Land-use suitability modelling as an input for spatial planning in Tlokwe local municipality, North-West province, South Africa

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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 policymakers 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.

GRONDGEBRUIKGESKIKTHEID-MODELLERING AS 'N INSET TOT RUIMTELIKE BEPLANNING IN DIE TLOKWE PLAASLIKE MUNISIPALITEIT, NOORDWES PROVINSIE, SUID-AFRIKA

Gedurende die laaste jare het kwessies, direk verwant met die toestand van die natuurlike omgewing, 'n toenemend belangrike rol in die globale arena van politiek en die burgerlike samelewing begin speel. Dit is van kardinale belang dat hierdie kwessies in beplanningsprosesse en ontwikkelingsraamwerke geïntegreer word, om sodoende die oogmerke van bewaring van die natuurlike omgewing en die bevordering van volhoubare ontwikkeling te bereik. Hierdie artikel ondersoek die gebruik van 'n GIS-gebaseerde ruimtelike modelleringmetode om bogenoemde te verwesenlik. Die sukses van so 'n benadering kan die effektiewe inkorporasie van omgewingsdata in ruimtelike beplanning, en meer spesifiek Ruimtelike Ontwikkelingsplanne (SDFs), verseker; iets wat selde die geval in Suid-Afrika is. Die studie het bevind dat die voorgestelde benadering met groot sukses gebruik kan word en dat dit beplanners en beleidmakers kan ondersteun in die uitdaging om grondgebruikbestuur op 'n volhoubare wyse uit te voer. Die studie het verder getoon dat 'n proaktiewe, interdissiplinêre benadering tot grondgebruikbestuur op 'n strategiese vlak binne Suid-Afrikaanse munisipaliteite moontlik is.

MORALO O NEPAHETSENG WA TSHEBEDISO YA LEFTSHE E LE PHEHISO YA MORALO O BATSI HO MMASEPALA WA LEHAE WA TLOKWE, PROFINSING YA NORTH-WEST, HO LA AFRIKA BORWA

Dilemong tse sa tswa feta, ditba tse mabapi le boem ba tikoloho ya tlhaho e simolotse ho phaella ho etsa mosebetsi o babatsehang sebayeng sa dipolotiki tsa lefatshe le setjhabeng. Ke ntho ya bohlokwa hore ditaba tsena di kenyeleditswe ditshebetsong tsa moralo le dibopehong tsa ntshetsopele ka mokgwa oo ka wona tshireletso ya tikoloho ay tlhaho le ntlafatso ya ntshetsopele e tswelang pele ya diphihlello e ka fihlellwlang ka wona. Ditaba tsena di hlahloba tshebediso ya mokgwa wa moralo wa ntshetsopele o theilweng hodima mokgwa wa moralo o batsi wa GIS ho fihlella tse mona hodimo. Katleho ya mokgwa wona e ka tiisa ho kopanngwa ha ditlhkisetso tse bolokilweng tsa tikoloho moralong wa sebak, le haholoholo Dibopehong tsa Ntshetsopele tsa Sebaka (SDFs) tseo hangata e seng tlwaelo mona ho la Afrika Borwa. Thuto ena e fumana hore mokgwa wona o ka sebediswa ka katleho e kgolo ebile o ka thusa baradi le ho baradi ba maano phepetsong ya ho lebisa tsamaisong ya tshebediso ya lefatshe mokgweng o tswelang pele. Thuto ena e bontsha mokgwa wa tshebetso le wa tsamaiso e nepahetseng tsamaisong ya tshebediso ya lefatshe o kgonehang boemong ba ho rala leano ho bommasepala ba Afrika Borwa.

1. INTRODUCTION

Migration in South Africa historically consisted of two main components, i.e. a natural process based on the socio-economic mobility of the white population group, and a regulated process of migration of the black population group (Mears, 2004: 16). The latter process was 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 formalised neighbourhoods, separated from white neighbourhoods. Since the abolishment of apartheid era planning practices in the 1990s (Drewes & Cilliers, 2004: 15), South Africa experienced rural-urban migration (urbanisation) and, consequently, urban development.

In developed countries, on the other hand, urban sprawl is one of the phenomena that coincides with a mature level of urbanisation. 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 & Kontuly (1993). Geyer & Kontuly (1993: 167-172) state 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 called productionism. These two processes are extremely relevant to the South African situation, and form a cycle that ultimately leads to decentralisation, deconcentration and 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 there are various explanations for the reasons why urban sprawl occurs. Various authors

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(Henderson, 1985: 180; Wu & Plantinga, 2003: 289; Nechyba & Walsh, 2004: 179; Wu, 2006: 528; Miceli & Sirmans, 2007: 5; Martinuzzi, Gould & Gonzalez, 2007: 196) have attempted to explain why urban sprawl transpires, but the majority of these explanations differs to a great extent. Henderson (1985: 180), for instance, argues that urban sprawl occurs because people tend to move outward in search of lower density areas, while Martinuzzi *et al.* (2007: 296) state that the reasons for urban sprawl cannot be generalised as it occurs for different reasons in different cities. Miceli & Sirmans (2007: 5) state that urban sprawl transpires because people with land on the periphery tend to leave it undeveloped, in the hope that its value may rise. This, in due course, forces development to continue in a fragmented manner behind that land.

Whatever the case may be, 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, pose a threat to the ecology of natural landscapes and sustainable development (Sudhira, Ramachandra & Jagadish, 2004: 33). There is certainly no way to prevent urban development from taking place; the challenge, however, will be to manage this development and its spatial implications 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, 1999: 120). It is no easy task to achieve this. It calls for interdisciplinary collaboration between 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, Schulenberger, Endlicher, Alberti, Bradley, Ryan, Simon & Zumbrunnen, 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). In 1987 it became a crucial 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, 1987: 48-57). This led to the realisation that man had the capability to save the fragile and often deteriorating relationship between himself and the biosphere via sustainable development (Brundtland, 2007: 12). This, in turn, led to the first Earth Summit held in Rio de Janeiro, Brazil in 1992.

The Earth Summit focused on the emerging environmental and developmental 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 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 followed by a Local Action 21 process (Marx, 2003: 15), aimed at assisting local governments in implementing their Local Agenda 21. One of the main goals of Local Action 21 was to advance the establishment of sustainable communities and cities (Otto-Zimmermann, 2002: 465-469). This idea 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 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 ensure the protection of biodiversity (UNCHS, 1996: 46-62). To reach the goal of sustainable human settlements, it is important that these three elements be treated with equal importance.

The importance of integrated environmental management, by means of integrating social and environmental data, must be realised. In other words, planners, ecologists and economists should collaborate 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 in all spheres of government (Retief, 2007: 11; Pekelharing, 2008: 55).

Although IDP is still a relatively new planning requirement, the success of its application can be observed in 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-oriented tasks in their areas of jurisdiction (Pekelharing, 2008: 54), and has been a legal requirement for local governments since November 1996 (DPLG, 2000: 3), when it was enforced by the *Local Government Transition Act (Second Amendment Act)* of 1996 (South Africa, 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 it is now enforced by the *Municipal Systems Act of 2000* (South Africa, 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. Unfortunately, the reality in South Africa is that this very seldom, if ever, effectively happens (Sowman & Brown, 2006; Retief, 2007). As this study deals with spatial planning and development, the focus will be on SDFs in particular. Annexure A indicates the different legislation and policies relevant to IDPs and SDFs while Annexure B summarises the relevance of these different legislations and policies to SDFs.

Of the policies and legislations mentioned in Annexures A and B, 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 an SDF (South Africa, 2000: 20). It is also stated that these development plans should comply with the Constitution and the Development Facilitation Act principles, i.e. sustainable development. Although the *Municipal Systems Act* does not describe the detail of a SDF, it does stress the importance of SDFs in spatial planning (South Africa, 2000: 23). The detailed 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;
- 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 utilisation of space in a specific area (South Africa, 2001a: 2).

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 (South Africa, 2001b: 19). It also states that a SDF should guide and inform on the following issues:

- Directions of growth;
- Conservation of the built and natural environment;
- Areas where particular types of land-use should be encouraged and others discouraged (this impliesthat land-uses should be encouraged or discouraged in terms of their suitability in a particular area), and
- Areas where the intensities of land-use should be increased or reduced (South Africa, 2001b: 19).

According to the *White Paper on Spatial Planning*, a SDF should be considered 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 a 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 & Cilliers (2004: 27) propose an integrated land-use management system that would guide decision-making, and show areas suitable for specific land-use while excluding others. This research aims to achieve the above by proposing an integrated GIS-based, spatial modelling approach to determine the most suitable areas for urban development (considering environmental and agricultural factors) and accordingly assist in the delineation of an urban edge. The proposed model will aim to realise the requirements described for SDFs in the *Local Government Municipal Planning and Performance Regulations of 2001* (South Africa, 2001a) and the *White Paper on Spatial Planning and Land-use Management of 2001* (South Africa, 2001b) by:

- Generating a land-use specific urban growth scenario;
- Identifying desired directions of urban growth;
- Providing a visual representation of the desired spatial form of the study area, and
- Identifying priority development areas.

Finally, the modelling results will be compared with the existing SDF for the study area in an attempt to assess the possible value of such an approach to spatial planning in South Africa. This study focuses on the value of a GIS-based land-use suitability modelling approach to spatial planning rather than on the detailed methodology involved in the modelling process.

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 1). Potchefstroom serves as a primary regional node (Maxim, 2008: 49), with a population of approximately 140.000, and 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 approximately 15% over the past 15 years. Potchefstroom has shown a positive economic growth rate over the past years, and has a relatively stable economy (Maxim, 2008: 13). This can be ascribed to Potchefstroom's diverse economy, which consists of various intertwining sectors. Although this study focuses on Potchefstroom and its immediate surroundings, the entire local municipality was included in the analysis to ensure an adequate buffer zone.

5. SPATIAL MODELLING

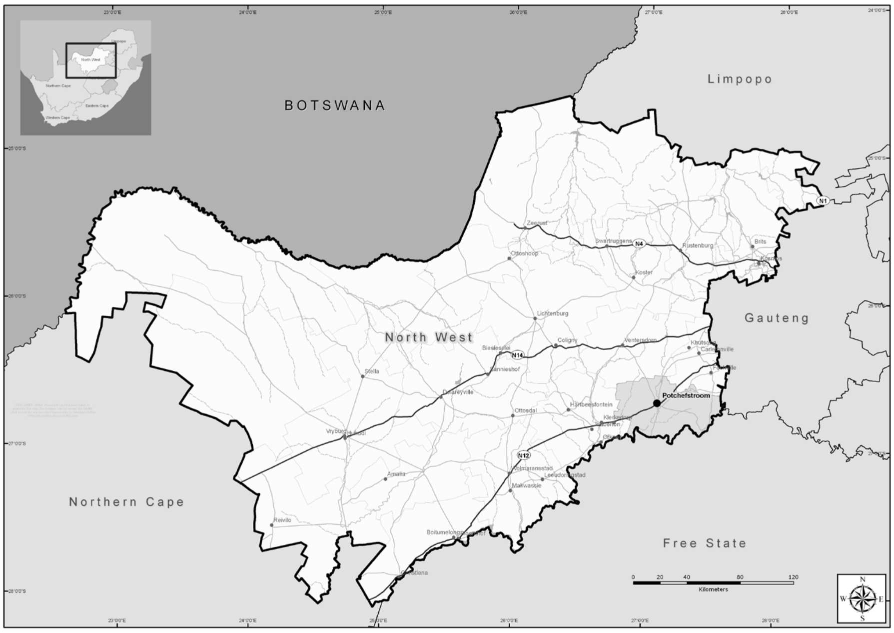


Figure 1: Potchefstroom locality map
Source: Authors' own compilation

According to Belton & Steward (2002: 1), every decision 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 (MCA) was developed in the 1960s 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 MCA and can potentially be used to assist planners and policymakers in the development of SDFs and other strategic plans.

The first traces of land-use suitability modelling date back to the late 19th century, when landscape architects superimposed transparent sheets of paper on a window to view multiple site characteristics at the same time (Carr & Zwick, 2007: 46). This technique came to be known as sieve mapping, and was later used for site suitability analysis by town planners in Scotland and England. In 1969 Ian McHarg proposed an alternative approach to planning that made use of sieve mapping techniques to take a wide variety of factors, such as soils, plants, animals, topography, ecosystems, *etc*. into consideration when planning physical development (McHarg, 1969). Since then, references to various approaches of land-use suitability modelling can be found in the works of Beek & Benemma (1972), Pathan, Jothimani, Choudhary, Som & Mukherjee (1992) and more recently Joerin, Theriault & Musy (2001) and Carr & Zwick (2005; 2007). In the South African context elements of land-use suitability modelling are observed in plans such as the Gauteng Conservation Plan (GDACE) (2005) and the North-West Conservation Assessment (Desmet, Schaller & Skowno, 2008), although the processes followed and outcomes obtained differ greatly from the one discussed in this article.

Though spatial models cannot incorporate all aspects of reality, they can still provide planners and policymakers with valuable 'what if?' scenarios, which can assist them in decision-making processes (Veldkamp & Lambin, 2001: 1; Koomen, Rietveld & De Nijs, 2007: 2). These 'what if?' scenarios have the advantage of broadening 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 2).

The approach developed 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 analysed 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. The most significant difference between this study and the LUCIS model is that the results of the suitability analysis were used in conjunction with population statistics to arrive at an urban rowth scenario, indicating specific future urban land uses (Figure 2). The method and results will be discussed in the following section, and the results will be compared to the existing SDF for the study area.

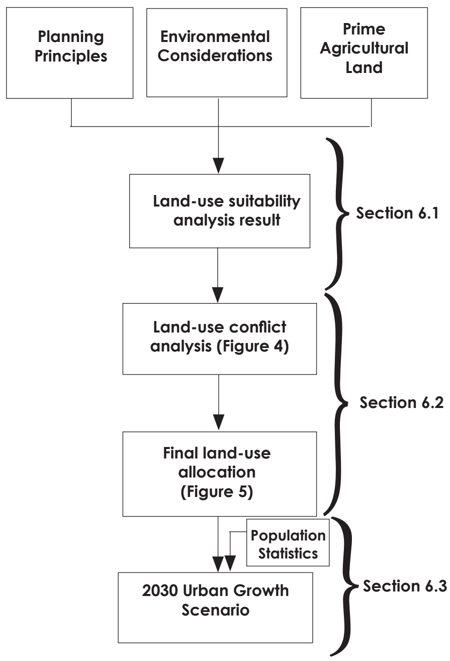


Figure 2: Analysis process
Source: Authors' own compilation

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 utilises 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 3a two datasets are overlaid at weights of 50% each; Figure 3b 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 3. Despite this disadvantage, weighted overlay has many advantages of which some of the most prominent ones 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.

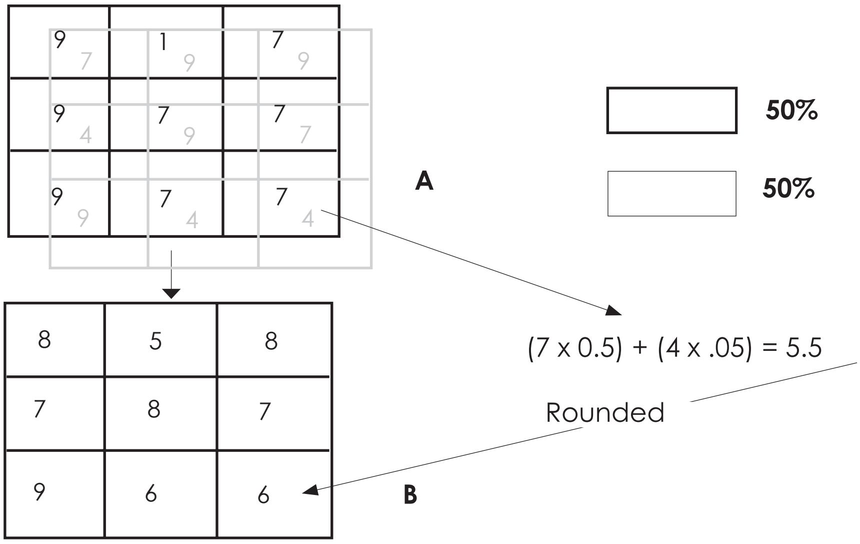


Figure 3: Weighted overlay procedure
Source: Authors' own compilation

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 1 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, they were overlaid at weights of equal importance to derive the land-use suitability result.

Three zonings were selected for the urban preference analysis, namely residential, commercial and industrial. Each one was divided into physical suitability and socio-economic suitability with corresponding data inputs for each category. Thirty-three 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 (the majority of the registered planners in Potchefstroom) 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 was calculated and analysed by means of an adapted Delphi method. These values were then used in different weighted overlay procedures to attain an urban preference layer.

For the agricultural and conservation preference layers, experts and expert reports were consulted. The agricultural layer used a process known as the CERES-maize model (Du Toit, Booysen & Human, 1994) to generate a potential yield layer for maize in the Potchefstroom area. This result was combined with an existing land capability layer retrieved from the Agricultural Research Council (2007: online) to arrive at an agricultural preference result for Potchefstroom. The North-West Province Conservation Assessment (Desmet *et al.*, 2008) was consulted for the biodiversity analysis. 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.

The above three preference layers 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 4): major conflicts (where all three land uses had equal importance); urban/conservation conflicts; urban/agriculture conflicts, and agriculture/conservation conflicts. The methodology 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 analysed 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. Some of the conflicts could be resolved by consulting the original datasets and normalising their values. Although the majority of the conflicts were resolved, in some cases no distinction could be made and land was again indicated as conflict areas (Figure 5). Once the majority of the conflicts were resolved and land uses were allocated, the final land-use allocation scenario (Figure 5) was obtained. The land-use suitability scenario indicates the suitability of land for specific land uses and distinguishes between land with high urban suitability, medium-/long-term urban suitability, high agricultural suitability, medium agricultural suitability, high conservation suitability and medium conservation suitability. It is important to realise that the land-use suitability scenario is purely a product of the input data and criteria used during analysis and is only a 'what if?' scenario of what might be. It is crucial that input criteria bare determined via a scientifically sound method and that the data used for the analysis is accurate and obtained from a dependable source.

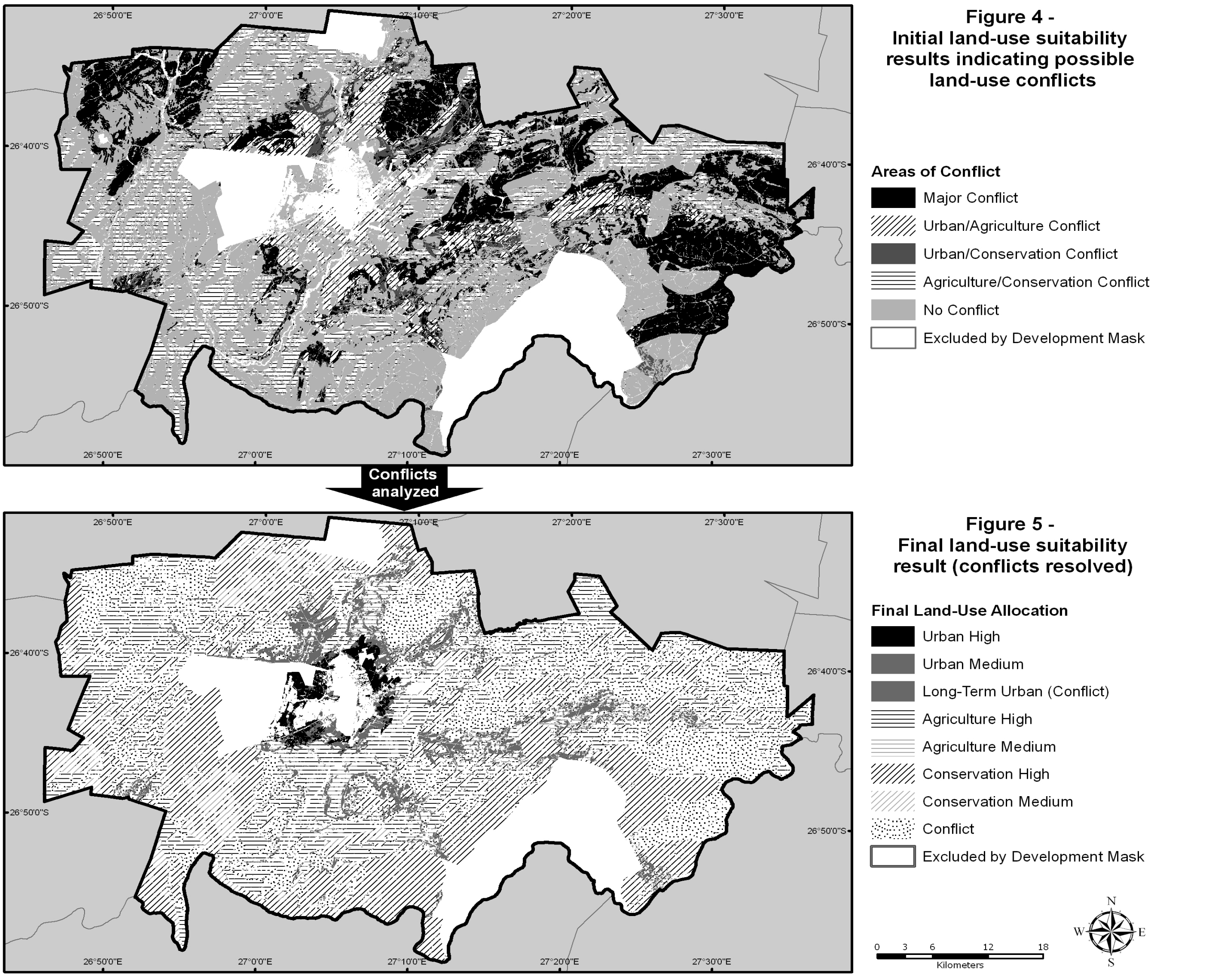
6.3 Urban growth modelling and model validation

The final land-use allocation result was used as the base dataset for modelling urban growth (Figure 2). 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 obtained from the Tlokwe Local Municipality land-use budget (DPLG, 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 m2) 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 6).

Because the datasets that were used to exclude existing urban land uses in the land-use suitability modelling phase were data from 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 also indicated the development of a commercial/business area 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 land-use suitability result (Figure 5) and the urban growth scenario (Figure 6) were compared to the existing SDF for Potchefstroom (Figure 7). The reason for this is that detailed urban ecological data (which was intentionally not used in this study) generated through research at the



Figures 4 & 5: Land-use suitability results
Source: Authors' own compilation

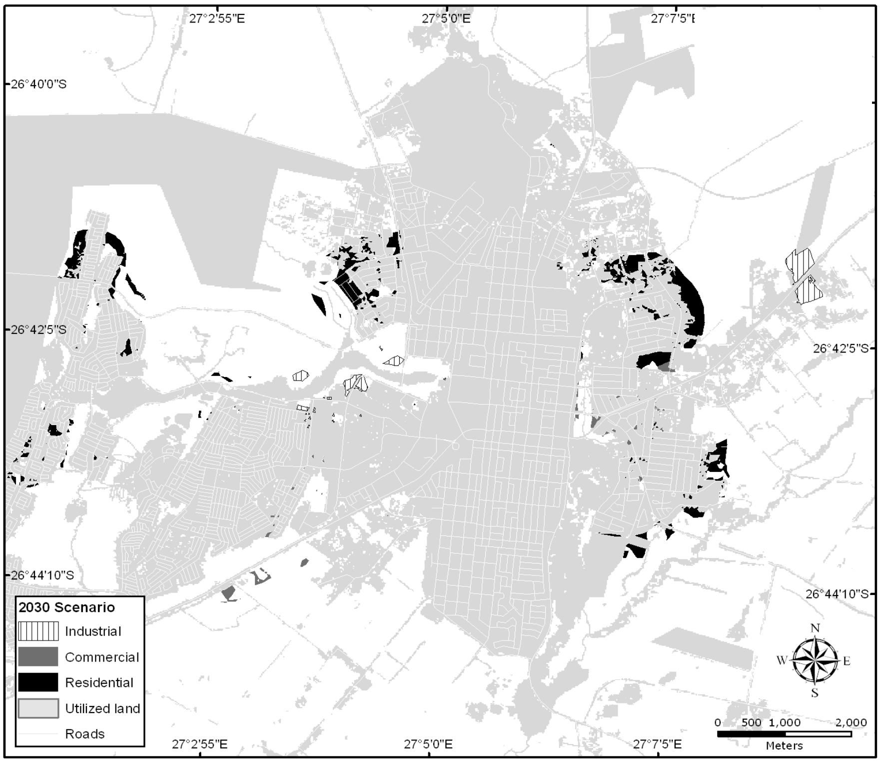


Figure 6: 2030 urban growth scenario
Source: Authors' own compilation

North-West University were considered in the development of the Potchefstroom SDF. Data of this nature is very scarce in South Africa, with very few municipalities having access to similar types of detailed expert data. Therefore, Potchefstroom's SDF can be considered an excellent example of a sustainable development-orientated strategic spatial plan and hence be an excellent criterion for the modelling results.

In comparing the suitability result (Figure 5) with the SDF, it was found that the land-use suitability scenario endorses the way in which Potchefstroom's SDF considered the importance of critical biodiversity areas and potential conservation areas when allocating land for future development. Some differences did exist, however, and the significant ones were identified and indicated in Figure 8 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.

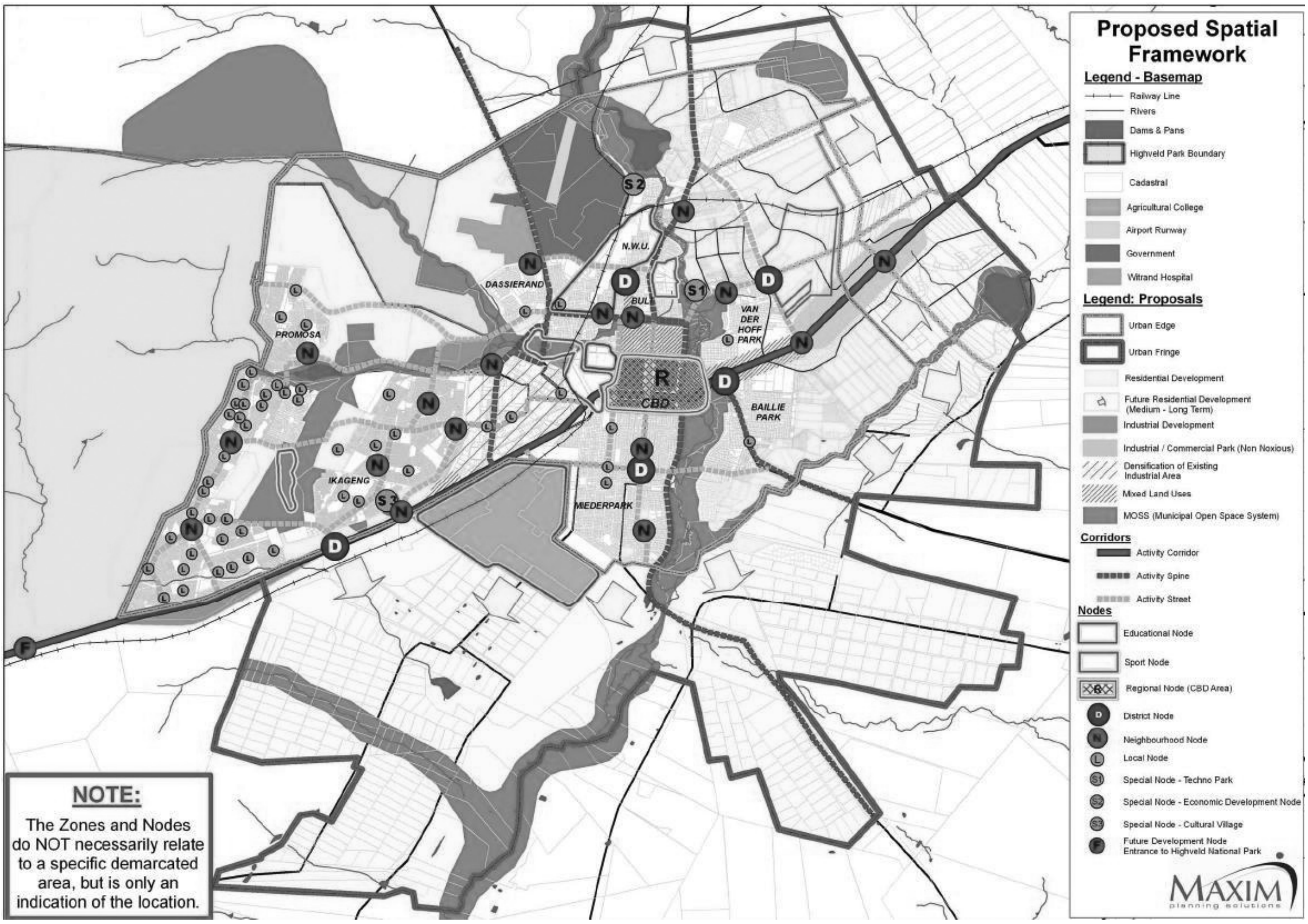


Figure 7: Proposed spatial framework
Source: Maxim, 2008: 20

Table 1: Overlay procedure and datasets

Final land-use allocation (Figure 5)										
Land-use conflict analysis (Figure 4)										
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	Proximity to prisons	Proximity to activity spines		Proximity to access routes	Optimal slopes for cropland				
Proximity 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

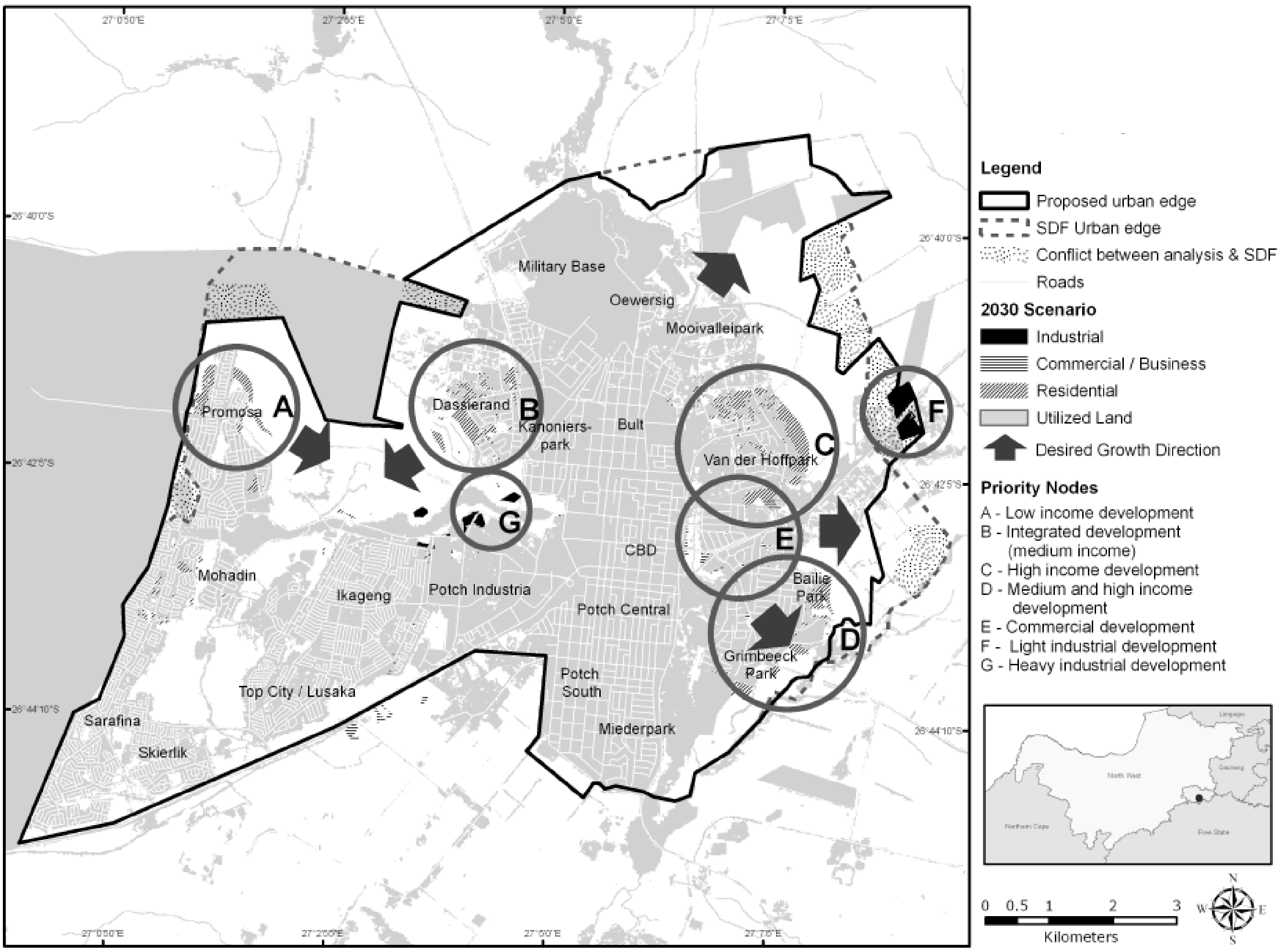


Figure 8: Comparison between SDF and analysis results
Source: Authors' own compilation

The greatest differences between the urban edge indicated in the existing SDF, and the newly proposed one, are on the eastern parts of town where development is currently taking place at a rapid rate.

The comparison between the urban growth scenario (Figure 6) and the SDF proved interesting. In the majority of instances, the urban growth results were 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 in Figure 8.

The first node (Node A) indicated a low-income development priority area in Promosa. The most likely reason for this is that the remainder 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. The second priority node (Node B) 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) 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, but to a lesser extent. The areas to the east and south-east of Baillie Park are suitable for future development, but will be constricted at some point by high potential agricultural land.

The fifth node (Node E) was the commercial development area to the east of the existing CBD. These indicated commercial areas are in close proximity to the N12 and the R53, making it 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) was the heavy industry zone, 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 can assist planners and policymakers in strategic planning processes and, in doing so, address the issue of effectively integrating environmental considerations into strategic plans. The fact that the modelling results and the existing SDF concur to a large extent proves that the method is effective. The study also 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 policymakers in identifying priority areas for development, and confining and restricting urban sprawl. The proposed approach could further assist policymakers 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* (South Africa, 2001a: 1-2) and the *White Paper on Spatial Planning and Land-use Management* (South Africa, 2001b: 19).

One of the most important objectives for spatial planning in the next 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 needs to be conducted into the methodologies for achieving this. Future research should attempt to incorporate public opinion as well as scientific considerations, while attempts should be made to include higher resolution (large-scale) 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 discourage urban sprawl in South Africa.

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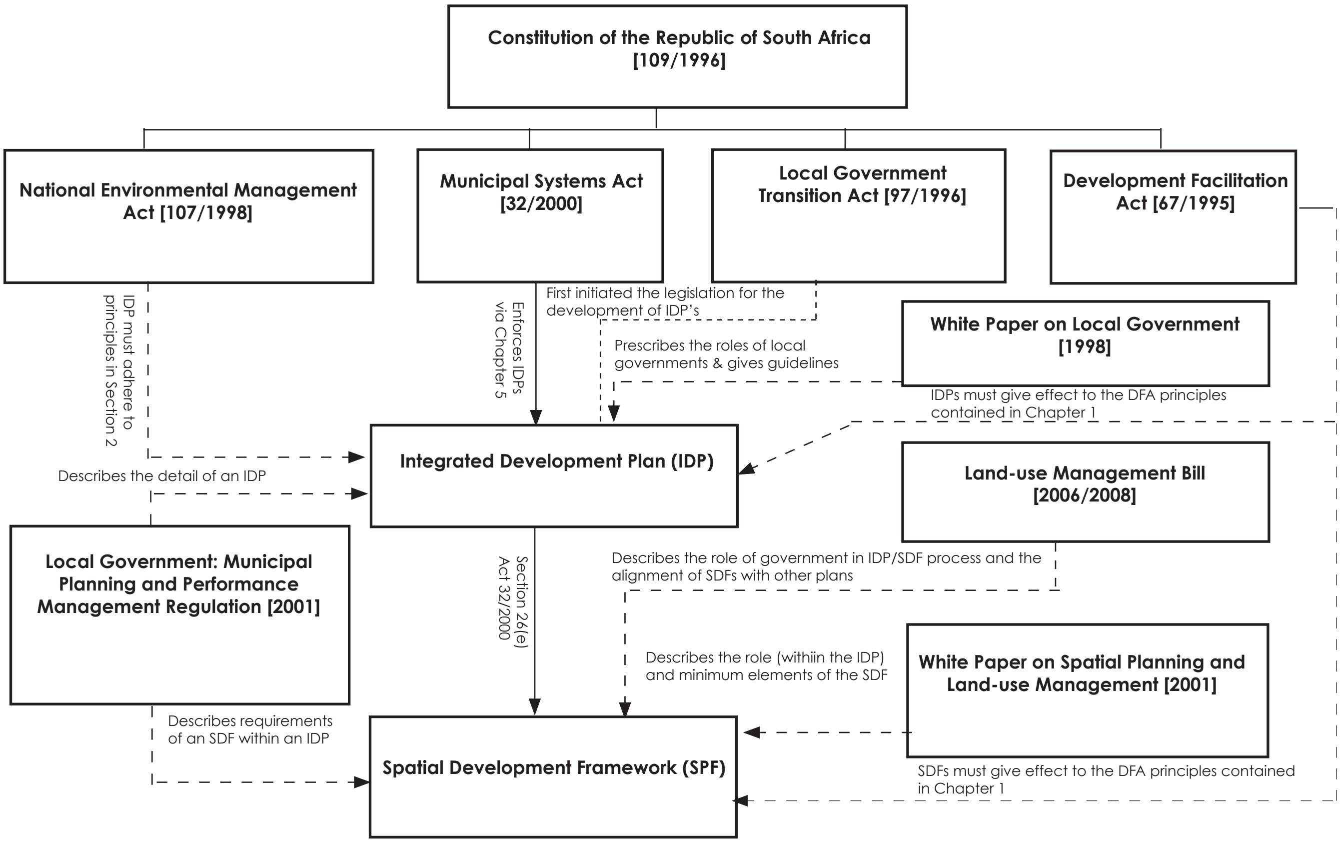
Annexure A: Legislation and policy related to SDFs



Annexure B: 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 must concur with its principles. The Constitution promotes sustainable development and recognises 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 Local Government Transition Act (Second Amendment 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 via 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 an 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 of the requirements of SDFs. It calls for the inclusion of a SEA on the impact of the SDF.