa. One of the future challenges will be to develop models that take these issues into consideration. The task should be undertaken to obtain large scale biodiversity and agricultural data for future studies. Furthermore, issues such as high, medium and low-density development have to be considered as output parameters in future research. Future studies that employ approaches such as Cellular Automata, Neural Networks and Dynamic Modelling should be conducted for the same area and compared as to find the best approach, or combination of approaches for optimal urban growth modelling in South Africa.

Acknowledgements

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Figure 1: Boolean logic overlay procedure

Figure 2: Potchefstroom locality map

Figure 3: The analysis procedure

Figure 4: Overlay analysis for determining land-use conflicts

Figures 5 – 7: Agriculture preference, conservation preference and urban preference

Figure 8: Land-use conflict scenario

Figure 9: Final land-use suitability and allocation

Figure 10: 2030 Urban growth scenario

Figure 1:

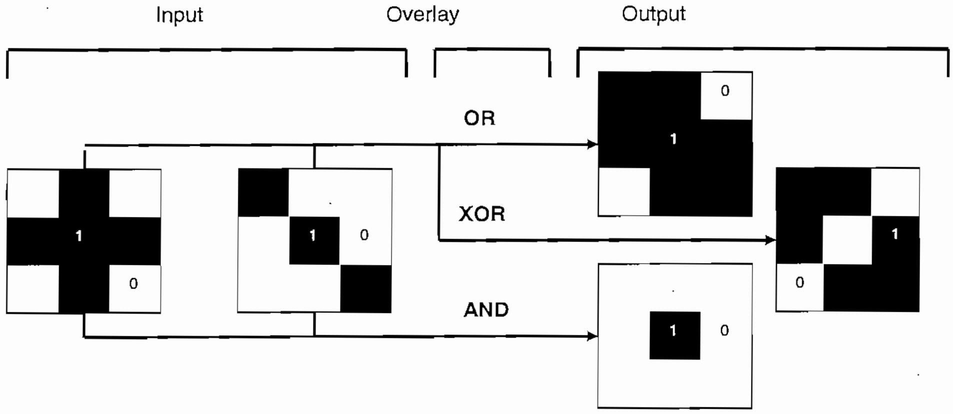


Figure 2:

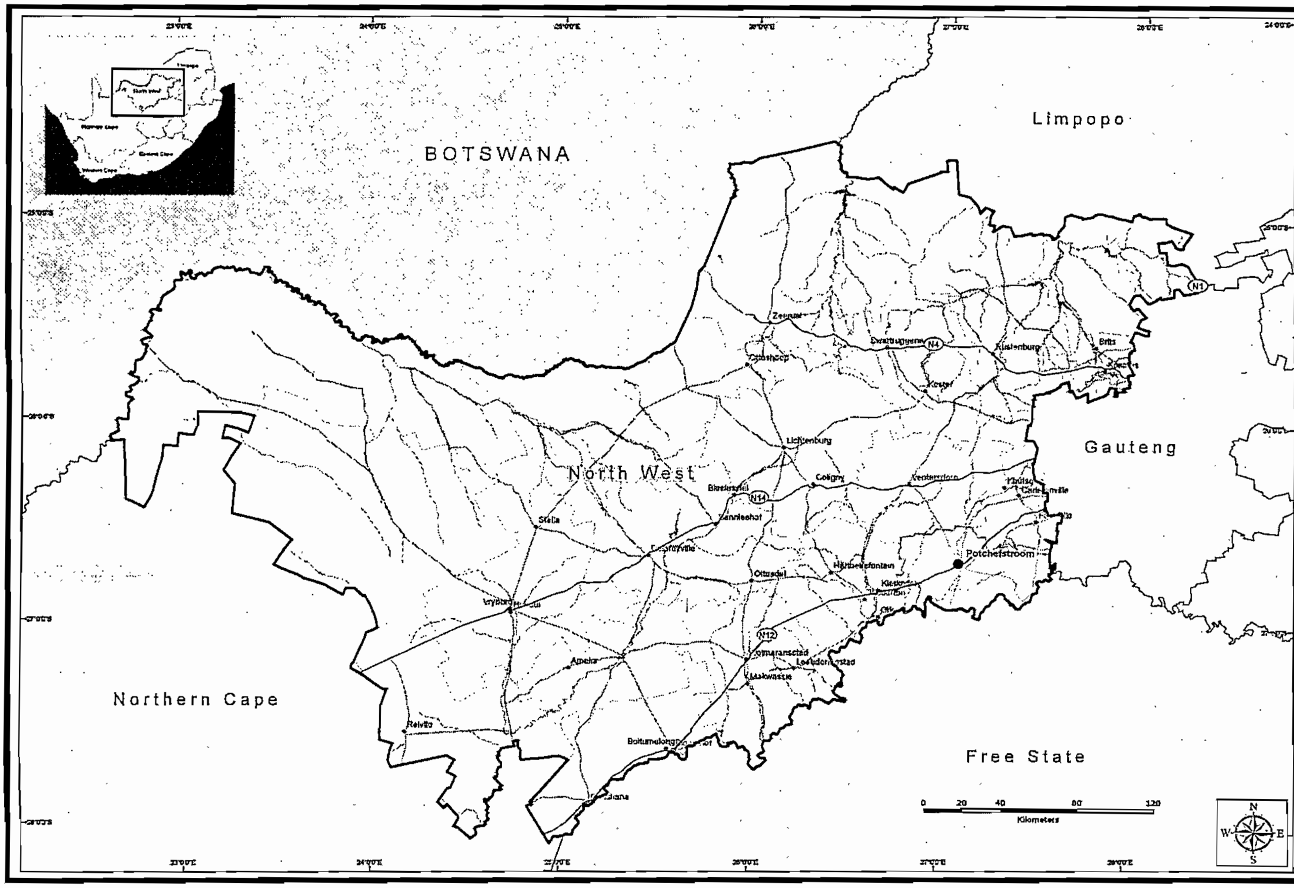

BOTSWANA
Limpopo
Gauteng
North West
Northern Cape
Free State
Lichtenburg
Potchefstroom
Klerksdorp
Vryburg
Zeerust
Rustenburg
Brits
Koster
Coligny
Ventersdorp
Ottosdal
Schweizer-Reneke
Wolmaransstad
Leeudoringstad
Makwassie
Bloemhof
Christiana
Delareyville
Stella
Reivilo
Amalia
Kilometers

Figure 3:

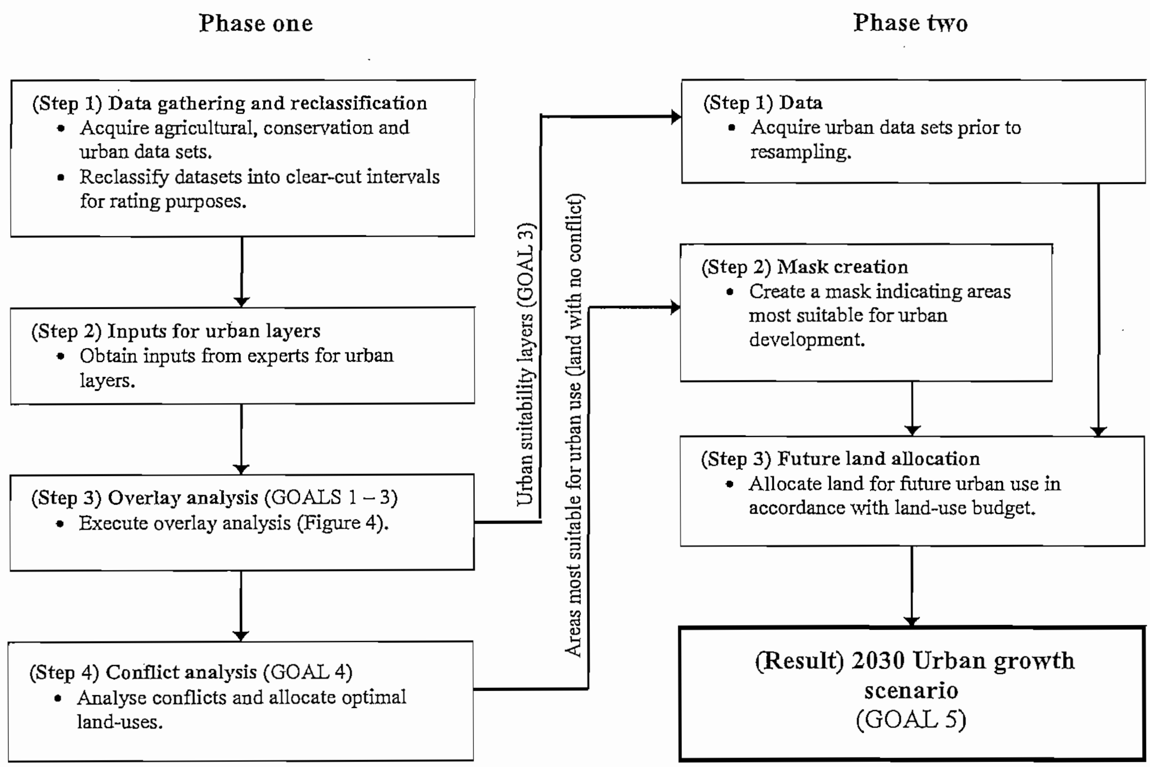
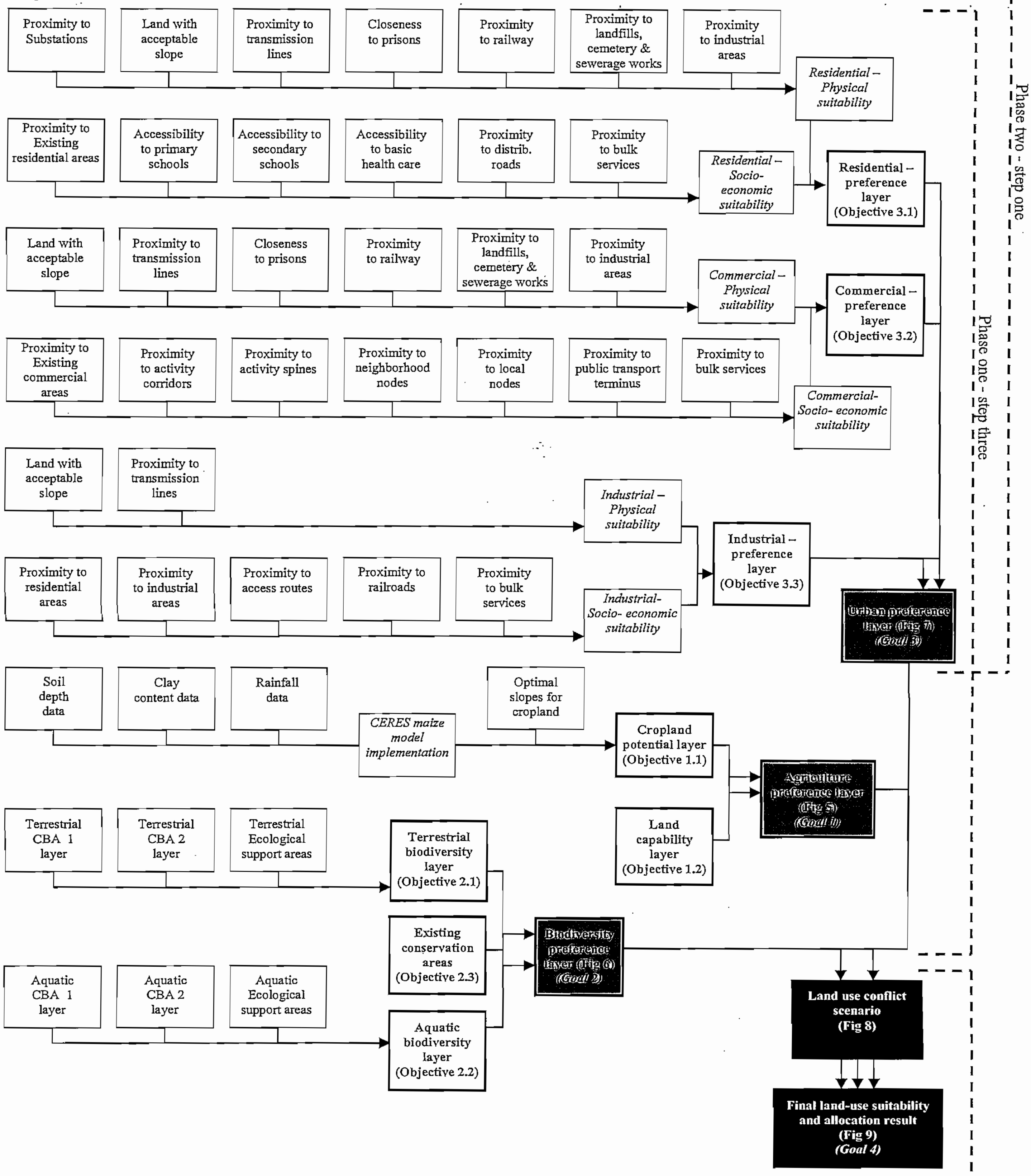
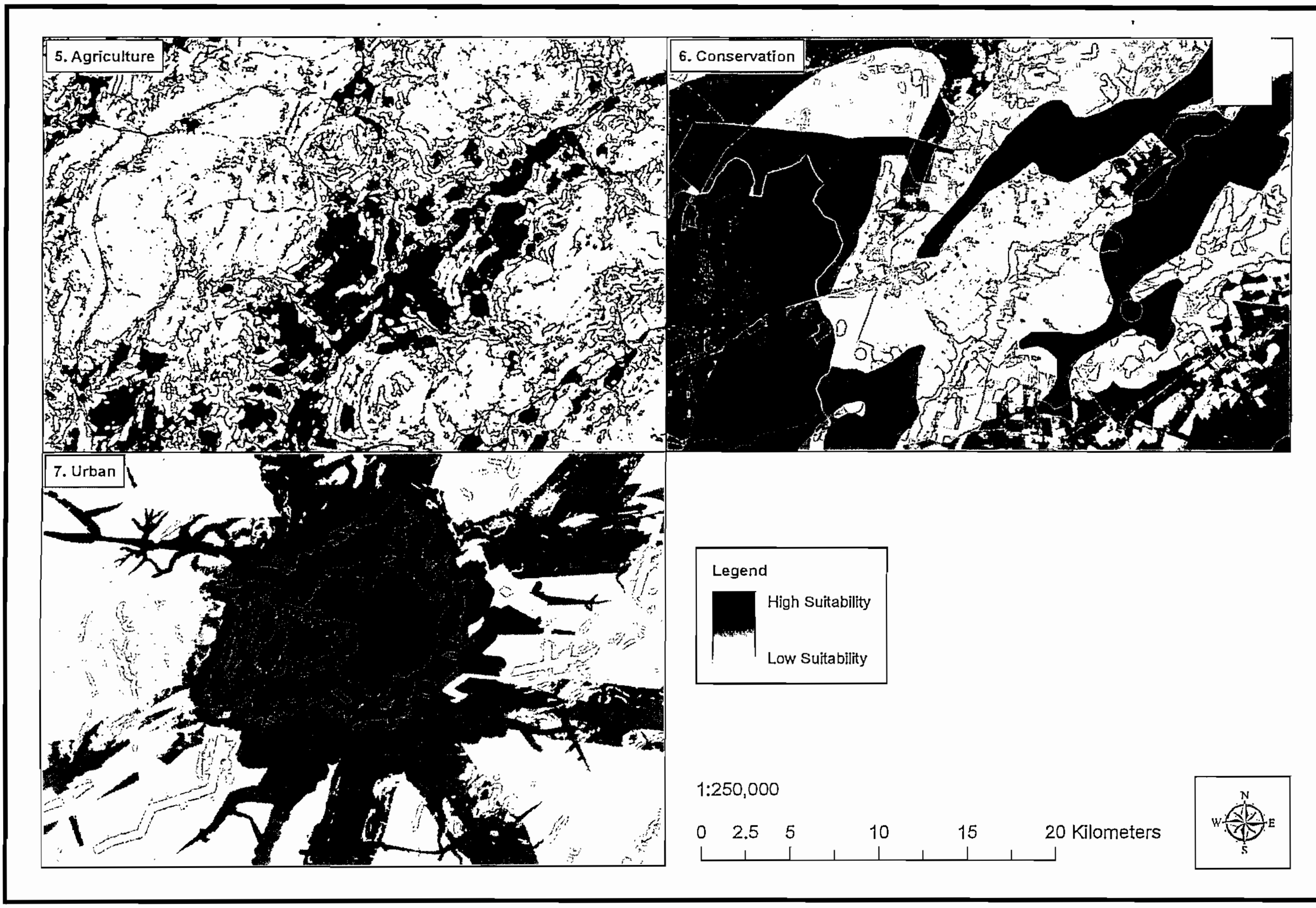

Phase one
Phase two
(Step 1) Data gathering and reclassification
• Acquire agricultural, conservation and urban data sets.
• Reclassify datasets into clear-cut intervals for rating purposes.
(Step 2) Inputs for urban layers
• Obtain inputs from experts for urban layers.
(Step 3) Overlay analysis (GOALS 1 – 3)
• Execute overlay analysis (Figure 4).
(Step 4) Conflict analysis (GOAL 4)
• Analyse conflicts and allocate optimal land-uses.
Urban suitability layers (GOAL 3)
Areas most suitable for urban use (land with no conflict)
(Step 1) Data
• Acquire urban data sets prior to resampling.
(Step 2) Mask creation
• Create a mask indicating areas most suitable for urban development.
(Step 3) Future land allocation
• Allocate land for future urban use in accordance with land-use budget.
(Result) 2030 Urban growth scenario
(GOAL 5)

Figure 4:


Proximity to Substations
Land with acceptable slope
Proximity to transmission lines
Closeness to prisons
Proximity to railway
Proximity to landfills, cemetery & sewerage works
Proximity to industrial areas
Residential – Physical suitability
Proximity to Existing residential areas
Accessibility to primary schools
Accessibility to secondary schools
Accessibility to basic health care
Proximity to distrib. roads
Proximity to bulk services
Residential – Socio-economic suitability
Residential – preference layer (Objective 3.1)
Land with acceptable slope
Proximity to transmission lines
Closeness to prisons
Proximity to railway
Proximity to landfills, cemetery & sewerage works
Proximity to industrial areas
Commercial – Physical suitability
Commercial – preference layer (Objective 3.2)
Proximity to Existing commercial areas
Proximity to activity corridors
Proximity to activity spines
Proximity to neighborhood nodes
Proximity to local nodes
Proximity to public transport terminus
Proximity to bulk services
Commercial- Socio- economic suitability
Land with acceptable slope
Proximity to transmission lines
Industrial – Physical suitability
Industrial – preference layer (Objective 3.3)
Proximity to residential areas
Proximity to industrial areas
Proximity to access routes
Proximity to railroads
Proximity to bulk services
Industrial- Socio- economic suitability
Urban preference layer (Fig 7) (Goal 3)
Phase two - step one
Phase one - step three
Soil depth data
Clay content data
Rainfall data
CERES maize model implementation
Optimal slopes for cropland
Cropland potential layer (Objective 1.1)
Land capability layer (Objective 1.2)
Agriculture preference layer (Fig 5) (Goal 1)
Terrestrial CBA 1 layer
Terrestrial CBA 2 layer
Terrestrial Ecological support areas
Terrestrial biodiversity layer (Objective 2.1)
Existing conservation areas (Objective 2.3)
Biodiversity preference layer (Fig 6) (Goal 2)
Aquatic CBA 1 layer
Aquatic CBA 2 layer
Aquatic Ecological support areas
Aquatic biodiversity layer (Objective 2.2)
Land use conflict scenario (Fig 8)
Final land-use suitability and allocation result (Fig 9) (Goal 4)


5. Agriculture
6. Conservation
7. Urban
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Low Suitability
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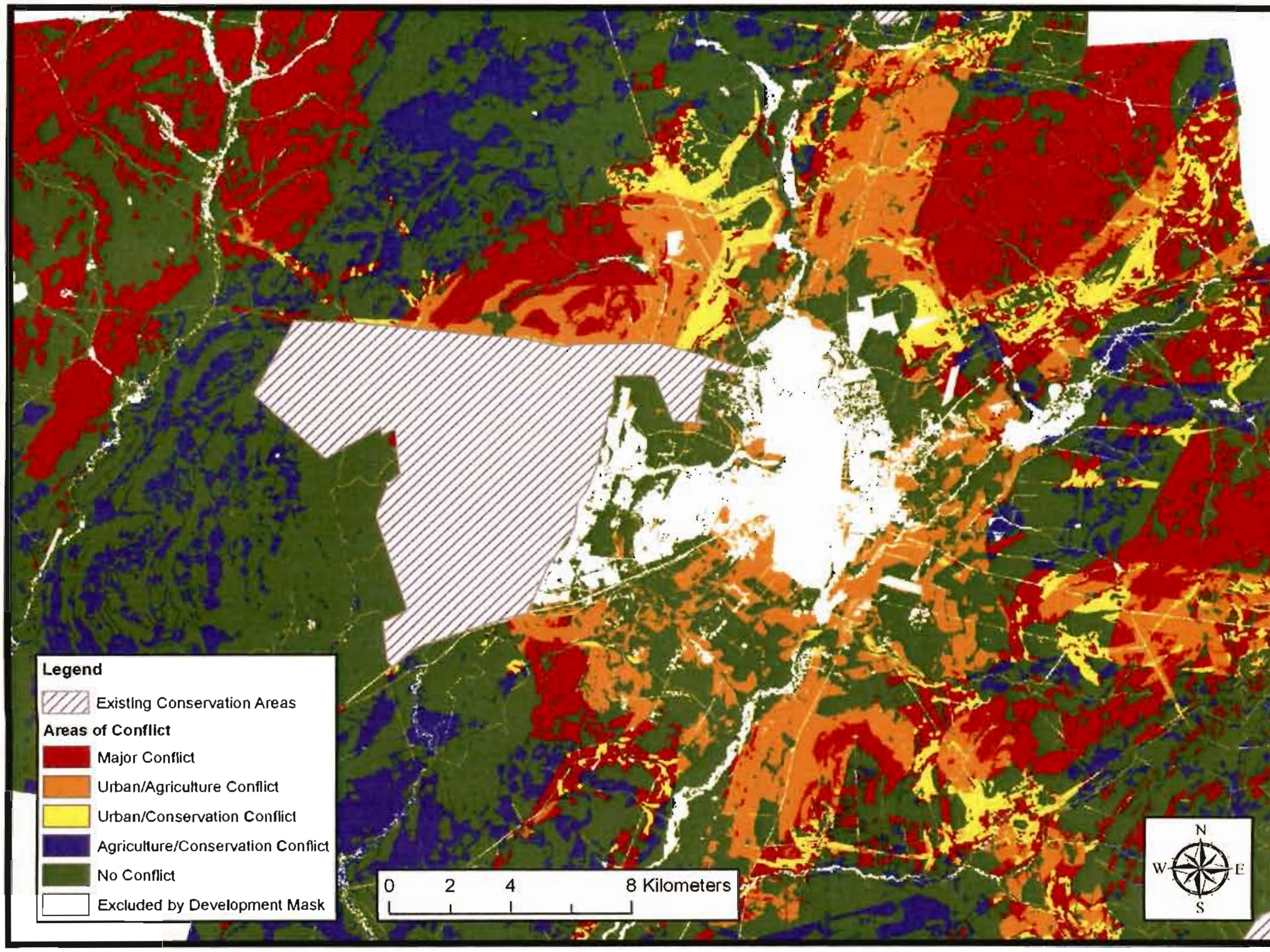
Figure 8:


Legend
Existing Conservation Areas
Areas of Conflict
Major Conflict
Urban/Agriculture Conflict
Urban/Conservation Conflict
Agriculture/Conservation Conflict
No Conflict
Excluded by Development Mask
0 2 4 8 Kilometers
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E
S

Figure 9:

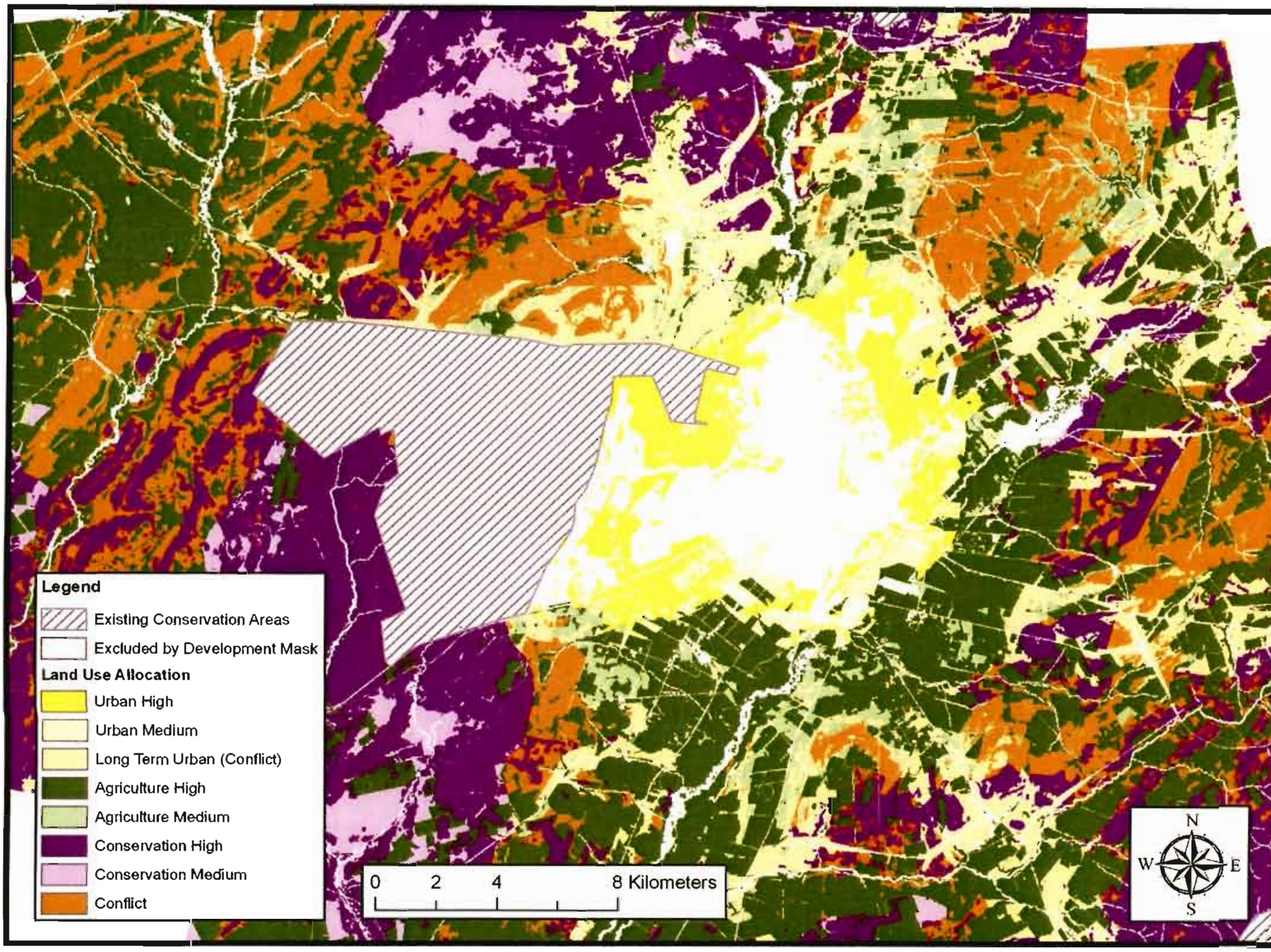
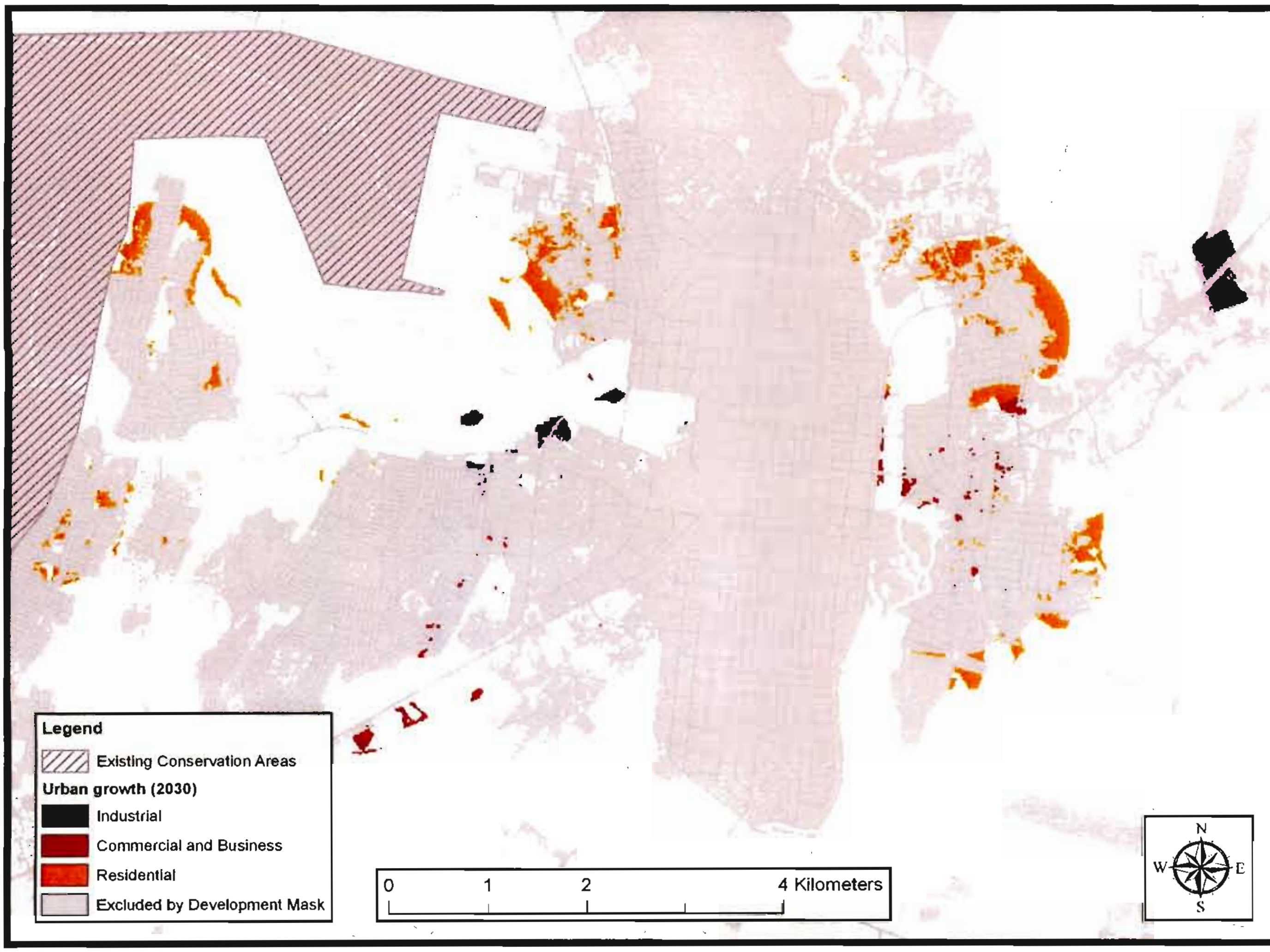

Legend
Existing Conservation Areas
Excluded by Development Mask
Land Use Allocation
Urban High
Urban Medium
Long Term Urban (Conflict)
Agriculture High
Agriculture Medium
Conservation High
Conservation Medium
Conflict
0 2 4 8 Kilometers
N
W
E
S

Figure 10:


Legend
Existing Conservation Areas
Urban growth (2030)
Industrial
Commercial and Business
Residential
Excluded by Development Mask
0
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4 Kilometers
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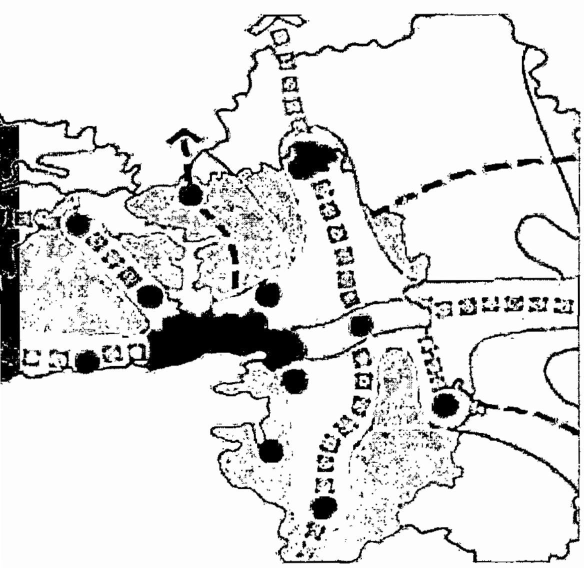
Chapter 7

Article 2



LAND-USE SUITABILITY MODELLING AS A FRAMEWORK FOR SPATIAL PLANNING IN TLOKWE LOCAL MUNICIPALITY, NORTH-WEST PROVINCE, SOUTH AFRICA

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LAND-USE SUITABILITY MODELLING AS A FRAMEWORK FOR SPATIAL PLANNING IN TLOKWE LOCAL MUNICIPALITY, NORTH-WEST, SOUTH AFRICA

LAND-USE SUITABILITY MODELLING AS A FRAMEWORK FOR SPATIAL PLANNING IN TLOKWE LOCAL MUNICIPALITY, NORTH-WEST PROVINCE, SOUTH AFRICA

Abstract

In recent years, issues related to the state of the natural environment have begun to play an increasingly more important role in the global arena of politics and civil society. It is crucial that these issues be integrated into planning processes and development frameworks in such a way that the protection of the natural environment and the promotion of sustainable development goals can be achieved. This article explores the use of a GIS-based spatial modelling method in achieving the above. The success of such an approach could ensure the effective incorporation of environmental data into spatial planning, and more specifically Spatial Development Frameworks (SDFs), which is not always the case in South Africa. The study found that such an approach could be used with great success and could assist planners and policy makers in the challenge of steering land-use management in a sustainable manner. The study showed that a pro-active, interdisciplinary approach to land-use management is possible on a strategic level in South African municipalities.

Keywords: Spatial planning; geographical information system (GIS); land-use suitability modelling; urban growth; Spatial Development Framework (SDF); Potchefstroom.

1. Introduction

Migration in South Africa historically consisted of two main components, i.e. a natural process based on socio-economic mobility of the white population group, and secondly a regulated process of migration of the black population group (Mears, 2004:16). The latter of these processes were enforced by explicit, racially motivated planning frameworks of the Apartheid era government (Williams, 2000:167), which forced non-white population groups to live in less formalized neighbourhoods, separated from white neighbourhoods. Since the abolishment of Apartheid era planning practices in the 1990s (Drewes & Cilliers, 2004:15), rural-urban migration (urbanization) and, consequently, urban development started to increase all around South Africa.

In developed countries, on the other hand, one of the phenomenons observed to coincide with a mature level of urbanization was that of urban sprawl. Urban sprawl is a trend set into motion by a variety of rationales, such as the desire to live closer to nature, the freedom to move and the fear of violence in urban areas (Berry, 1976:19-21). The most accurate description of the situation in South Africa however, can be deduced from the scenario sketched by Geyer and Kontuly (1993). Geyer and Kontuly (1993:167-172) states that privileged people tend to move away from the densely populated city, towards the open outskirts of town, a process they refer to as environmentalism. Poorer people moving to the city in search of jobs and new opportunities in turn, fill the places of the privileged in a process they call productionism.

These two processes are extremely relevant to the South African situation, and form a cycle that eventually leads to decentralization, deconcentration and ultimately urban sprawl.

The term urban sprawl has been used to describe a broad variety of undesirable aspects of urban growth (Miceli & Sirmans, 2007:4), but to date various explanations exist on the reasons why urban sprawl occurs. Various authors (Henderson, 1985:180; Wu & Plantinga, 2003:289; Nechyba & Walsh, 2004:179; Wu, 2006:528; Miceli & Sirmans, 2007:5; Martinuzzi *et al.,* 2007:196) have attempted to explain why urban sprawl transpires, but most of these explanations differ to a great extent. Henderson (1985:180) for instance argues that urban sprawl occur because people tend to move outward in search of lower density areas, while Martinuzzi *et al.* (2007:296) states that the reasons for urban sprawl can't be generalized and that it occurs for different reasons in different cities. Miceli and Sirmans (2007:5) again, states that urban sprawl transpires because people with land on the periphery tend to leave it undeveloped, in the hope that its value may rise, which in due course forces development to continue in a fragmented manner behind that land.

Whatever the case may be, the fact remains that urban areas will continue to develop, and given the structure of South African cities, this development will almost certainly be horizontal and outward towards the periphery of the city, which will in turn present a threat to the ecology of natural landscapes and sustainable development (Sudhira *et al.*, 2004:33). There is certainly no way to prevent urban development from taking place, the challenge however, will be to manage this development and the spatial implications thereof in a sustainable manner.

2. Sustainable development

To ensure the protection of biodiversity and to prevent environmental degradation around urban areas, ecological information needs to be considered in spatial planning processes (Niemelä, 1999a:120). To achieve this, is by no means an easy task and calls for interdisciplinary collaboration between disciplines, such as spatial planning and urban ecology.

Urban ecology broadly refers to ecological research conducted in built-up areas (Niemelä, 1999:58), aimed at revealing how human and ecological processes can coexist in a sustainable manner (Marzluff *et al.*, 2008:vii). This utilisation of ecological data to achieve sustainable development, is directly linked to spatial planning, which can assist in implementing sustainable development in plans and policies.

The term 'sustainable development' was first coined in the *World Conservation Strategy* compiled by the International Union for Conservation of Nature and Natural Resources in 1980 (Dresner, 2002:30), and in 1987 became a very important issue in international politics when it was used in the United Nations initiated Brundtland Report, to express a new approach to managing the environment and development

(WCED, 1987:48-57; Deelstra, 1998:17). This new approach proposed that governments should focus on promoting socio-economic development, while limiting the negative impact of development on the environment (WCED, 1984:48-57). This led to the realization that man had the capability to save the fragile and often deteriorating relationship between himself and the biosphere via sustainable development (Brundtland, 2007:12), which in turn led to the first Earth Summit held at Rio de Jeinero, Brazil in 1992.

The Earth Summit focused on the emerging environmental and development crisis at the time (Dresner, 2002:38) and led to the adoption of Agenda 21, which was intended as a global policy framework aimed at guiding governments around the world in the implementation of sustainable development (Schwabe, 2002:13). Agenda 21 aimed to achieve the above by means of a set of developmental and environmental objectives (UN, 1992:3) that aimed to achieve the successful and effective integration of environmental and developmental issues. Agenda 21 acknowledged the importance of local governments in its successful implementation (Marx, 2003:12-15; Urquhart & Atkinson, 2000:13), and stated that local governments should implement Agenda 21 on a local scale via a Local Agenda 21 that reflects their unique circumstances and requirements (UN, 1992:285-286). The Local Agenda 21 process was later followed up by a Local Action 21 process (Marx, 2003:15), which was aimed at assisting local governments in implementing their Local Agenda 21s. One of the main goals of Local Action 21 was to advance the establishment of sustainable communities and cities (ICLEI, 2002:1-9); an idea which was further encouraged by the Habitat Agenda.

The Habitat Agenda states that sustainable human settlements will only be achieved if towns and cities can become economically buoyant, socially vibrant and environmentally sound, with full respect for cultural, religious and natural heritage (UNCHS, 1996:43). The three equally important elements of sustainable human settlements are then, social development, improvement of urban economies and sustainable land-use or environmental sustainability (UNCHS, 1996:48-69). The Habitat Agenda calls for the establishment of legal frameworks to facilitate the implementation of sustainable development plans, and to assure the protection of biodiversity (UNCHS, 1996:46-62). To reach the goal of sustainable human settlements, it is important that the three mentioned elements be treated at equal importance.

The importance of integrated environmental management, by means of integrating social and environmental data, has to be realized. In other words, planners, ecologists and economists should work together in an integrated manner to reach the different sustainable development goals, such as economic development and environmental protection. By integrating urban ecology into spatial planning in a multidisciplinary manner, sustainable development, with regard to the protection of the natural landscapes can successfully be achieved.

3. Spatial planning in South Africa

South Africa has acknowledged the concept of sustainable development in various legal and policy documents (Drewes & Cilliers, 2004:16), and has legally adopted an integrated approach towards sustainable development. The Integrated Development Planning (IDP) process is an example of such an approach and aims to strategically align sustainable development as an element of integrated planning on all spheres of government (Retief, 2007:11; Pekelharing, 2008:55).

Although IDP is still a relatively new planning requirement, the success off its application can be observed all around South Africa (Binns & Nel, 2002:931). An IDP provides local governments with a holistic, integrated and participatory strategic plan, to guide them in their development orientated tasks in their areas of jurisdiction (Pekelharing, 2008:54), and has been a legal requirement for local governments ever since November 1996 (DPLG, 2000:3), when it was enforced by the Second Amended Local Government Transition Act of 1996 (RSA, 1996:15). The IDP aims to assist in the management and allocation of scarce resources between different sectors and geographical areas in a sustainable manner (DPLG, 2000:14) and is now enforced by the Municipal Systems Act of 2000 (RSA, 2000).

The Spatial Development Framework (SDF) forms a core component of the IDP and provides development direction, co-ordinates initiatives and identifies key development areas within a local or district municipality (Maxim, 2008:6). According to Retief (2007:11), SDFs provide a link between IDP and land-use management, and if integrated with environmental considerations, could potentially make a significant contribution to sustainable development. Because this study deals with spatial planning and development, the focus will fall on SDFs in particular. Figure 1 indicates the different legislation and policies relevant to IDPs and SDFs while Table 1 summarizes the relevance of these different legislation and policies to SDFs.

Table 1. Relevance of policy and legislation to SDFs

Relevant Policy / Legislation	Relevance to SDFs
The Constitution of the Republic of South Africa [109/1996]	All laws are subject to the constitution. All legislation and policy with regard to planning have to concur with its principles. The constitution promotes sustainable development and recognizes the important role that local governments have to play in development planning (IDP/SDF).
Development Facilitation Act [97/1995]	IDPs and SDFs must give effect to the principles contained in Chapter 1 of the act.
The Second Amended Local Government Transition Act [97/1996]	First legislation to enforce the development of IDPs. It further describes the role that the IDP should play in municipal planning processes.

National Environmental Management Act [107/1998]	States that municipalities should adhere to its principles when developing policies and plans, such as IDPs and SDFs. NEMA calls for the promotion of sustainable development when planning or developing.
The Municipal Systems Act [32/2000]	Provides municipalities with core principles, mechanisms and processes to assist them in planning processes. It enforces the implementation of IDPs through Section 25 and discusses the core requirements of IDPs. It enforces the development of SDFs and requires planning to be sustainable development orientated.
White Paper on Spatial Planning and Land Use Management [2001]	States that a SDF should operate as an indicative plan within the IDP. Identifies the four main components of a SDF and discusses the primary purpose and goals of an SDF.
Land Use Management Bill [2006]	Calls for intergovernmental support in the development of SDFs, as well as the alignment of SDFs with other strategic plans and policies.
Land Use Management Bill [2008]	Calls for the alignment of SDFs with other strategic plans and policies.
The White Paper on Local Government [1998]	Elaborates on the roles that local governments have to play in development and planning, and in effect the IDP process. It provides guidelines with regard to the preparation of IDPs.
The Local Government: Municipal Planning and Performance Regulations [2001]	Provides details on IDPs as well as a comprehensive explanation on the requirements of SDFs. It calls for the inclusion of a SEA on the impact of the SDF

Source: Own creation

Of the policy and legislation mentioned in Figure 1 and Table 1, the most relevant ones are, the Municipal Systems Act of 2000, the White Paper on Spatial Planning and Land Use Management of 2001, and the Local Government: Municipal Planning and Performance Regulations of 2001. In Section 26(e) of The Municipal Systems Act, requirements are set for the development of a SDF (RSA, 2000:20). It is also stated that these development plans should be compliant with the Constitution and the Development Facilitation Act principles, i.e. sustainable development. Although the Municipal Systems Act does not describe the detail of an SDF, it does stress the importance of SDFs in spatial planning (RSA, 2000:23). The detail requirements of SDFs are communicated via the Local Government Municipal Planning and Performance Regulations of 2001, which provides regulations in the context of the Municipal Systems Act. The Regulations state that a SDF should:

- Contain strategies and policies which indicate desired patterns of land-use within the municipality;

- Provide strategic guidance in respect of the location and nature of development within the municipality;
- Should contain a strategic assessment of the environmental impact of the SDF; and
- Provide a visual representation of the desired spatial form of the municipality, which indicates where investment should be made, where intervention is required, and indicate desired or undesired utilization of space in a particular area.

The White Paper on Spatial Planning and Land-use Management states that the primary purpose of a SDF is to present local governments with spatial development goals that will guide and inform them on decisions relating to land-use (RSA, 2001:19). It further states that a SDF should guide and inform on the following issues (RSA, 2001:19):

- Directions of growth;
- Conservation of the built and natural environment;
- Areas where particular types of land-use should be encouraged and others discouraged (this means to say that land-uses should be encouraged or discouraged in terms of their suitability in a particular area); and
- Areas where the intensities of land-uses should be increased or reduced.

According to the White Paper on Spatial Planning, an SDF should be seen as a strategic and flexible forward planning tool, assisting local governments in decisions on land development.

Although the concepts of conservation and the protection of the environment are principles that should be contained in an SDF, the reality is that issues such as conservation, biodiversity and rehabilitation are not the main concerns in developing countries, but rather issues such as eradication of poverty, redistribution of wealth, equity and wealth creation (Hindson, 1994:3-7). To address this issue, Drewes and Cilliers (2004:27) propose an integrated land-use management system that would guide decision-making, and also show areas suitable for specific land-uses while excluding others. This study proposes a GIS-based, spatial modelling approach to determine where the most suitable areas will be for urban development (considering environmental and agricultural factors) and accordingly assist in the delineation of a new urban edge. The study aims to identify desired directions of growth, provide a representation of the desired spatial form of Potchefstroom and identify priority development and conservation areas.

4. Study area

Potchefstroom is situated in the Tlokwe Local Municipality, North-West Province, South Africa on both sides of the N12 Treasure Corridor (Figure 2). Potchefstroom serves as a primary regional node (Maxim, 2008:49), and has a population of approximately 140,000 people, with a stable population growth of approximately 1% - 1.3% per annum. The total built-up area of the city is approximately 116km^2, and has shown an overall growth rate of about 15% over the last 15 years. Potchefstroom has shown a positive economic growth rate over the past years, and has a relatively stable economy (Maxim, 2008:13). The aforementioned can be ascribed to Potchefstroom's diverse economy, which consists of various intertwining sectors. Although the focus of the study falls on Potchefstroom and its immediate surroundings, the whole local municipality was included during analysis to ensure an adequate buffer zone.

5. Spatial modelling

According to Belton and Steward (2002:1), every decision that is taken in life involves the balancing of different factors. This balancing of different factors can take place knowingly or unknowingly, and can be referred to as multiple-criteria decision making. Due to the complexity of multiple-criteria decision making, multi-criteria analysis was developed in the 1960's as a tool to assist decision makers in making complex comparative assessments (European Commission, 2003:1). Spatial modelling, and more specifically land-use suitability modelling, are examples of multi-criteria analysis and can potentially be used to assist planners and policy makers in the development of SDFs and other strategic plans.

Although spatial models cannot incorporate all aspects of reality, it can still provide planners and policy makers with valuable 'what if?' scenarios, which can assist them in decision-making processes (Veldkamp & Lambin, 2001:1; Koomen *et al.*, 2007:2). These 'what if?' scenarios, have the advantage that it can broaden the users' view of the future, by indicating how land-uses might change and urban growth might transpire (Koomen *et al.*, 2007:3). This study employed a land-use suitability analysis approach that employed three input criteria to arrive at a suitability result. These input criteria were, prime agricultural land, environmental considerations and planning principles (Figure 3).

The approach built forth on ideas presented in a similar model known as the Land-Use Conflict Identification Strategy (LUCIS), developed by Margaret Carr & Paul Zwick at the University of Florida's GeoPlan centre (Carr & Zwick, 2007). The LUCIS method attempted to identify land suitable for three different land-uses, by superimposing different datasets relevant to the three land-uses via an approach known as weighted overlay. The result was a map, indicating the optimal land suitable for each of the three analyzed land-uses. Weighted overlay was also used to execute the suitability analysis for this study, the results of which will be elaborated on in the next section of this article. The most significant difference between this study and the LUCIS model, was that the results of the suitability analysis were used in conjunction with population statistics to arrive at an urban growth scenario, indicating specific future urban land-uses (Figure 3). The methodology and results will be discussed, in the following section, and the results will be compared to the existing SDF for the study area.

6. The use and effectiveness of spatial modelling in spatial planning

As stated, the study implemented a weighted overlay procedure to arrive at a land-use suitability scenario. A weighted overlay procedure utilizes different types of datasets as inputs of varied importance. In a weighted overlay, datasets are given weights of importance while criteria within datasets are rated on a fixed scale, varying from good to bad. In Figure 4a two datasets are overlaid at weights of 50% each, Figure 4b shows the results of the weighted overlay. One of the disadvantages of this approach is that it rounds the result of the overlay to the nearest whole number, as can be observed in Figure 4. Despite this disadvantage, weighted overlay has many advantages. Some of the most prominent of these advantages are that it allows for the inclusion of expert knowledge in the overlay process, that there is no restriction to the number of datasets that can be overlaid, and that it is time efficient.

6.1. Land-use suitability analysis

To arrive at the suitability scenario for this study, various datasets had to be overlaid at different weights of importance. Table 2 depicts the different datasets that were used in the land-use suitability analysis. The urban, agriculture and biodiversity preference datasets were first generated in isolation from each other, and once they were attained, were overlaid at weights of equal importance to derive the land-use suitability result.

For the urban preference analysis three zonings were selected. They were residential, commercial and industrial. Each one was further divided into physical suitability and economical suitability with corresponding data inputs for each category. All and all, 33 data layers were used to generate the urban preference layer, and the criteria in each dataset had to be rated on a scale of zero to five, with zero being least suitable and five being most suitable. The criteria of each dataset differed, depending on the type of dataset. For example, the 'proximity to substations' dataset had ten intervals, starting at 0 – 500m and ending at > 30km, while the 'accessibility to primary schools' dataset, had four intervals, starting with 0 – 10 minutes and ending with > 30 minutes. Eight registered town and regional planners (which is all of the registered planners in Potchefstroom) portraying from academic institutions, the private sector and public sector, were asked to rate the different criteria in the datasets, as well as the importance of each dataset in proportion to the rest in its category, by means of a questionnaire. The mean of the different ratings for each category in each dataset were calculated and analyzed by means of an adapted Delphi method. These values were then used in different weighted overlay procedures, to eventually attain an urban preference layer.

For the agricultural and conservation preference layers, experts and expert reports were consulted. The agricultural layer utilized a process known as the CERES-maize model (Du Toit, *et al.*, 1994) to generate a potential yield layer for maize in the Potchefstroom area. This result were combined with an existing land capability layer retrieved from the Agricultural Research Council (2007), to arrive at a agricultural preference result for Potchefstroom. For the biodiversity analysis, the North West province conservation assessment (Desmet *et al.*, 2008) was consulted. The assessment indicated terrestrial and aquatic critical biodiversity areas (CBAs) as well as ecological support areas (ESAs). These identified areas were used along with existing conservation areas to generate a biodiversity preference layer for the study area.

Next, the three preference layers as discussed above were overlaid at weights of equal importance. The resulting layer indicated areas suitable for urban, agriculture and conservation, as well as areas where potential land-use conflict might exist. Land-use conflict means that two, or in some cases three, of the competing land-uses scored the same suitability score during the overlay process and that one could not be identified as the most suitable. Four types of conflicts were identified (Figure 5). They were major conflicts (where all three land-uses had equal importance), urban/conservation conflicts, urban/agriculture conflicts and agriculture/conservation conflicts. The methodology that was used to resolve these conflicts will subsequently be discussed.

6.2. Land-use conflict analysis and final land-use allocation

To attain a final land-use suitability result, the land-use conflicts had to be resolved. To achieve this, areas, indicated as conflicting areas, had to be analyzed and allocated to one of the two or three conflicting land-uses as described in Section 6.1. For this the original urban, agriculture and conservation preference datasets had to be consulted. By consulting the original datasets and normalizing their values, some of the conflicts could be resolved. Although most of the conflicts were resolved, in some cases no distinction could be made and land was again indicated as conflict areas (Figure 6). Once most of the conflicts were resolved and land-uses were allocated the final land-use allocation dataset (Figure 6) could be used to model future urban growth.

6.3. Urban growth modelling and model validation

The final land-use allocation result was used as the base dataset for modelling urban growth (Figure 3). From the land-use allocation result (i.e. the land-use suitability result), the areas with the highest urban suitability were extracted. These areas were further refined by extracting the most suitable land for residential, commercial and business land-uses. To indicate potential future urban development, some statistics were required, which were obtained from the Tlokwe Local Municipality land-use budget (DLPG, 2008). The Tlokwe Local Municipality land-use budget indicated the amount of land required for each land-use in 2030, as calculated from predicted population growth. These amounts (expressed in m^2) were allocated to the most suitable land for each urban zoning (residential, commercial and industrial). The result was an urban growth scenario for 2030, indicating where different types of urban development may transpire (Figure 7).

Table 2. Overlay procedure and datasets

Final land-use allocation (Figure 6)										
Land-use conflict analysis (Figure 5)										
Suitability result										
Urban preference layer						**Agricultural preference layer**		**Biodiversity preference layer**		
Residential preference layer		Commercial preference layer		Industrial preference layer		Cropland potential layer	Land capability layer	Terrestrial biodiversity layer	Aquatic biodiversity layer	Existing conservation areas
Residential physical suitability	Residential socio-economic suitability	Commercial physical suitability	Commercial socio-economic suitability	Industrial physical suitability	Industrial socio-economic suitability	*Soil depth data*		*Terrestrial CBA 1 layer*	*Aquatic CBA 1 layer*	Existing conservation areas
Proximity to substations	*Proximity to existing residential areas*	*Land with acceptable slope*	*Proximity to existing commercial area*	*Land with acceptable slope*	*Proximity to residential areas*	*Clay content data*		*Terrestrial CBA 2 layer*	*Aquatic CBA 2 layer*	
Land with acceptable slope	*Accessibility to primary schools*	*Proximity to transition lines*	*Proximity to activity corridors*	*Proximity to transition lines*	*Proximity to industrial areas*	*Rainfall data*		*Terrestrial ecological support areas*	*Aquatic ecological support areas*	
Proximity to transition lines	*Accessibility to secondary schools*	*Closeness to prisons*	*Proximity to activity spines*		*Proximity to access routes*	*Optimal slopes for cropland*				
Closeness to prisons	*Accessibility to basic health care*	*Proximity to railway*	*Proximity to neighbourhood nodes*		*Proximity to railroads*					
Proximity to railway	*Proximity to distribution roads*	*Proximity to landfills cemetery & sewerage works*	*Proximity to local nodes*		*Proximity to bulk services*					
Proximity to landfills cemetery & sewerage works	*Proximity to bulk services*	*Proximity to industrial areas*	*Proximity to public transport terminus*							
Proximity to industrial areas			*Proximity to services*							

= Weighted overlay

Because the datasets that were used to exclude existing urban land-uses in the land-use suitability modelling phase were data of 2006, a three year development gap was presented for indication by the model. The model successfully indicated the development of the newly built Mooi River Mall, as well as the development of an industrial park that is currently in planning. The model further indicated the development of a commercial/business area almost exactly where developers are envisioning a new hotel. It can thus be concluded that the model presents a fairly accurate scenario of how development may transpire in Potchefstroom.

6.4. Comparison of results to existing spatial plans

In an effort to determine the value and use of such an approach to spatial planning, the resulting land-use suitability result (Figure 6) and the urban growth scenario (Figure 7) were compared to the existing SDF for Potchefstroom (Figure 8). In comparing the suitability result with the SDF, it was found that Potchefstroom's SDF considered the importance of high agricultural land and conservation areas when allocating land for future development. Some differences did exist however, and the significant ones were identified and indicated on Figure 9 as conflicting areas. The conflicts were mostly where the SDF indicated future residential development on high potential agricultural land. These conflicts, along with the land-use suitability result, were used to delineate a new urban edge for Potchefstroom. The biggest differences between the urban edge indicated in the existing SDF, and the newly proposed one, is on the eastern parts of town where development is currently taking place at a rapid rate.

The comparison between the urban growth scenario and the SDF proved to be quite interesting. The urban growth results were in most cases reflected in the SDF, but the urban growth scenario proved to indicate more detail with regard to different urban land-use types. The scenario made it possible to identify some priority nodes with regard to urban land-use development. Seven priority nodes that indicate where certain land-use types should be encouraged were identified from the urban growth scenario, and will now be discussed as indicated on Figure 9.

The first node (Node A) indicated a low-income development priority area in Promosa. The most likely reason for this is because the rest of Potchefstroom's low-income areas, such as Ikageng, Sarafina and Skierlik, are restricted for future development by the newly established Highveld National Park, Potch Industria and the N12. According to the analysis, the areas to the north and east of Promosa seem to be the most likely areas for future low-income development to transpire. The second priority node (Node B) that was identified was the medium income node, which is in the Dassierand area. This area currently consists of medium income housing and will most likely continue to develop as such. By consulting the land-use suitability result, it was established that it would be desirable for Dassierand to expand towards the south-west, while Promosa expands towards the south-east. This will lead to integrated development by linking low and medium income residential areas, and adhere to the integrated development principles encouraged by policy and legislation.

The third node (Node C) that was identified, was the high income development node to the western side of the Van der Hoffpark residential area. This area has some of the highest real estate values in Potchefstroom and is currently developing on plots adjacent to the city. From the results it can be anticipated that this high-income development will continue eastward from Van der Hoffpark, and north-eastward behind Mooivalleipark. These areas have some of the lower agricultural and conservational potentials in the Potchefstroom area, and are suitable for future high-income residential development.

Node D was identified as a middle- and high-income development node, and is situated on the periphery of Baillie Park and Grimbeeck Park. The area is currently developing in the form of Residential 2 and 3 developments, although Residential 1 developments are also visible. The areas to the east and south-east of Baillie Park is suitable for future development, but will be constricted at some point by high potential agricultural land.

The fifth node (Node E) that was identified, was the commercial development area to the east of the existing CBD. These indicated commercial areas are in close proximity to the N12 as well as the R53, which makes it very accessible to consumers. Node F was also identified alongside the N12, as a light industry development node, which is perfect for the development of non-noxious industries due to its accessibility and greenfield-status. The final node (Zone G) that was identified was the heavy industry zone, which is situated to the north of Potch Industria.

7. Conclusion and recommendations

Although no land-use suitability modelling or urban growth modelling approach can ever be completely accurate, such approaches could most definitely assist planners and policy makers in strategic planning processes. The study proved that land-use suitability modelling could be used very effectively in identifying land suitable for future urban development, while protecting high potential agricultural land and high biodiversity areas. It was further established that urban growth scenarios could assist planners and policy makers in identifying priority areas for development and confining and restricting urban sprawl. The proposed approach could further assist policy makers in reaching the strategic goals of identifying desired directions of urban growth, conserving natural environments, identifying areas where certain land-uses should be encouraged or discouraged and delineating an urban edge as stipulated in the Local Government: Municipal Planning and Performance Regulations of 2001 (RSA, 2001a:1-2) and the White Paper on Spatial Planning and Land-use Management (RSA, 2001b:19).

One of the most important objectives for spatial planning in the next few decades, will be the challenge of effectively integrating environmental and agricultural data into spatial plans. This mammoth task is crucial if sustainable urban development is to be achieved. Although an approach such as the one presented in this study can assist planners in achieving the above, further research need to be conducted into the methodologies of achieving this. Future research should attempt to incorporate public opinion as well as scientific considerations, while attempts should be made to include higher resolution environmental and agricultural data in land-use suitability analysis processes. GIS-based interdisciplinary approaches should be adopted in spatial planning to ensure the development of sustainable towns and cities and the discouragement of urban sprawl in South Africa.

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Figure 1. Legislation and policy related to SDFs
Figure 2. Potchefstroom locality map
Figure 3. Analysis process
Figure 4. Weighted overlay procedure
Figure 5. Initial land-use suitability results indicating possible land-use conflicts
Figure 6. Final land-use suitability result
Figure 7. 2030 Urban growth scenario for Potchefstroom urban area
Figure 8. Potchefstroom SDF (Potchefstroom, 2008)
Figure 9. Comparison between SDF and analysis results: newly delineated urban edge and priority nodes

Figure 1: Legislation and policy related to SDFs

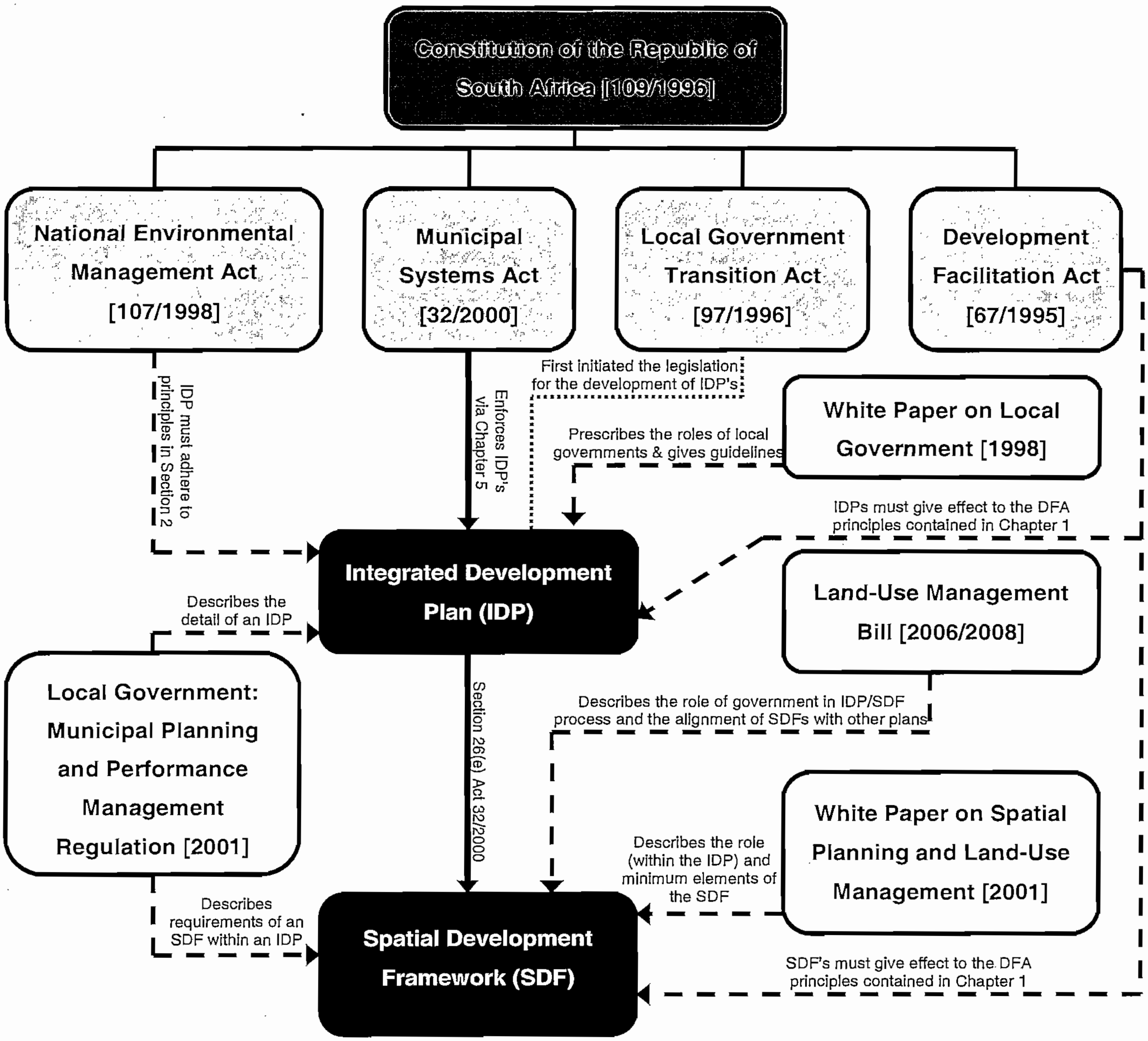


Figure 2: Potchefstroom locality map

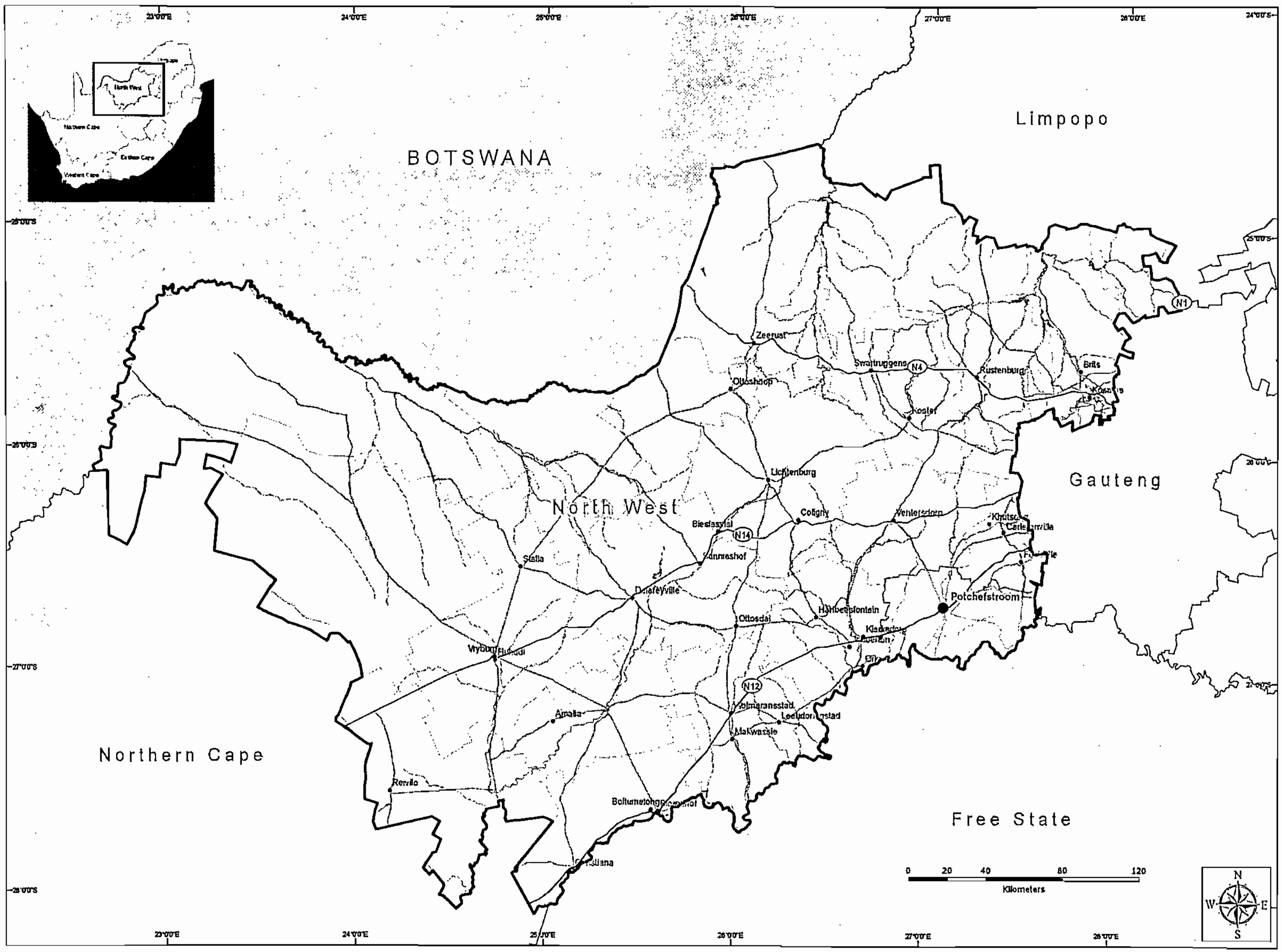


Figure 3: Analysis process

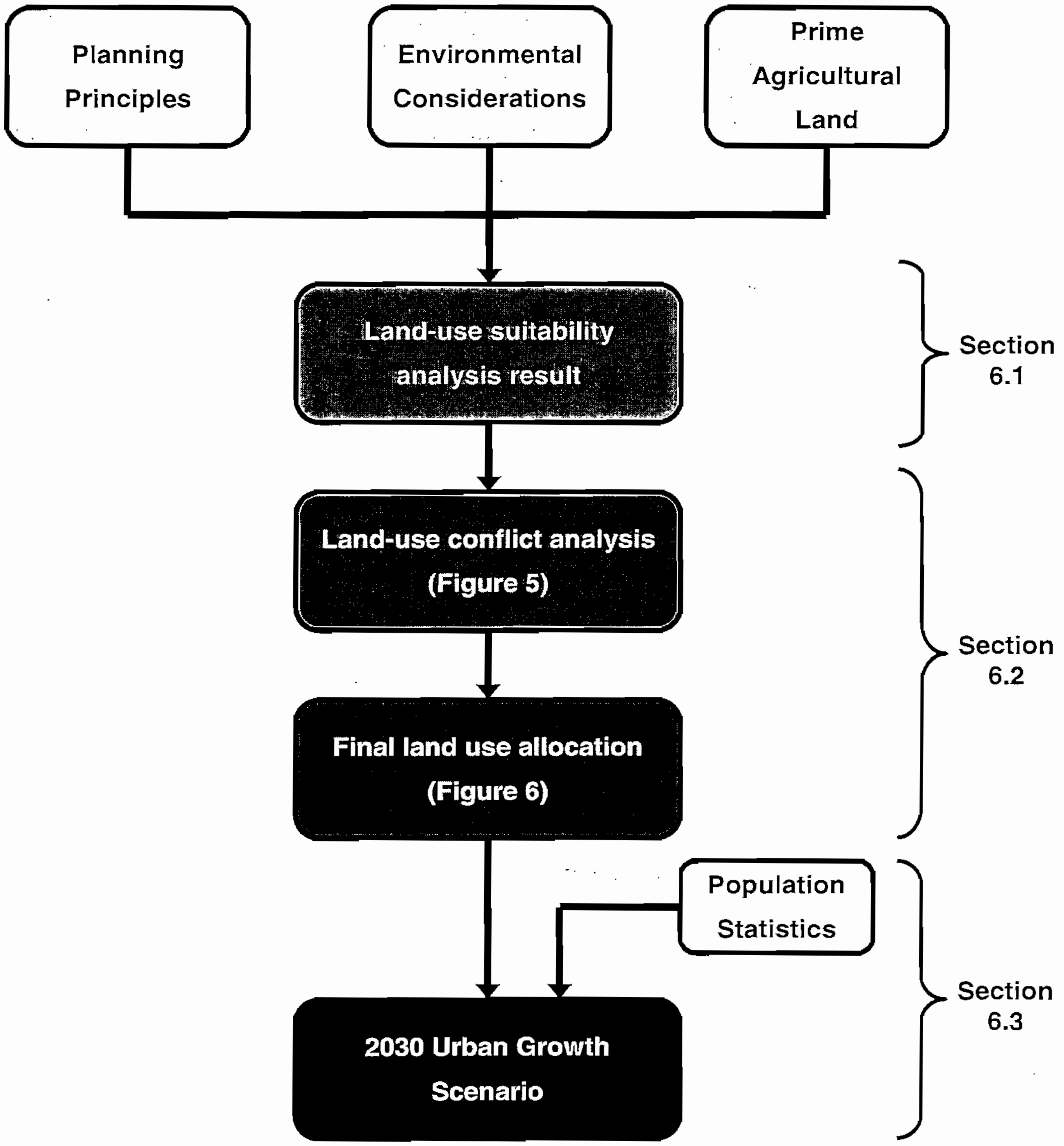
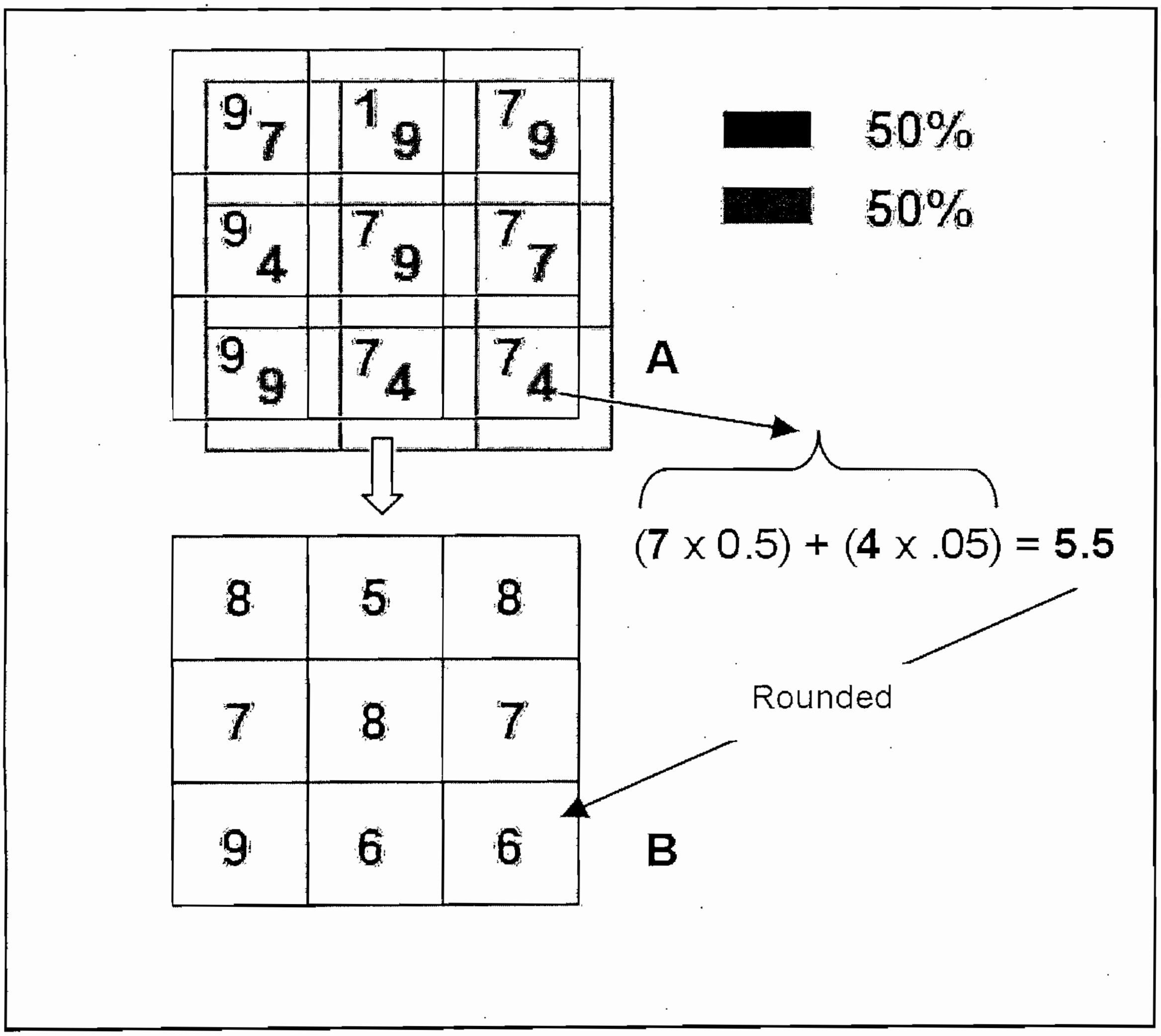


Figure 4: Weighted overlay procedure



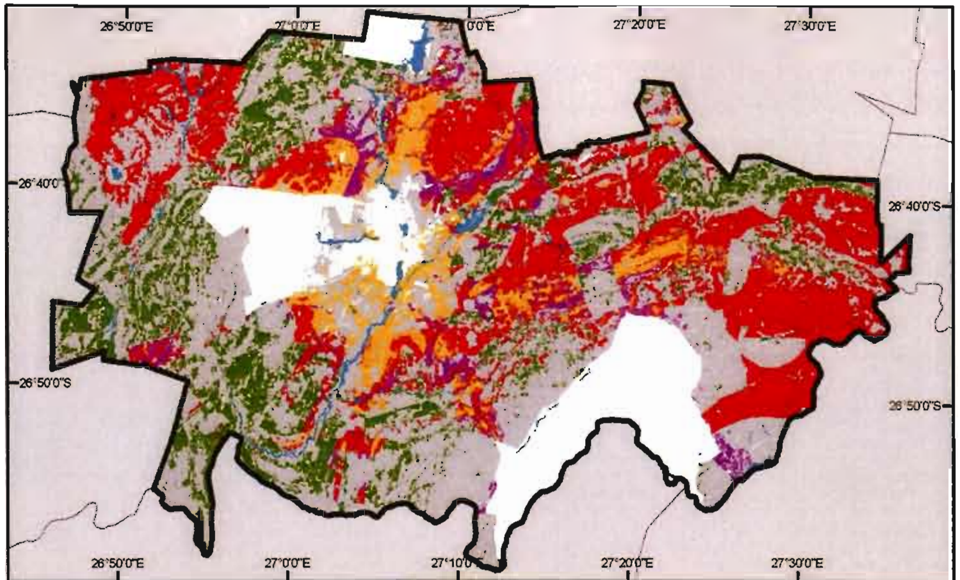


Figure 5 - Initial land-use suitability results idicating possible land-use conflicts

Areas of Conflict

- Major Conflict
- Urban/Agriculture Conflict
- Urban/Conservation Conflict
- Agriculture/Conservation Conflict
- No Conflict
- Excluded by Development Mask

Hydrology

- Water

Conflicts analyzed

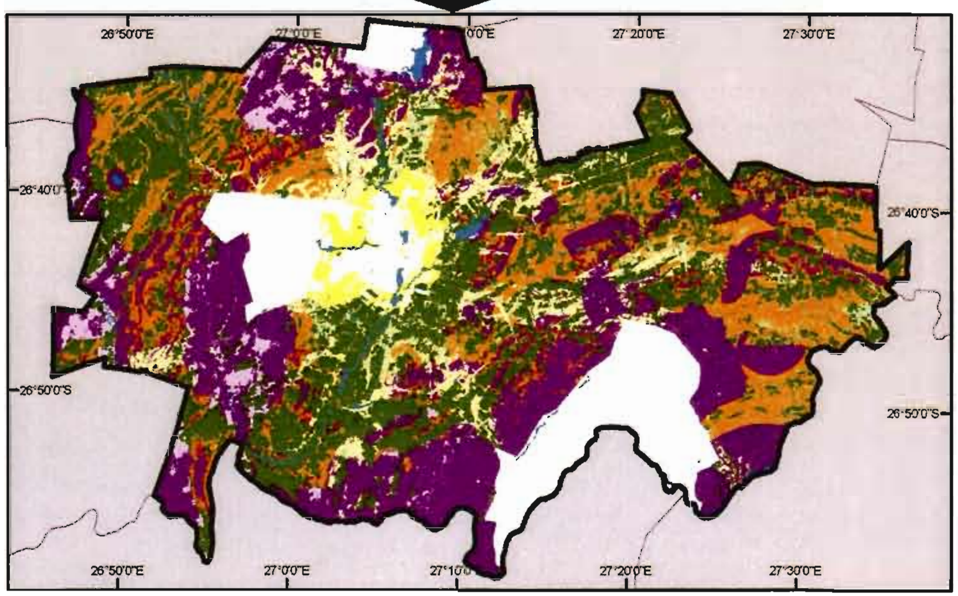


Figure 6 - Final land-use suitability result (conflicts resolved)

Final Land Use Allocation

- Urban High
- Urban Medium
- Long Term Urban (Conflict)
- Agriculture High
- Agriculture Medium
- Conservation High
- Conservation Medium
- Conflict
- Excluded by Development Mask

Hydrology

- Water

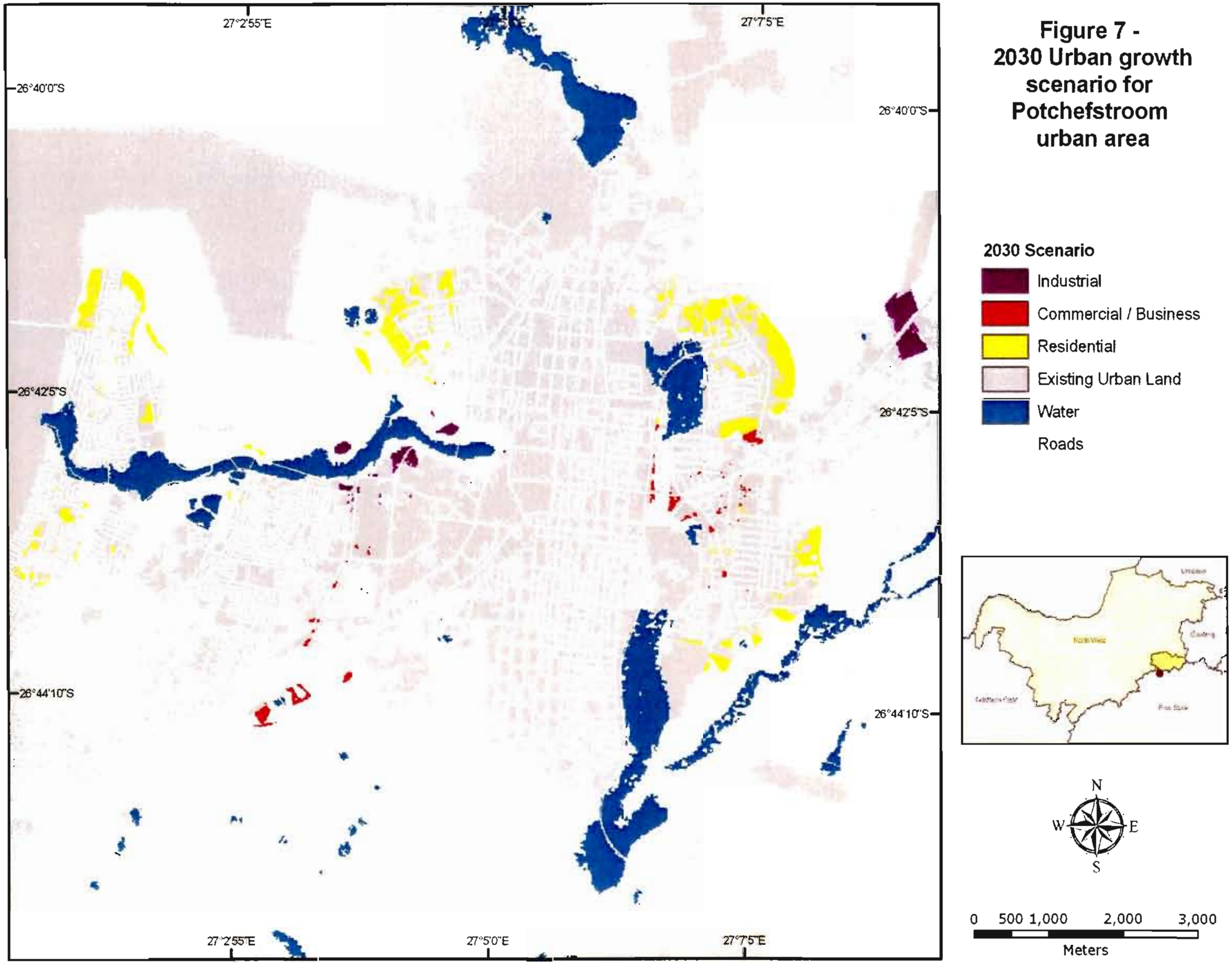
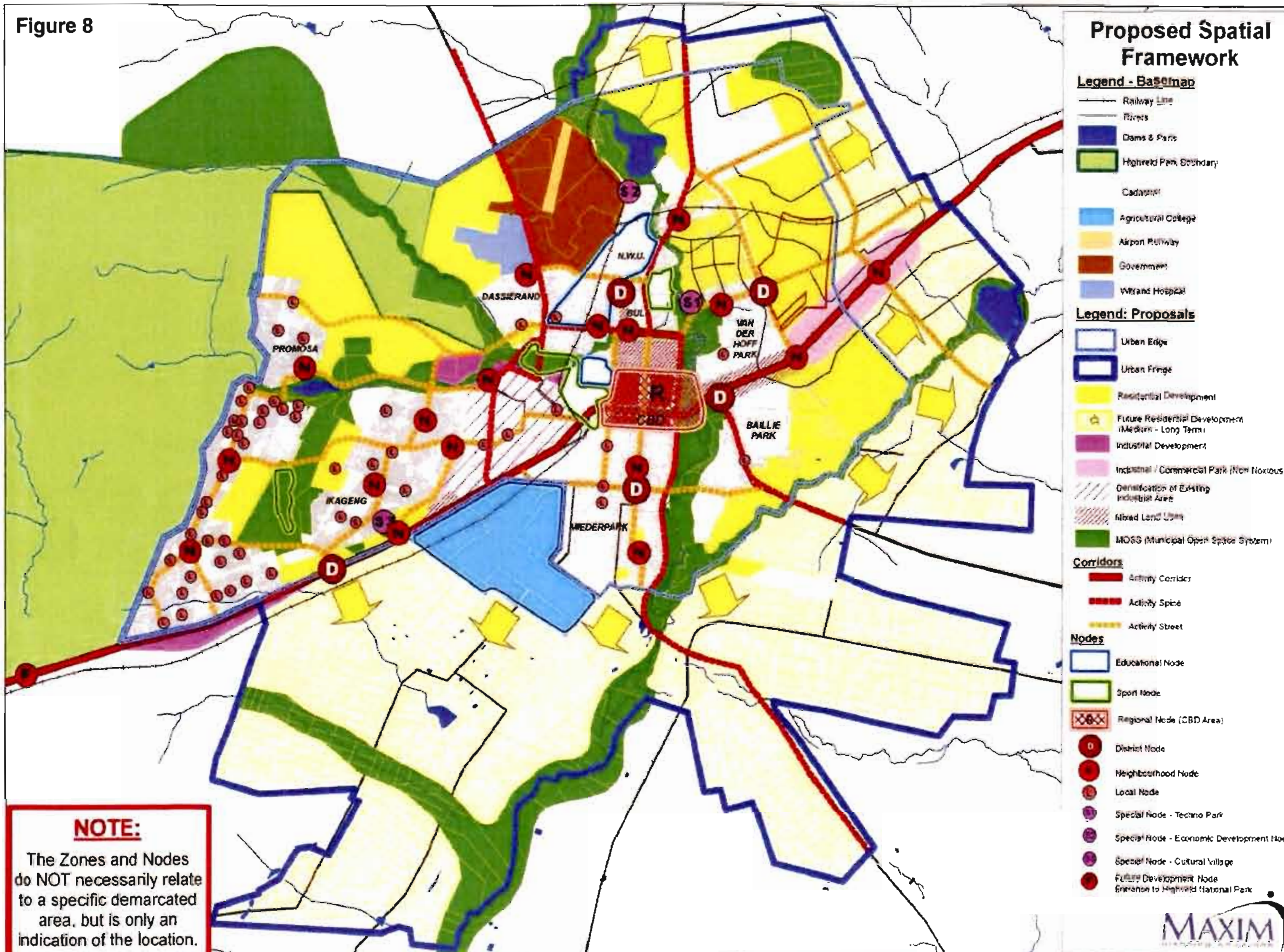


Figure 7 - 2030 Urban growth scenario for Potchefstroom urban area

Figure 8



NOTE:

The Zones and Nodes do NOT necessarily relate to a specific demarcated area, but is only an indication of the location.

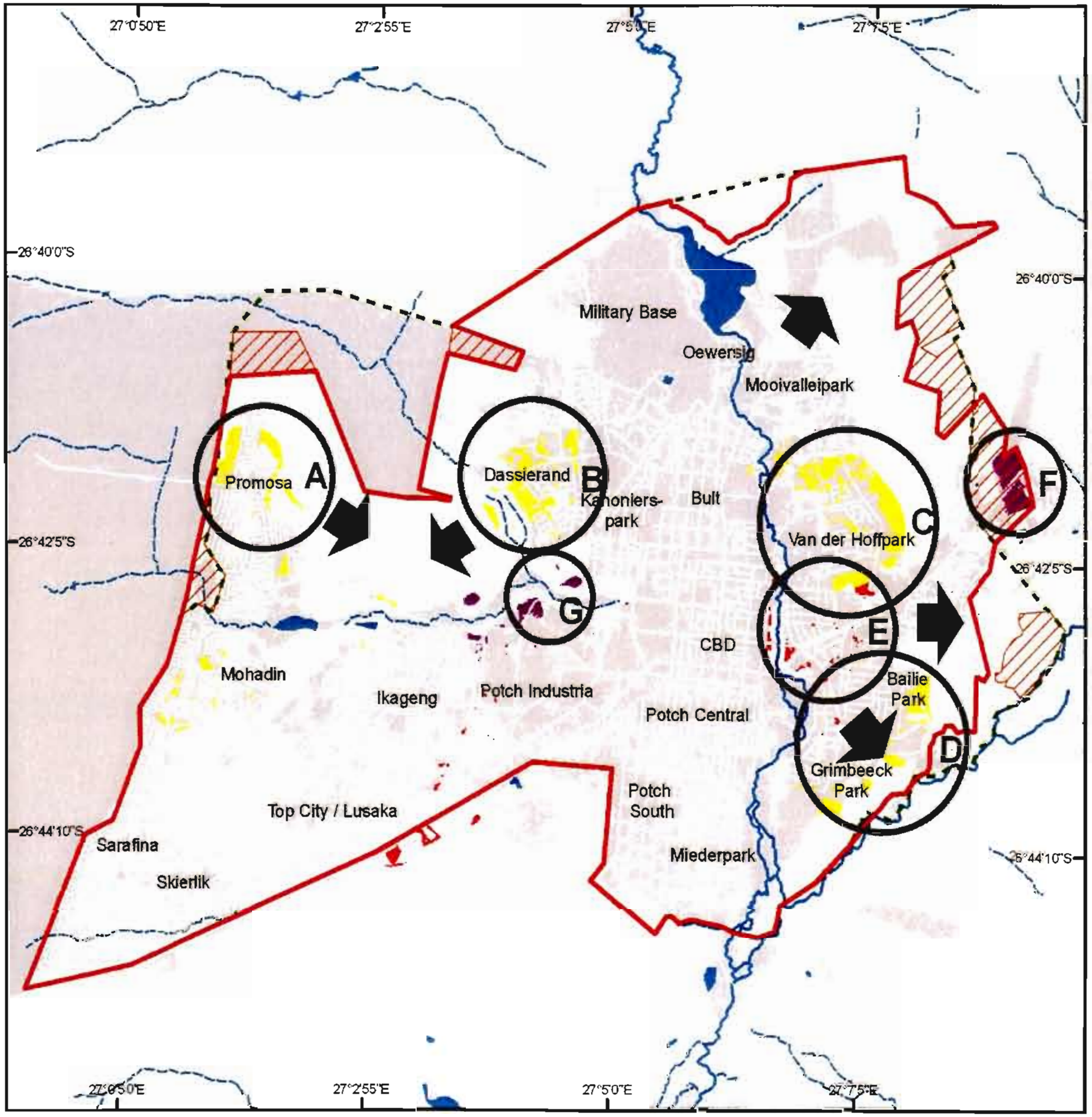


Figure 9 - Comparison between SDF and analysis results: newly delineated urban edge and priority nodes

Legend

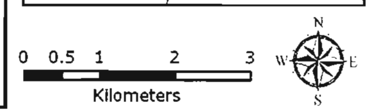
Proposed urban edge
SDF Urban edge
Conflict between analysis & SDF
Roads

2030 Scenario

Industrial
Commercial / Business
Residential
Water Bodies
Existing Urban Land
Desired Growth Direction

Priority Nodes

A - Low income development
B - Integrated development (medium income)
C - High income development
D - Medium and high income development
E - Commercial development
F - Light industrial development
G - Heavy industrial development



Chapter 8

Synthesis and Conclusion

"Planning is bringing the future into the present so that you can do something about it now"

- Alan Lakein

Dirk Cilliers

13077767

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Chapter 8: Synthesis and Conclusion

8.1. Introduction

This study was initiated to examine the value of a land-use suitability and urban growth model in spatial planning in South Africa. This was done by means of examining the effectiveness and relevance of a multidisciplinary, environmental sensitive, land-use modelling approach in spatial planning and determining the value of such an approach as a support tool in the development of spatial development plans and strategies. The following objectives, as depicted in Chapter One, were successfully achieved in this study:

- The design and implementation of a multidisciplinary, environmental sensitive, land-use suitability model for Potchefstroom in the Tlokwe Local Municipality, North-West, South Africa;
- The development of an urban growth scenario for 2030 by means of combining the above results with urban growth statistics; and finally
- The valuation of such an approach for spatial planning in South Africa, by comparing the results of the study with existing spatial plans for the study area.

This chapter will provide a broad synthesis of the literature that was discussed in Chapters Two to Five, provide recommendations for consideration in future studies and provide concluding remarks with regard to the use of a land-use suitability model in spatial planning in South Africa.

8.2. Synthesis

This section will attempt to identify and discuss the relationships between different sections of the literature as discussed in Chapters One to Five by means of the synthesis matrix shown in Table 8.1. The dots indicate where different sections relate with one another.

Table 8.1. Synthesis

	2.2	2.3	2.4	2.5	3.2	3.3	4.4.1	4.4.2	4.4.3	4.4.4	4.4.5	4.4.6	4.5.1	4.5.2	5.2	5.3
2.2. The development of central places	■															
2.3. Forces that influence urban morphology		■														
2.4. Models of urban structure	•	•	■													
2.5. Urban sprawl			•	■												
3.2. Sustainable development					■											
3.3. Urban ecology					•	■										
4.4.1. Constitution of the RSA		•			•		■									
4.4.2. Development facilitation act		•		•	•	•	•	■								
4.4.3. National environmental management act		•			•	•	•		■							
4.4.4. Municipal Systems Act		•			•		•	•	•	■						
4.4.5. Municipal planning and performance regulations		•			•		•	•			■					
4.4.6. Land-use management bills		•					•					■				
4.5.1. White paper on local government		•					•						■			
4.5.2. White paper on spatial planning and land-use management		•			•	•	•			•				■		
5.2. Multi criteria analysis											•		•		■	
5.3. Spatial modelling											•		•		•	■

Source: Own Creation

When conducting a study of an urban nature, it is crucial that the theoretical concepts of urban structure and development be thoroughly investigated. Chapter Two thus presented an overview on planning theory applicable to the study. In Section 2.2 the central place theories of Christaller (1966) and Lösch (1954) were discussed followed by an examination of the models of urban structure in Section 2.4. Section 2.2 revealed that Christaller's central place theory state that development centralizes around a nucleus or a central point (Christaller, 1966:14), a principle which is also visible in some of the discussed urban structure models such as Burgess' concentric zone model (Johnson, 1967:163), Hoyt's sector model (Herbert, 1972:72) and Mann's model of the urban structure (Waugh, 2000:423). Section 2.3 briefly discussed the forces that influence urban morphology and subsequently cause the changes described by the models discussed in Section 2.4. Some of these forces, such as demand and supply, were particularly evident in Alonso's theory of land-use and the bid-rent theory as discussed in Section 2.4.2.

From the discussed models of urban structure it was determined that urban development tends to be outward towards cheaper land, which relates to the concept of urban sprawl discussed in Section 2.5. The concept of urban sprawl is visible in Simon's (1989) modernized apartheid model, Kearsley's (1983) modified Burgess model, White's (1987) model of the 21st century city, Mann's (1965) model of urban *structure, Harris* and Ullman's (1945) multiple nuclei model, and the bid-rent theory. Furthermore, the phenomenon of urban sprawl as observed in the aforementioned models, can in most cases be directly linked to Berry's (1976:19-21) reasons for deconcentration as discussed in Section 2.5 and clearly deals with development transpiring around, and adjacent to the built-up areas.

Other forces found to influence urban morphology (other than supply, demand and Berry's reasons for deconcentration), were political policies and legislation as discussed in Chapter Four. Policies and legislation aim to guide development in certain ways and empowers spatial planning in South Africa. From Sections 4.4 and 4.5 it is clear that planning laws and policies communicates government's aims and intentions with regard to planning and development. From the Development Facilitation Act (RSA, 1995) for instance, it is clear that urban sprawl is seen as a negative phenomenon in South Africa. The Development Facilitation Act (RSA, 1995:8-9) strongly discourages the manifestation thereof, and encourages the development of sustainable 'compact cities'. This is in line with the Agenda 21 and Habitat Agenda principles discussed in Section 3.2, and more specifically the Constitution of the Republic of South Africa (RSA, 1996), which further promotes sustainable development and is the first constitution to be development orientated and more specifically sustainable development orientated.

Along with the Development Facilitation Act (RSA, 1995), the National Environmental Management Act (RSA, 1998), discussed in Section 4.4.3, also encourages sustainable development in South Africa. The Municipal Systems Act (RSA, 2000:18) and the Local Government: Municipal Planning and Performance Regulations (RSA, 2001a:1-2) further calls for the reflection of the sustainable development principles described in the Development Facilitation Act (RSA, 1995:8-9), in the Integrated Development Planning process described in Sections 4.4 and 4.5. The concept of sustainable development is put into action via the White Paper on Spatial Planning and Land-Use Management (RSA, 2001b:19), which calls for the conservation of both the built-up and the natural environment in accordance with sustainable development goals as described in Section 3.2. However, in Chapter Three it was revealed that the implementation of sustainable development as expressed above is rarely achieved in South Africa due to various differing reasons. To address this issue, Section 3.3 examined the possible use of urban ecology in achieving sustainable development goals. Section 3.3.3 indicated that urban ecology could assist planners and governments in achieving environmentally sustainable development, preventing the loss of biological diversity and conserving the built environment as called for in the various policies and legislation discussed in Chapter Four.

In the final literature chapter, i.e. Chapter Five, the basic concepts with regard to GIS-based spatial modelling were discussed. It was concluded that multi-criteria analysis and spatial modelling can assist planners in identifying areas where particular land-uses should be encouraged and others discouraged in accordance with the requirements stated in the White Paper on Spatial Planning and Land-Use Management (RSA, 2001b:19) and the Local Government: Municipal Planning and Performance Regulations (RSA, 2001a:1-2). It was further recognized that these two approaches could assist Town and Regional Planners in delineating an urban edge and indicate desired directions of growth, as respectively required by the Municipal Planning and Performance Regulations (RSA, 2001a:2) and the White Paper on Spatial Planning and Land-Use Management (RSA, 2001b:19).

8.3. Conclusion and Recommendations

As stated, this study examined the value of a GIS-based land-use suitability and urban growth modelling approach in spatial planning in South Africa. The fact that such an approach deals with environmental and agricultural issues in a pro-active manner, proved to be a valuable asset in reaching sustainable developmental goals, as set out in the Constitution of the Republic of South Africa (RSA, 1996:8). It was found that the development of a fairly accurate urban growth scenario, is possible for the South African context with the available data in the country. It was further established that the use of such scenarios could assist planners and policy makers in the development of Spatial Development Frameworks.

In the first article (Chapter Six) it was found that an easy-to-use and transparent land-use suitability analysis, utilizing a weighted overlay procedure, could be used to great success as a base dataset for developing urban growth scenarios. It was further recognized that such approaches have potential for use in spatial planning in South Africa, and that it could be used quite effectively in the development of spatial plans. It was established that the approach generated fairly accurate results, although it was agreed that other methodologies should also be experimented with to find the best and most accurate method, or combination of methods, for modelling urban growth. From the first article it is clear that the land-use suitability modelling approach, as basis to urban growth modelling, is very effective, but that more and better detailed large scale data (specifically agricultural and environmental) is crucial for higher accuracy and more effective land-use suitability and urban growth analysis.

In the second article (Chapter Seven), which focussed on the value of a land-use suitability analysis approach to spatial planning in South Africa, it was found that such an approach could contribute significantly to some aspects of the Spatial Development Framework (SDF). Although the comparison between the existing SDF and the analysis results showed that Potchefstroom's SDF considered and portrayed some environmental and agricultural factors, there were still some minor disparities between the two. These disparities were addressed in the newly demarcated urban edge, which differs slightly from the original one proposed by the SDF. It was shown that land-use suitability and urban growth scenarios could assist in identifying areas of development priority and could further assist in indicating future directions for urban growth, which is in accordance with the SDF principles as stated in The Local Government: Municipal Planning and Performance Regulations of 2001 (RSA, 2001a:1-2) as well as the White Paper on Spatial Planning and Land-use Management (RSA, 2001b:19).

It is proposed that the recommendations made in these articles could improve the way in which spatial plans are developed in South Africa and that the proposed approach could assist planners and policy makers in decision-making processes. The utilization of different types of land-use change or urban growth analysis techniques, as recommended in Chapter Six (article one), could assist decision makers in making better informed decisions with regard to strategic planning. As stated in Chapter Seven (article two), the use of such an approach could also assist decision makers in pro-actively incorporating agricultural and environmental data in strategic spatial plans, potentially reducing conflicts between different stakeholders. One challenge that emerged, however, were the challenge to develop models that also take issues such as segregated cities with mixed densities and different transport systems into consideration, while at the same time incorporating public opinions and scientific considerations into the model. Nonetheless, it is believed that the utilization of such an approach, as discussed in this study, could advance sustainable development by involving experts from various disciplines as well as the public in the process of identifying areas suitable for specific land-uses, while at the same time excluding others. It is further hoped that the utilization of land-use suitability modelling approaches will broaden communities' and government's views on sustainable development, and the importance of pro-actively planning for it.

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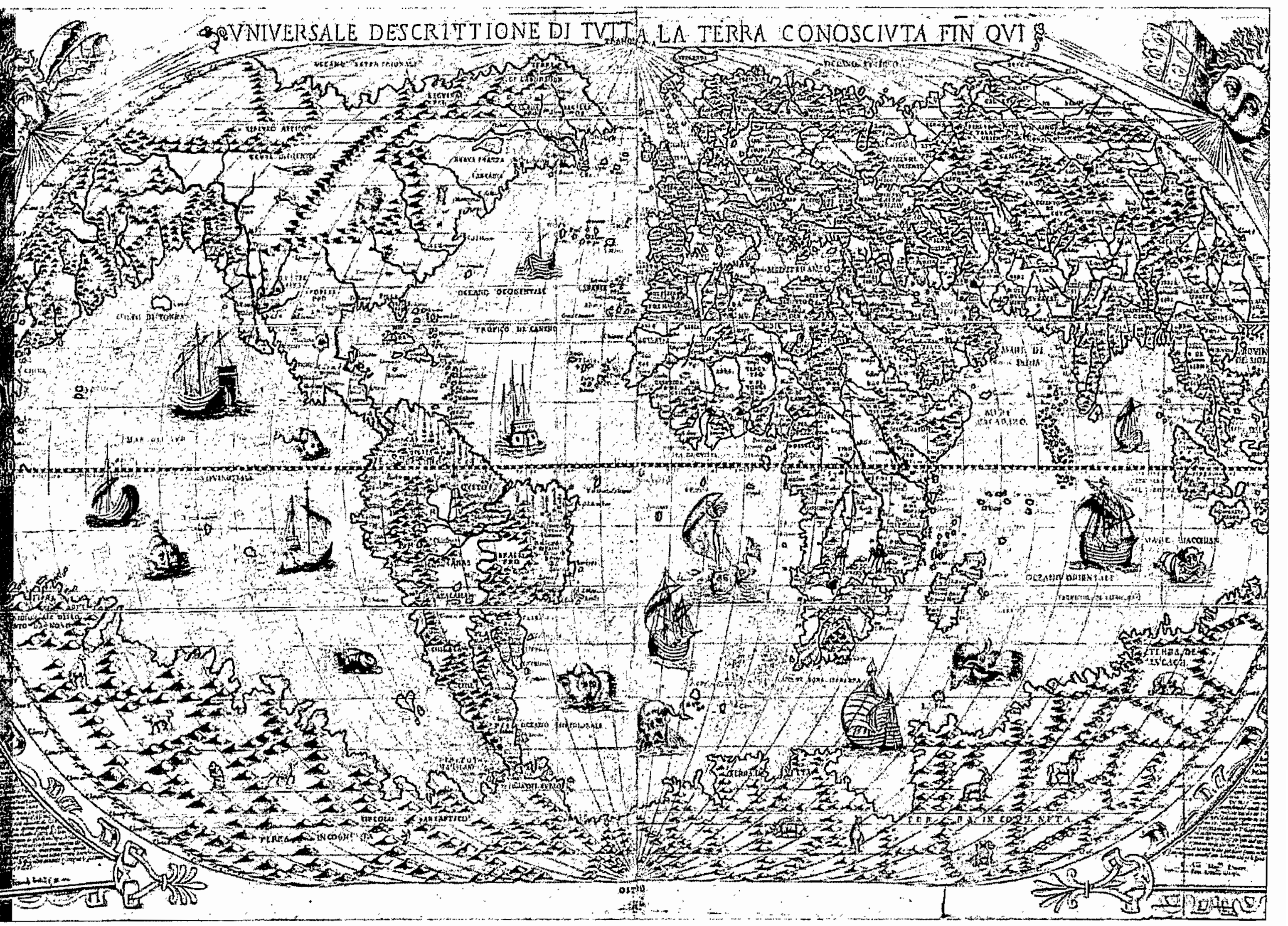
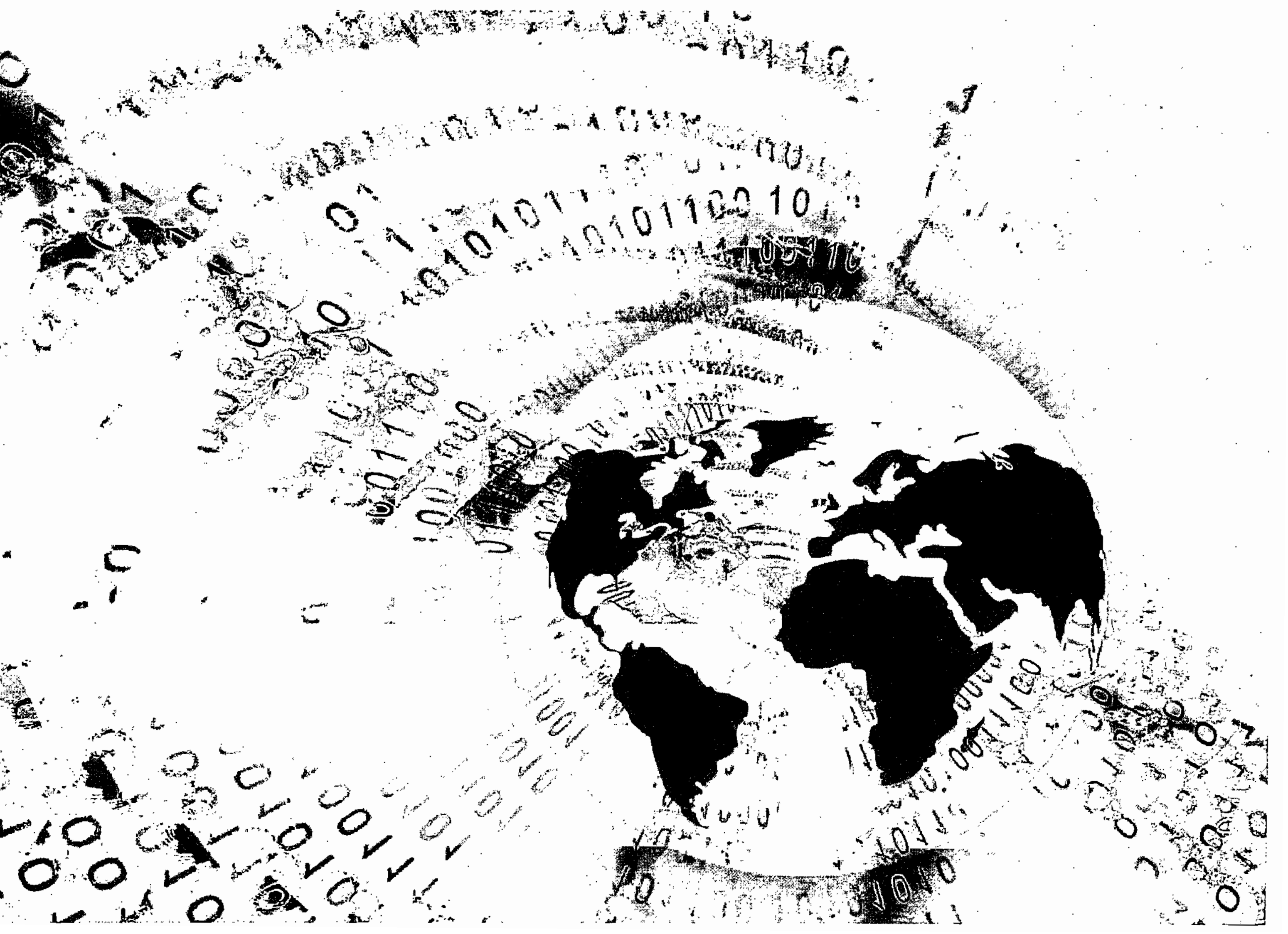
Annexure 1

Maps



Annexure 2

Questionnaire



NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOMKAMPUS

This study forms part of a M.Art *et* Scien. dissertation examining the use of development-suitability modeling in spatial- and forward planning in South Africa.

I would like to take a few minutes of your time to briefly explain to you what the study entail.

Current realities such as population growth, urban development and agricultural expanse threaten to shatter the intricate balance that exists between different land-uses. Although numerous studies have been conducted regarding land-use suitability analysis, few of them effectively address the issue of land-use conflict identification and dealing with it in a multi-disciplinary manner. The aim of this research is to address this issue by means of implementing the LUCIS-model (Land-Use Conflict Identification Strategy) in Tlokwe Local Municipality, North West Province, South Africa.

In order to implement LUCIS successfully weights of importance have to be allocated to the different datasets used in the study. The aim of this exercise is to assign a basic value of importance for each set of criteria by means of gaining the inputs of professional planners and simplifying the results with the help of an adapted Delphi method.

Method

On each page you will find a question accompanied by a image of the data and a table for rating importance. Read the question and award a rating by making x's in the accompanied table (see the example on page two).

Thank you for participating in this study, I am confident that the results will provide new insights into the use of GIS methodologies in spatial planning.

Sincerely,

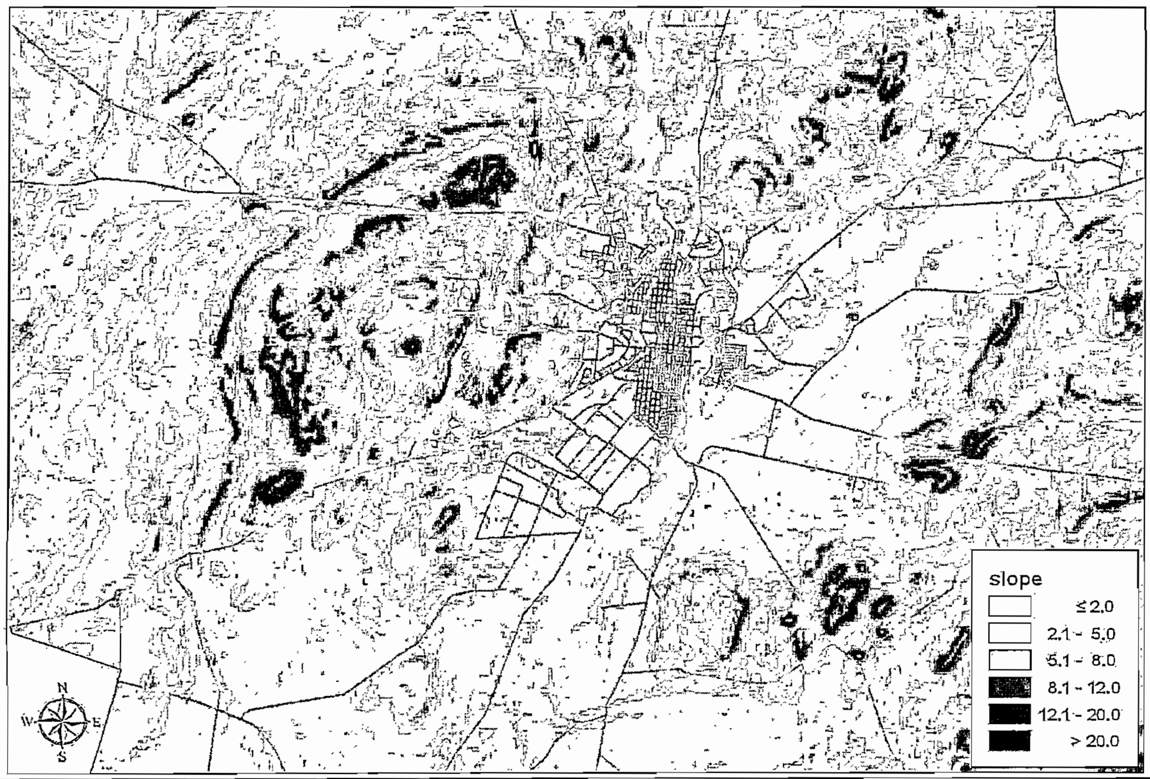
Dirk Cilliers
Email: Dirk.cilliers@nwu.ac.za
Office: 018 299 1589
Cell: 084 517 7979

Rate the desirability of each of the given **travel time** intervals for **residential development** with regard to **primary schools** (includes pre-schools and crèches).

Travel time to schools (minutes)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 10						X
10 – 20					X	
20 – 30					X	
30 +			X			

Question 1

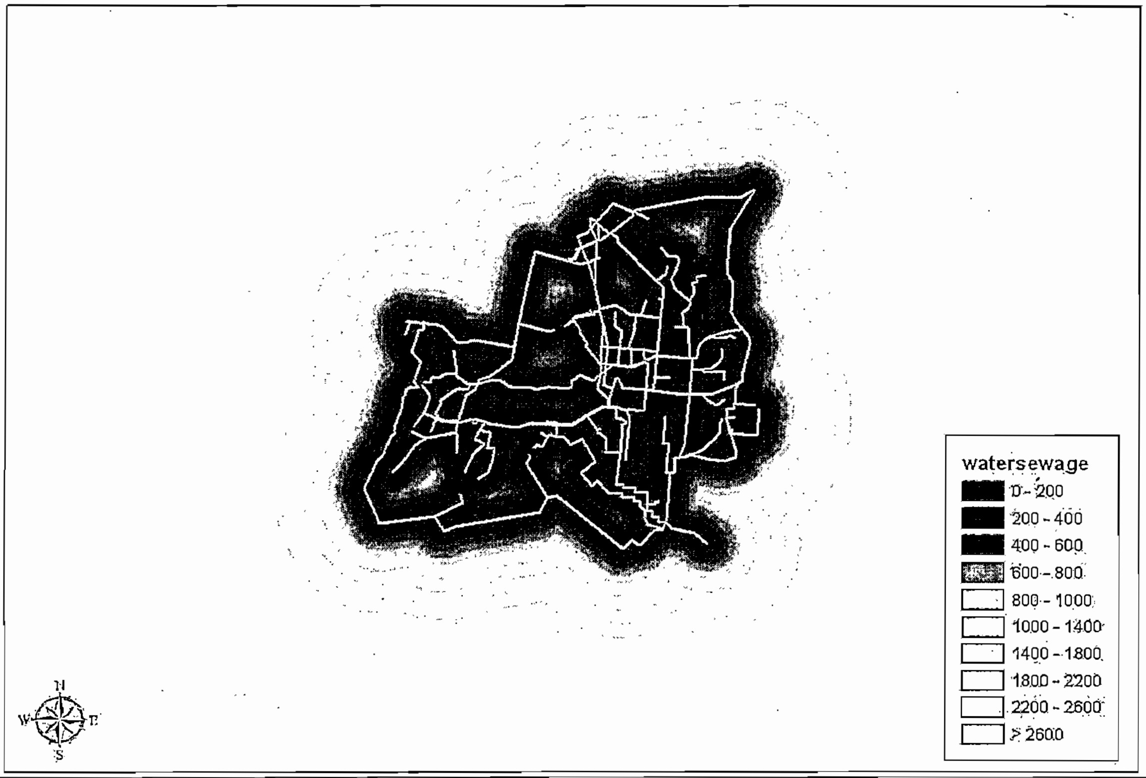
Rate the desirability of each of the given **proportional** intervals for **urban development** with regard to **slope**.



Slope in percentage (%)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
< 2						
2.1 – 5						
5.1 – 8						
8.1 – 12						
12.1 – 20						
>20						

Question 2

Rate the desirability of each of the given **distance** intervals for **urban development** with regard to available **bulk water and sewerage** access points.



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

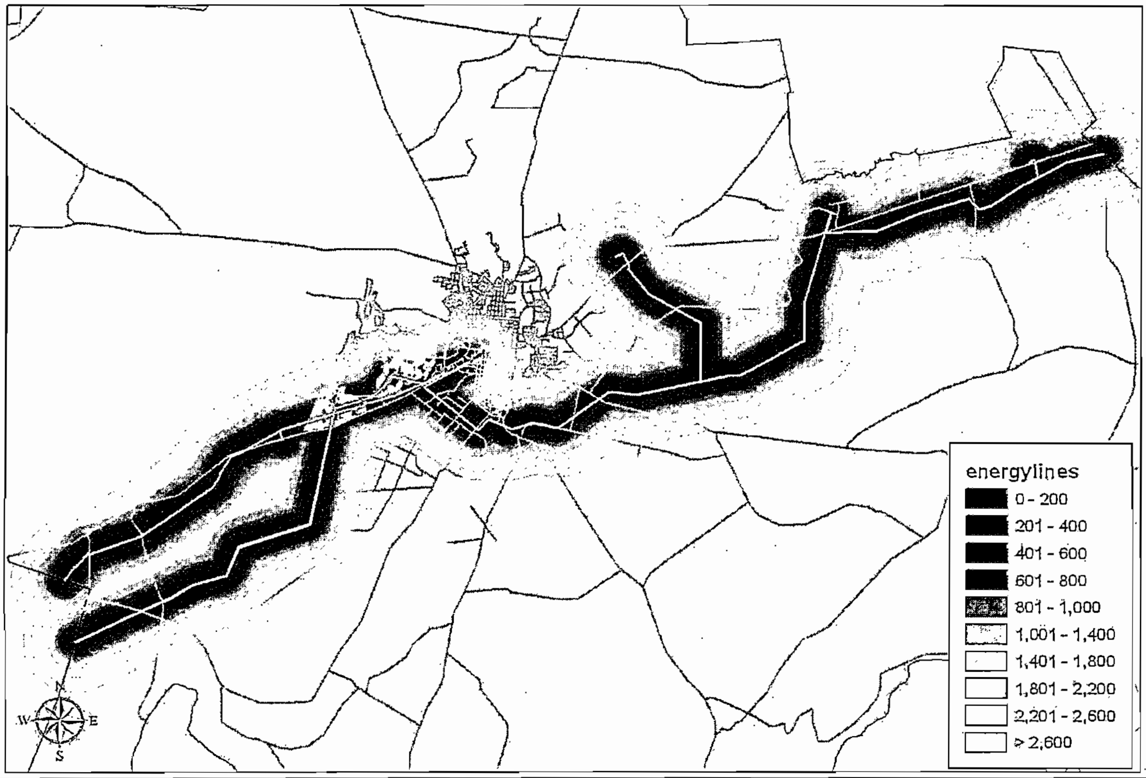
Question 3

Rate the desirability of each of the given **distance** intervals for **urban development** with regard to available **electrical energy access points.**

Distance in meters (m)	**Restricted**	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 4

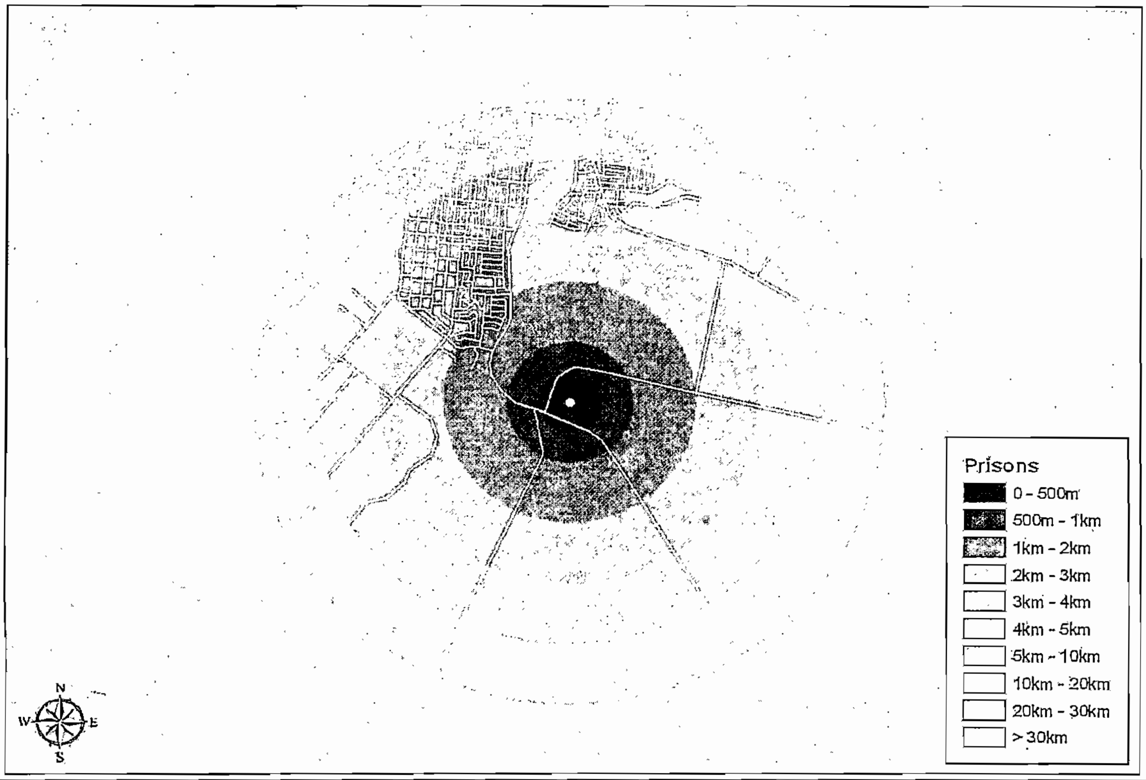
Rate the desirability of each of the given **distance** intervals for **residential development** with regard to **high voltage energy lines** (seen as a negative factor).



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 5

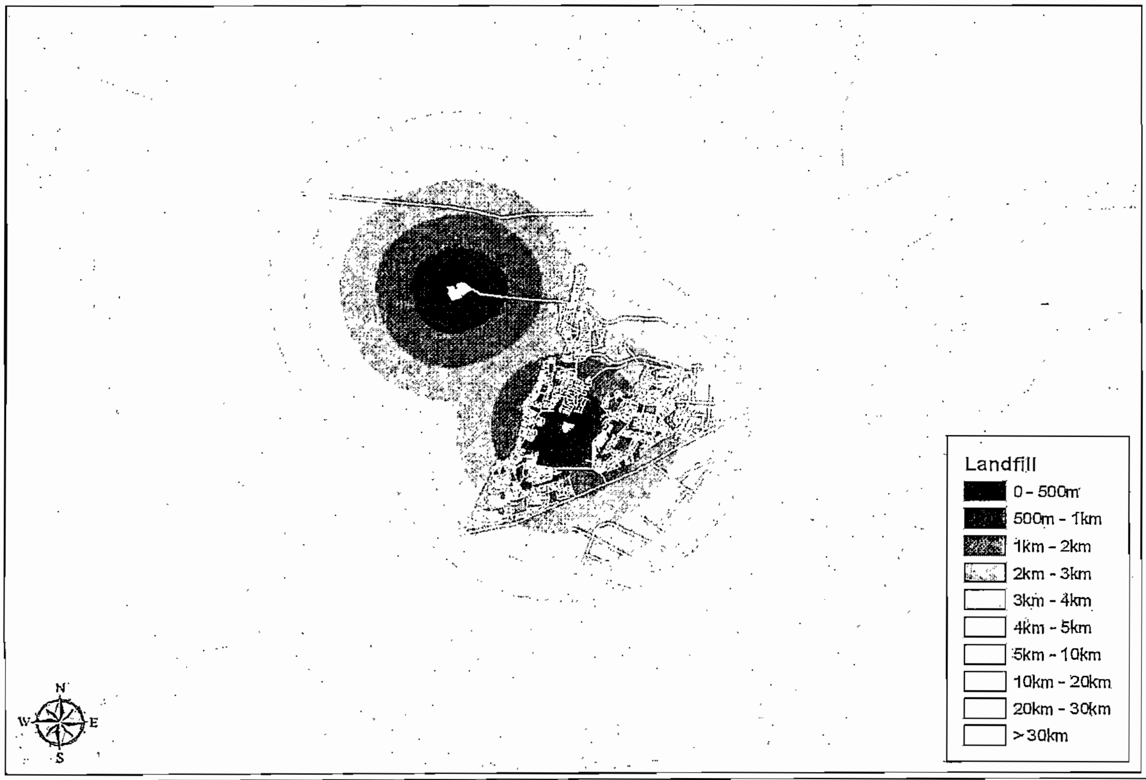
Rate the desirability of each of the given **distance** intervals for **residential and commercial development** with regard to **prisons.**



Distance	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 500m						
500m – 1km						
1km – 2km						
2km – 3km						
3km – 4km						
4km – 5km						
5km – 10km						
10km – 20km						
20km – 30km						
> 30km						

Question 6

Rate the desirability of each of the given **distance** intervals for **residential and commercial development** with regard to **landfill sites.**



Distance	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 500m						
500m – 1km						
1km – 2km						
2km – 3km						
3km – 4km						
4km – 5km						
5km – 10km						
10km – 20km						
20km – 30km						
> 30km						

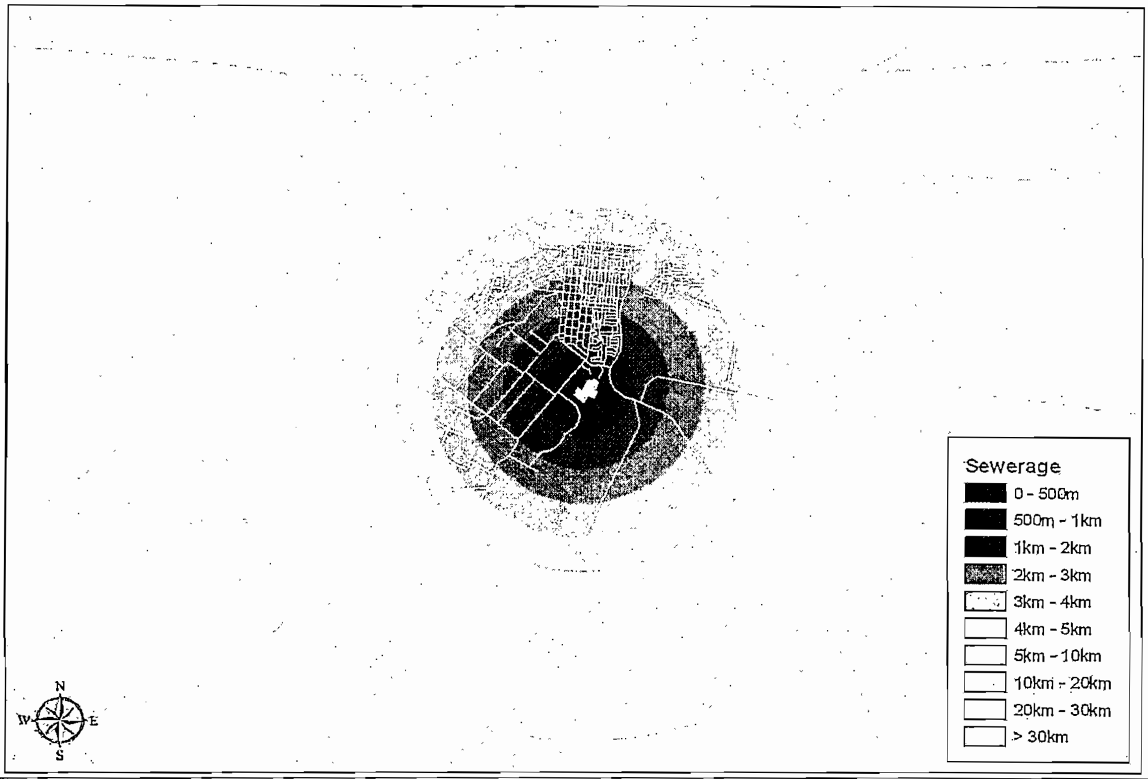
Question 7

Rate the desirability of each of the given **distance** intervals for **residential and commercial development** with regard to **cemeteries.**

Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 - 400						
401 – 800						
801 – 1200						
1201 – 1600						
1601 – 2000						
2001 – 2400						
2401 – 2800						
2801 – 3200						
3201 – 3600						
> 3600						

Question 8

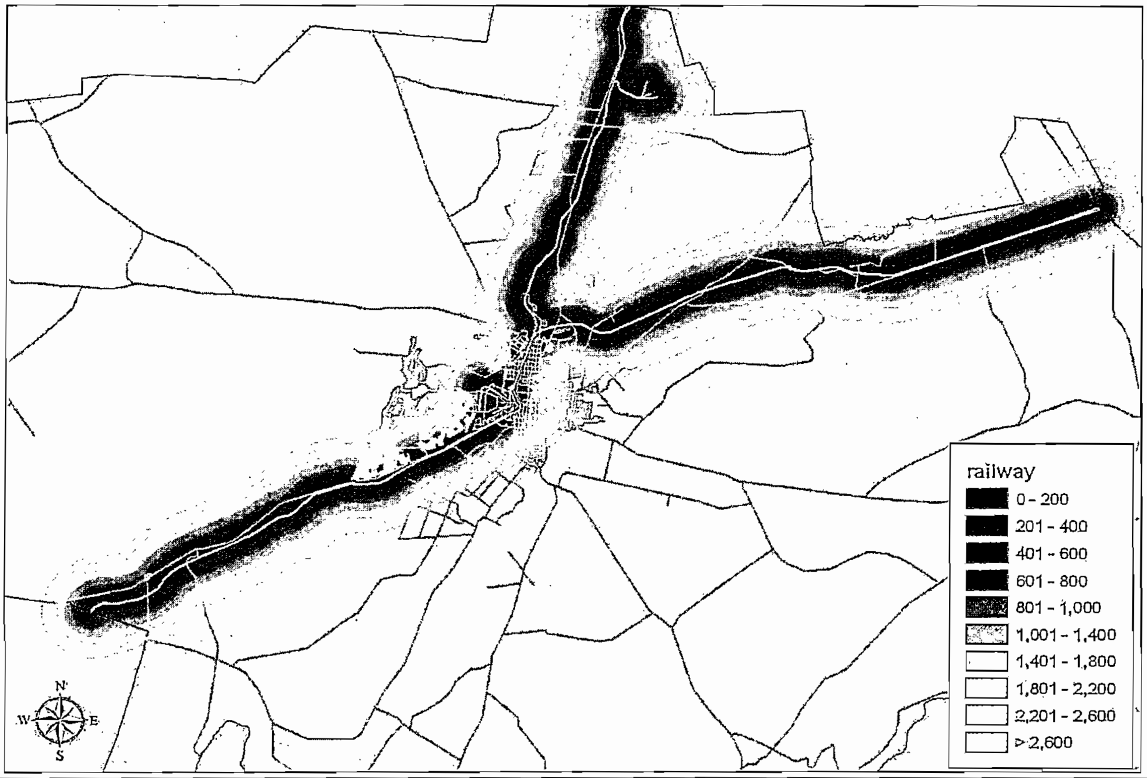
Rate the desirability of each of the given **distance** intervals for **residential and commercial development** with regard to **sewage works**.



Distance	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 500m						
500m – 1km						
1km – 2km						
2km – 3km						
3km – 4km						
4km – 5km						
5km – 10km						
10km – 20km						
20km – 30km						
> 30km						

Question 9

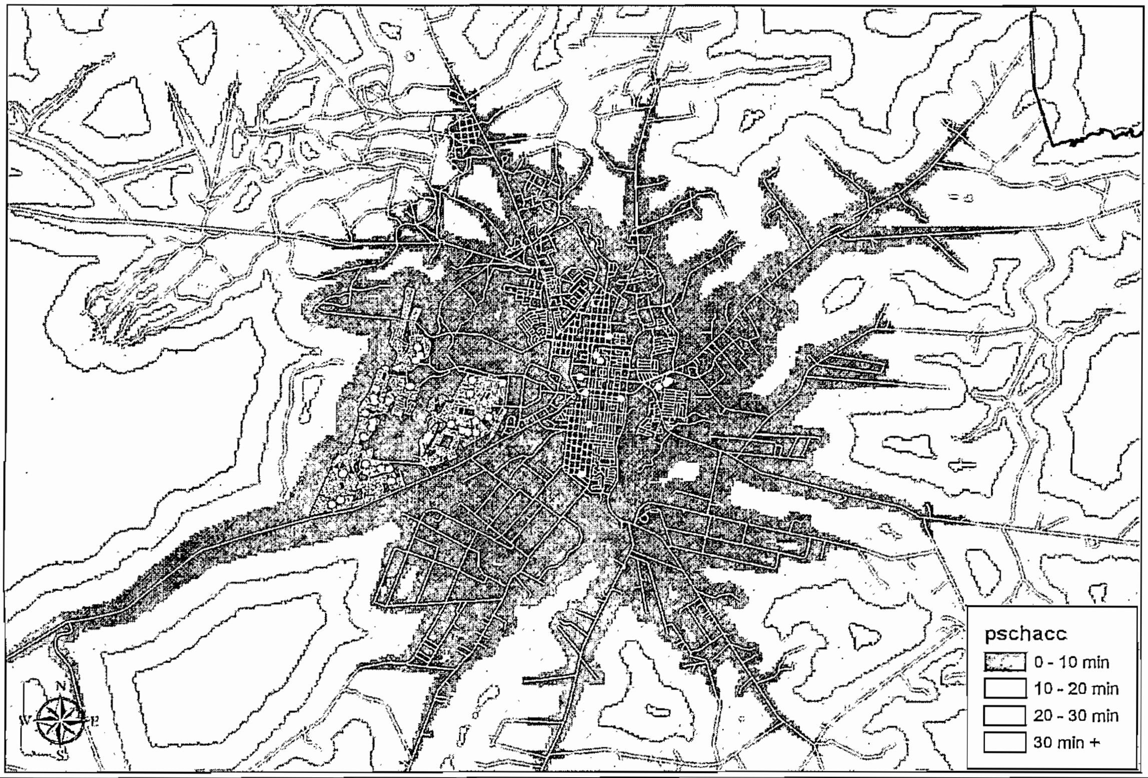
Rate the desirability of each of the given **distance** intervals for **residential development** with regard to **railway lines.**



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 10

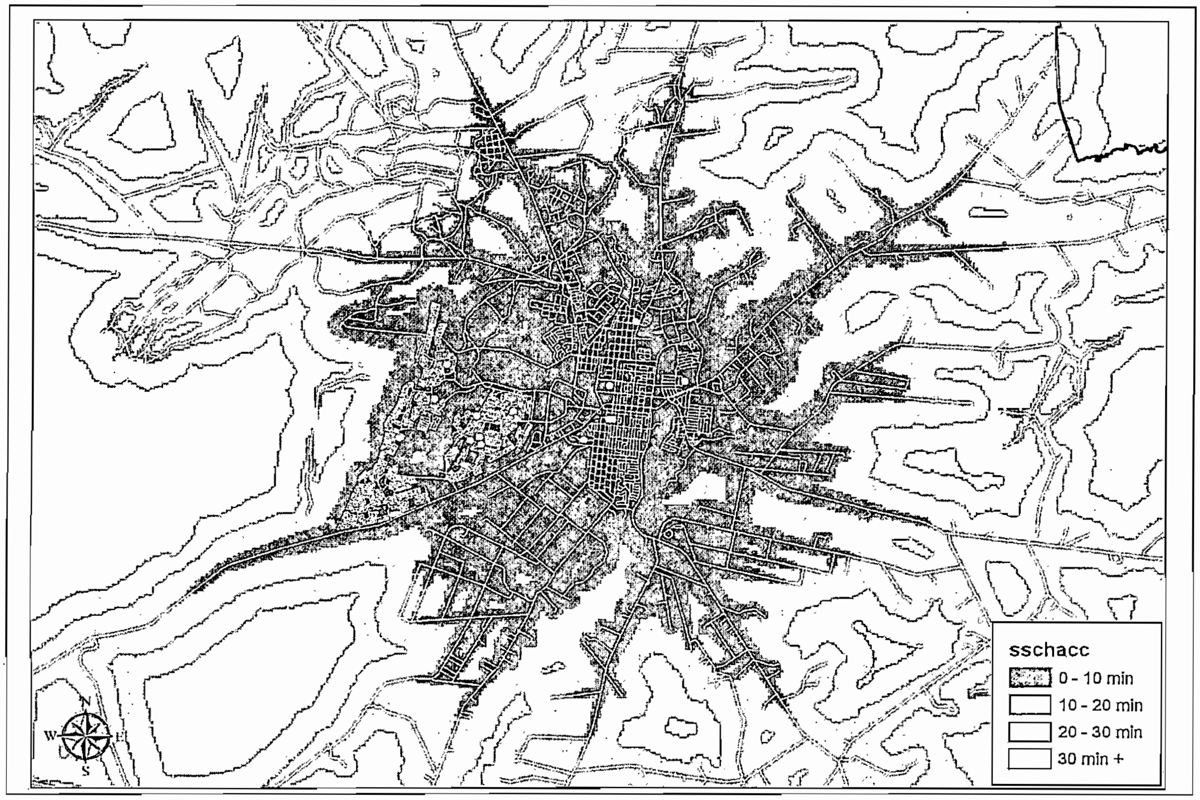
Rate the desirability of each of the given **travel time** intervals for **residential development** with regard to **primary schools** (includes pre-schools and crèches).



Travel time to schools (minutes)	**Restricted**	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 10						
10 – 20						
20 – 30						
30 +						

Question 11

Rate the desirability of each of the given **travel time** intervals for **residential development** with regard to **secondary schools**.



Travel time to schools (minutes)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 10						
10 – 20						
20 – 30						
30 +						

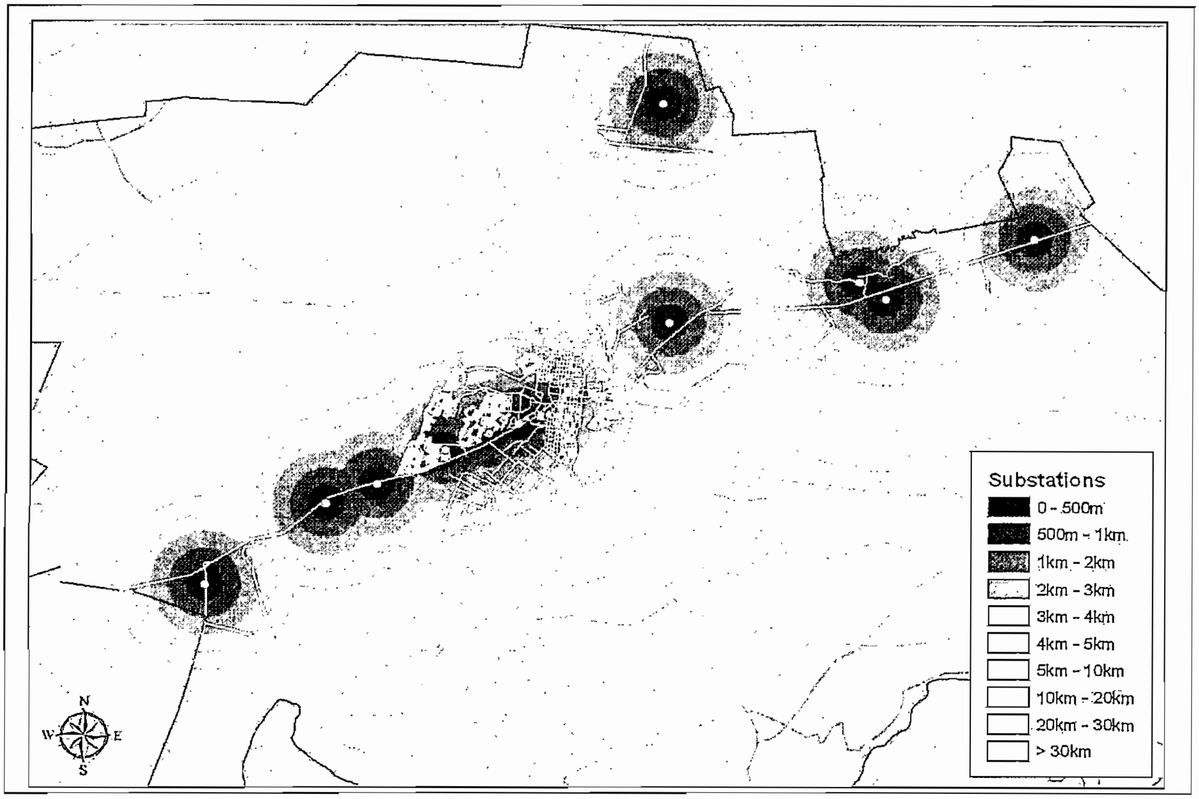
Question 12

Rate the desirability of each of the given **travel time** intervals for **residential development** with regard to **basic health care**.

Travel time to health care (minutes)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 10						
10 – 20						
20 – 30						
30 +						

Question 13

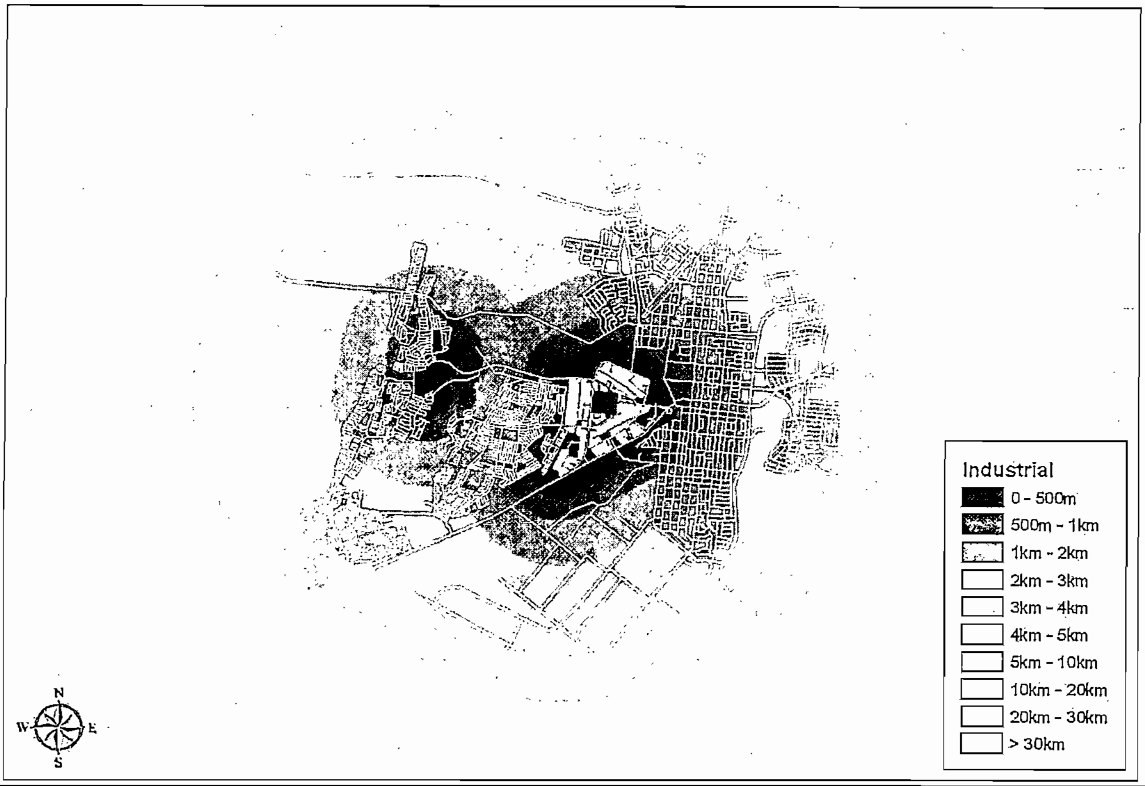
Rate the desirability of each of the given **distance** intervals for **residential development** with regard to **energy substations 88KV+** (seen as a negative factor).



Distance	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 500m						
500m – 1km						
1km – 2km						
2km – 3km						
3km – 4km						
4km – 5km						
5km – 10km						
10km – 20km						
20km – 30km						
> 30km						

Question 14

Rate the desirability of each of the given **distance** intervals for **residential development** with regard to **industrial areas** (seen as a negative factor).



Distance	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 500m						
500m – 1km						
1km – 2km						
2km – 3km						
3km – 4km						
4km – 5km						
5km – 10km						
10km – 20km						
20km – 30km						
> 30km						

Question 15

Rate the desirability of each of the given **distance** intervals for **residential development** with regard to **road networks** (distributor roads).

Distance	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 500m						
500m – 1km						
1km – 2km						
2km – 3km						
3km – 4km						
4km – 5km						
5km – 10km						
10km – 20km						
20km – 30km						
> 30km						

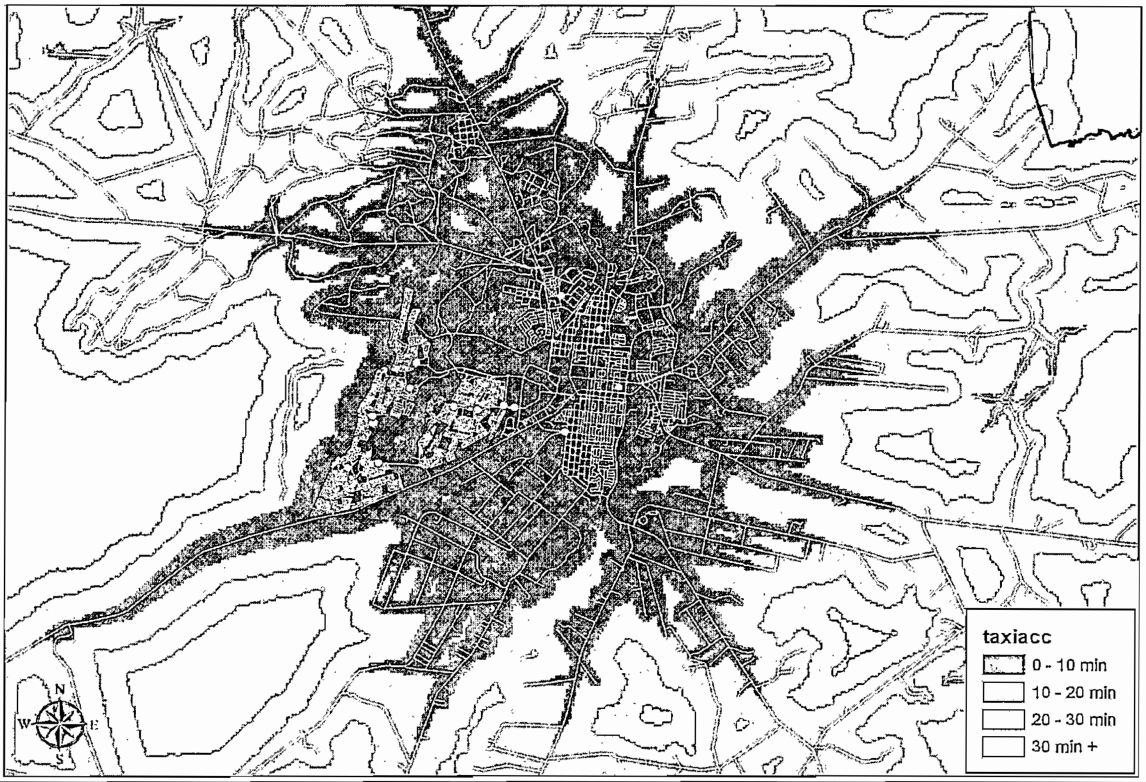
Question 16

Rate the desirability of each of the given **distance** intervals for **residential development** with regard to existing **residential areas.**

Distance in meters (m)	**Restricted**	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 17

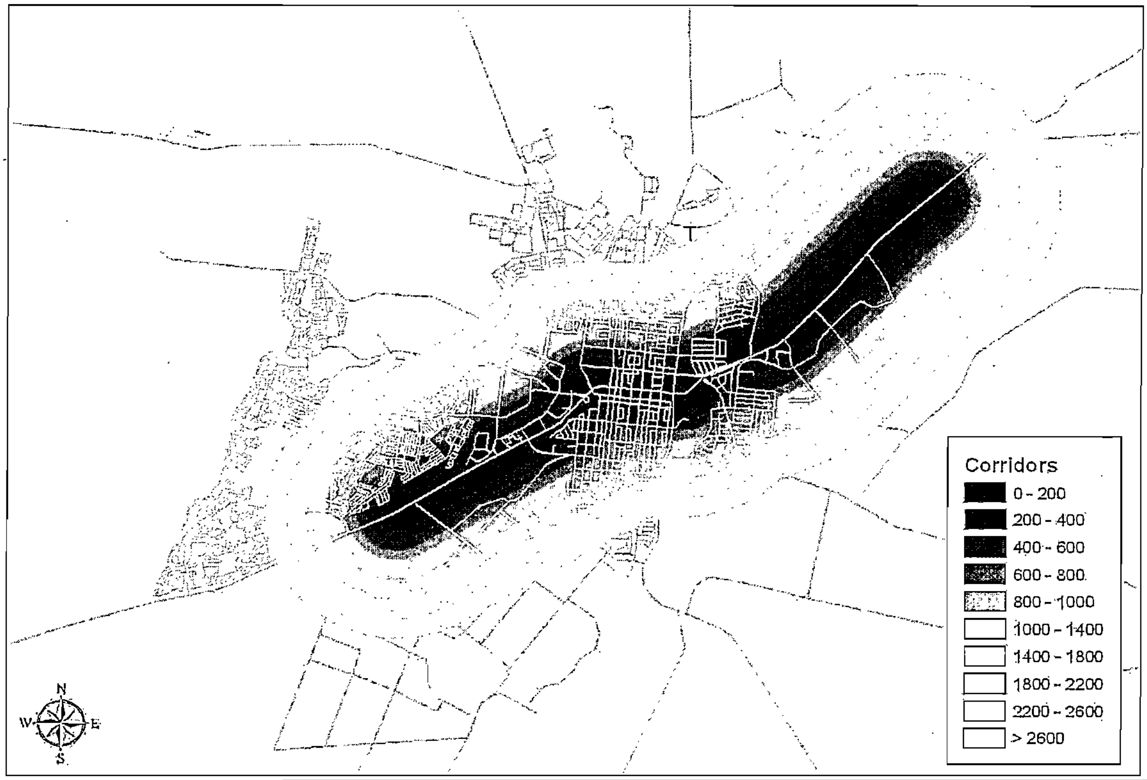
Rate the desirability of each of the given **travel time** intervals for **commercial development** with regard to **public transport terminus**.



Travel time to terminus (minutes)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 10						
10 – 20						
20 – 30						
30 +						

Question 18

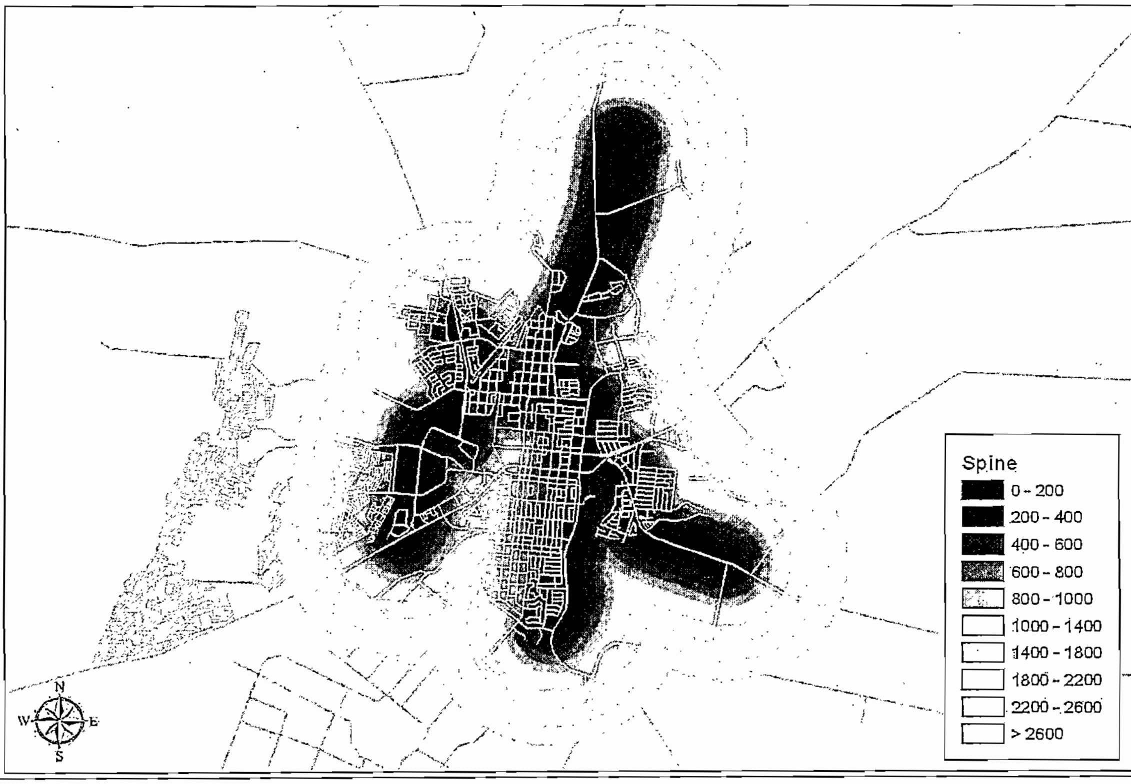
Rate the desirability of each of the given **distance** intervals for **commercial development** with regard to **activity corridors.**



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 19

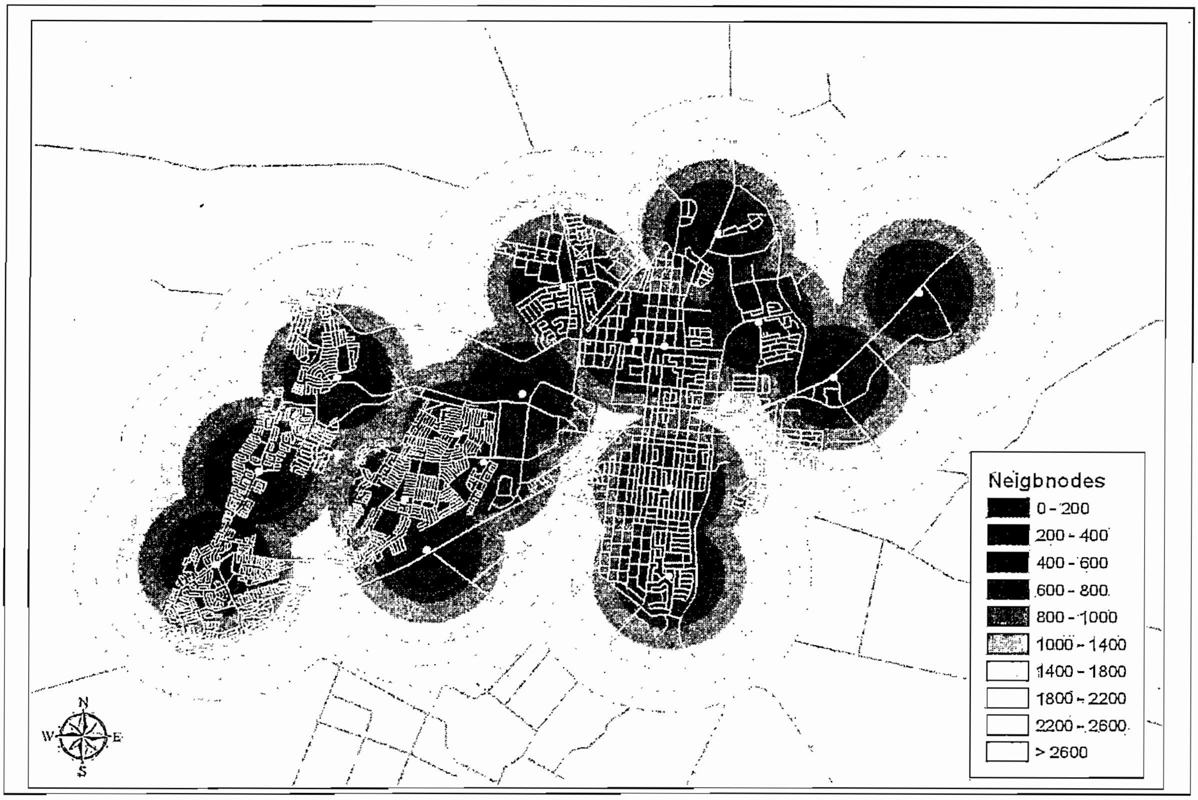
Rate the desirability of each of the given **distance** intervals for **commercial development** with regard to **activity spines.**



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 20

Rate the desirability of each of the given **distance** intervals for **commercial development** with regard to **existing neighborhood nodes.**



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

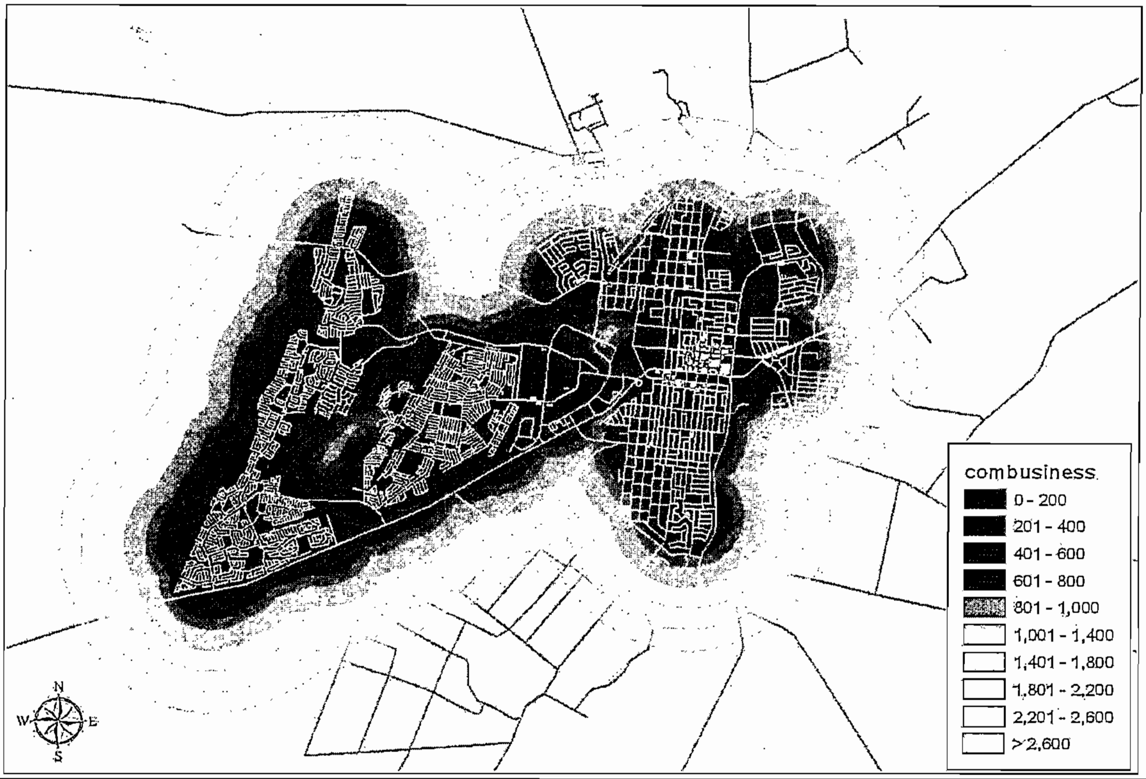
Question 21

Rate the desirability of each of the given **distance** intervals for **commercial development** with regard to **existing local nodes.**

Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 22

Rate the desirability of each of the given **distance** intervals for **commercial development** with regard to existing **commercial and business land uses**.



Distance in meters (m)	**Restricted**	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

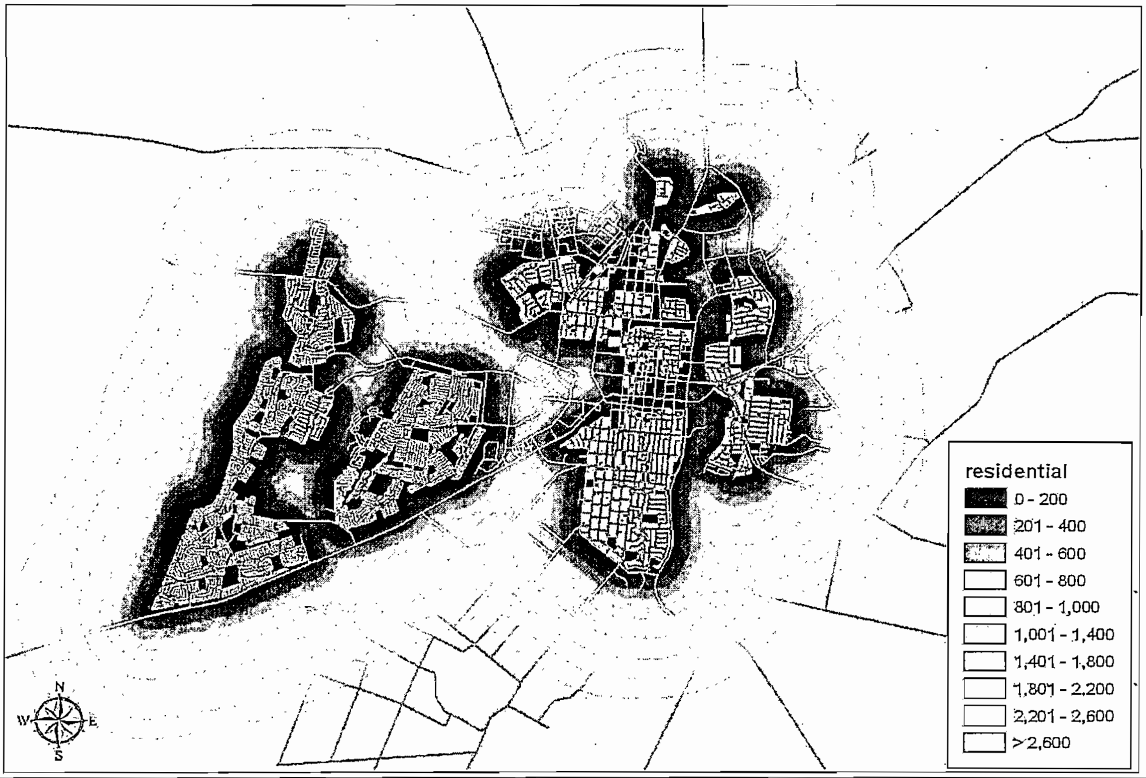
Question 23

Should **commercial and business** development be restricted (to a certain degree) to within the **urban fringe**?

Yes	
No	

Question 24

Rate the desirability of each of the given **distance** intervals for **industrial development** with regard to existing **residential areas.**



Distance in meters (m)	**Restricted**	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 25

Rate the desirability of each of the given **distance** intervals for **industrial development** with regard to existing **industrial areas**

Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 - 400						
401 – 800						
801 – 1200						
1201 – 1600						
1601 – 2000						
2001 – 2400						
2401 – 2800						
2801 – 3200						
3201 – 3600						
> 3600						

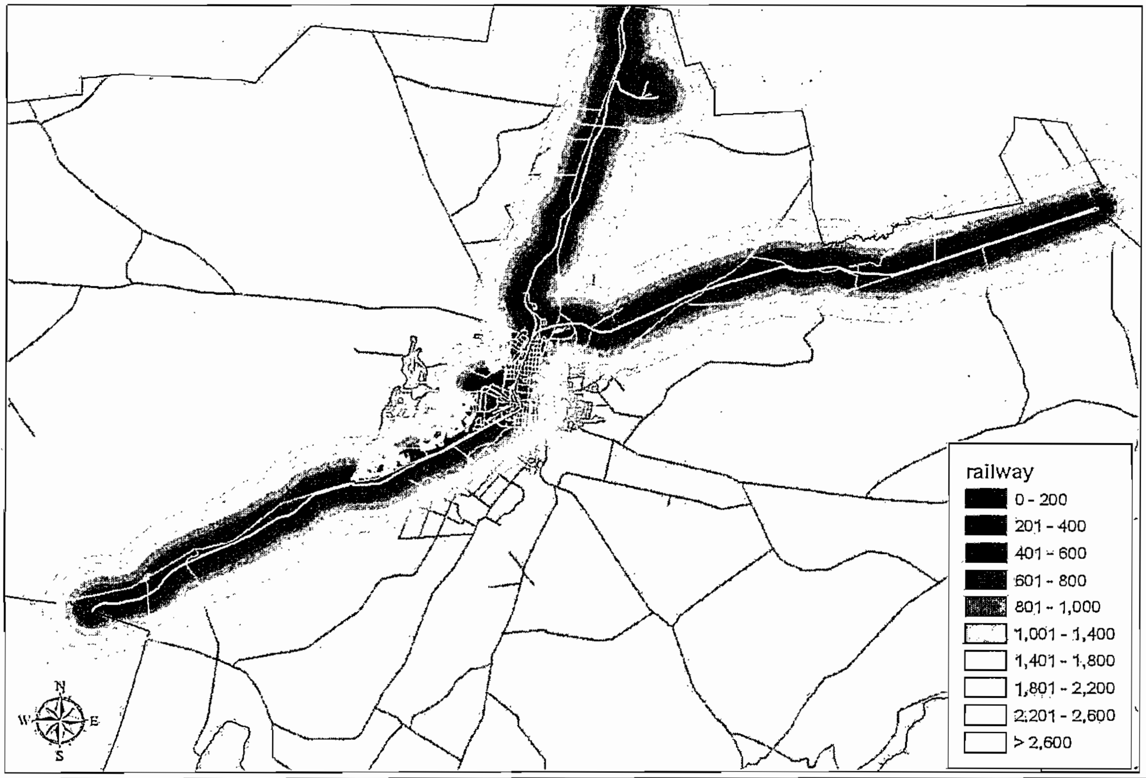
Question 26

Rate the desirability of each of the given **distance** intervals for **industrial development** with regard to **road networks** (main access routes).

Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Question 27

Rate the desirability of each of the given **distance** intervals for **industrial development** with regard to **railway lines**.



Distance in meters (m)	Restricted	Very bad 1	Bad 2	Neutral 3	Good 4	Very good 5
0 – 200						
201 – 400						
401 – 600						
601 – 800						
801 – 1000						
1001 – 1400						
1401 – 1800						
1801 – 2200						
2201 – 2600						
> 2600						

Section B: Overall weights of importance

In this second and final section weights of importance has to be given to each of the datasets discussed in Section A. Please rate the datasets as done in the example.

Residential – *Socio-economic aspects*	**Weight** *(the sum of all the values must equal 100)*
Proximity to Primary Schools	**20 %**
Proximity to Secondary Schools	**10 %**
Proximity to Health Services	**25 %**
Proximity to Existing Residential Development	**30 %**
Proximity to Prisons	**15 %**
	Total = 100

Residential – *Physical aspects*	**Weight** *(the sum of all the values must equal 100)*
1.1.1_Proximity to substations (negative factor)	
1.1.2_ID land with good slope	
1.1.3_Proximity to transmission lines (servitute)	
1.1.4_Closeness to prisons	
1.1.5_Proximity to railway (bad)	
1.1.6_Proximity to lanfills, cemetry and sewerage	
1.1.7_Proximity to industrial areas	

Residential – *Socio-economic aspects*	**Weight** *(the sum of all the values must equal 100)*
1.2.1_Proximity to existing residential areas	
1.2.2_Proximity to primary schools	
1.2.3_Proximity to secondary schools	
1.2.4_*Proximity* to basic health care	
1.2.5_Proximity to distribution roads	
1.2.6_Proximity to bulk services	

Commercial – *Physical aspects*	**Weight** *(the sum of all the values must equal 100)*
2.1.1_Slope of land	
2.1.2_Proximity to transmission lines (servitute)	
2.1.3_Closeness to prisons	
2.1.4_Proximity to railway (bad)	
2.1.5_Proximity to lanfills, cemetry and sewage	
2.1.6_Proximity to industrial areas	

Commercial – *Socio-economic aspects*	**Weight** *(the sum of all the values must equal 100)*
2.2.1_Proximity to existing commercial	
2.2.2_Proximity to existing activity corridors	
2.2.3_Land close to major activity splines	
2.2.4_Land proximity to neighborhood nodes	
2.2.5_Land proximity to local nodes	
2.2.6_Land proximity to public transport terminus	
2.2.7_Proximity to bulk services	
2.2.8_Land within urban edge	

Industrial – *Physical aspects*	**Weight** *(the sum of all the values must equal 100)*
3.1.1_Slope of land	
3.1.2_Proximity to transmission lines (servitude)	

Industrial – *Socio-economic aspects*	**Weight** *(the sum of all the values must equal 100)*
3.2.1_Proximity to residential areas	
3.2.2_Proximity to industrial areas	
3.2.3_Proximity to access	
3.2.4_Proximity to railroads (positive factor)	
3.2.5_Proximity to services	

Thanks for your time and contribution!