

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Introduction

*“Ecosystems are facing ever increasing levels of human pressures which imperil the goods and services they provide to humanity” (Mouillot *et al.*, 2011)*

The consequence of human activities has effects on multiple scales, leading to a chain reaction of extreme modification of biotic structure and composition, which in turn influences the ways in which ecosystems function (Chapin *et al.*, 2000; Hooper *et al.*, 2005; Schulze & Mooney, 1993). Human decisions and actions are driven by their socio-economic aspirations, which are in turn adversely affecting the environment through altering species traits (Chapin *et al.*, 2000). Altered species traits ultimately affect biodiversity and ecosystem processes, which in turn influence the socio-economic activities of humans (Chapin *et al.*, 2000) (Figure 1.1).

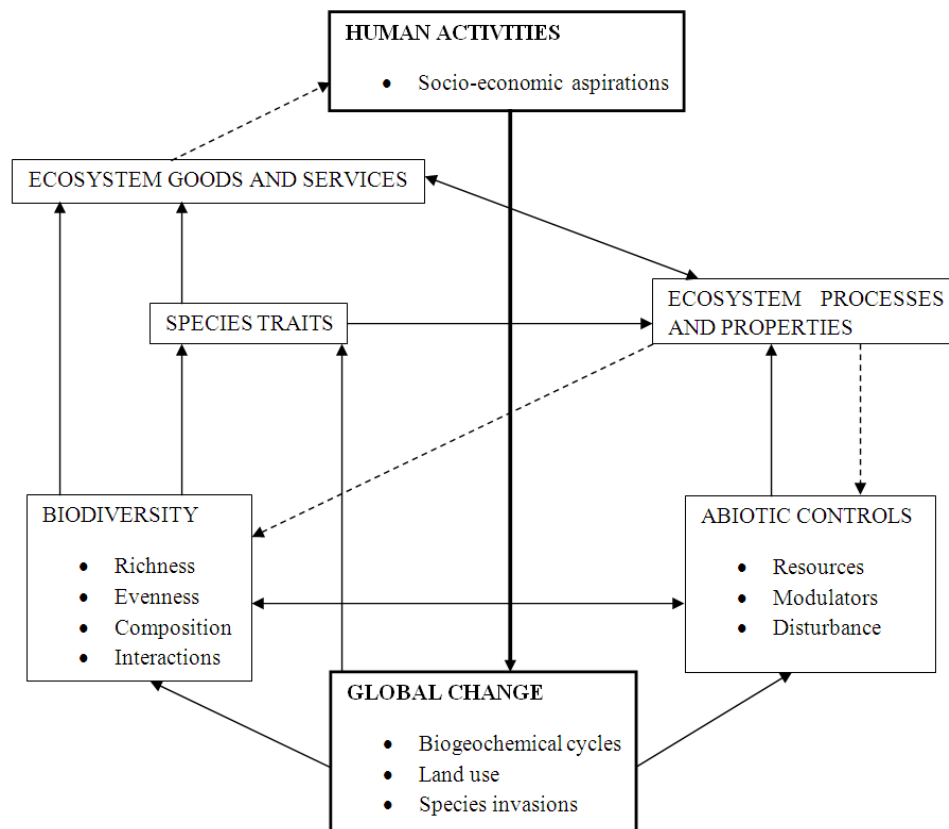


Figure 1.1: The connection between human activities and global change through alteration of biotic and abiotic aspects of an ecosystem, which influences the ecosystem properties and processes. A change in ecosystem processes and properties may alter biodiversity directly or through altering the abiotic environment. Species traits are also influenced by changes in biodiversity, ultimately influencing ecosystem goods and services. Altered goods and services may influence human activities (such as human reaction to environmental problems) (after Chapin *et al.*, 2000).

In order to provide for their most basic needs such as food and shelter, humans have caused the destruction and transformation of many habitats across the globe (August *et al.*, 2002; Ojima *et al.*, 1994). An increasing number of people on earth reside in urban areas, with no predictable decrease in the rate of urban settlement (Niemelä *et al.*, 2011). The landscapes that result from urbanisation are extensively modified, but there is little knowledge on how an urban matrix influences ecosystem processes and biological diversity (Niemelä *et al.*, 2011). The study of urban-rural gradients has the possibility of improving our understanding of how organisms respond to the continuous process of urbanisation with humans as an integral part of urban ecosystems (McDonnell & Pickett, 1990).

Grasslands are known to be biologically diverse, productive, and occur in mineral rich soils (Gibson, 2009; Henwood, 1998), which is why it has been a popular biome for agriculture, mining, and human settlement in South Africa (Fairbanks *et al.*, 2000) resulting in extensive transformation, fragmentation, biodiversity loss, and exotic invasions (Mucina & Rutherford, 2006). Several vegetation units in the Grassland biome of South Africa are regarded as vulnerable and endangered, including the Rand Highveld Grassland in which this study was conducted (Mucina & Rutherford, 2006). Vegetation performs many functions (e.g. regulation of biogeochemical cycles) and delivers many goods (e.g. food and shelter) and services (such as climate regulation, nutrient cycling, hydrologic and atmospheric cycles) which are not only important for human well-being (Christensen *et al.*, 1996; Daily, 1997; Henry, 2005) but also for the persistence of ecological processes within biological communities (Tilman, 2001). The characteristics of species and the suites of species traits present in ecosystems have also surfaced as being good indicators for the rate of ecological processes (response traits) (Mason *et al.*, 2005) and may also have substantial influences on ecosystems (effect traits) (Chapin *et al.*, 1997).

When determining whether a landscape is functioning optimally, in terms of fine-scale biogeochemical parameters, the processes and fluxes of matter within the landscape must be considered (Tongway & Hindley, 2004). Healthy, self-sustaining landscapes possess fine-scale patchiness (e.g. vegetation patches) that are able to capture and conserve water and resources flowing through the system (resource sinks), and are characterised by soil surface properties that are indicative of stable, permeable, and nutrient-rich soils (Ludwig *et al.*, 2005; Tongway & Hindley, 2004; Tongway & Ludwig, 2006).

In this dissertation an urbanisation gradient approach will be used to quantify matrix conditions and the possible effects thereof on the plant diversity and certain ecosystem processes of grassland fragments in the vulnerable South African Rand Highveld Grassland vegetation unit (Mucina & Rutherford, 2006). The landscape matrix is the most encompassing landscape component (Forman & Godron, 1986), and for the purpose of this study it is the landscape type (e.g. urban or rural) in which the selected grassland fragments are imbedded.

1.2 Research objectives

1.2.1 General objective

In this study the aim is to explore the differences and similarities between grassland fragments, positioned along an indirect urban-rural gradient, in terms of plant species composition, species diversity, plant functional diversity, and fine-scale biogeochemical landscape functionality in the Rand Highveld Grassland vegetation type in the Tlokwe Municipal area. This comparison between plant species- and landscape function properties for rural and urban selected grassland fragments will allow for recommendations to be made in terms of conservation priorities of the grassland remnants.

1.2.2 Specific objectives

The specific objectives of this study are:

- To quantify an urbanisation gradient in the Tlokwe Municipal area using landscape metrics and demographic- and physical variables. The selected urbanisation measures will be used as indicators for specific anthropogenic influences such as percentage impervious surfaces, density of people, habitat loss, and fragmentation.
- To compare species diversity and –composition, and plant functional diversity of the Rand Highveld Grassland remnants situated in matrix areas along an urbanisation gradient.
- To compare the landscape functionality and spatial attributes of Rand Highveld Grassland remnants which are exposed to varying degrees of adjacent anthropogenic disturbance
- To investigate relationships between fine-scale biogeochemical landscape functionality, plant species diversity and plant functional diversity.

1.2.3 Hypotheses

The hypotheses set for this study that selected grassland fragments situated in matrix areas exposed to increased human impacts will:

- Contain more exotic species with higher species diversity and functional diversity.
- Support different proportions of specific plant traits.
- Be characterised by a fine-scale landscape structure that is diagnostic of a system that is not actively capturing and conserving vital resources such as soil particles, water and nutrients.
- Have lower stability, infiltration and nutrient cycling soil surface indices, resulting in lower total Soil Surface Assessment (SSA) functionality

than rural/peri-urban areas.

1.3 Study area

The city of Potchefstroom is situated in the Tlokwe Municipality, North West Province, South Africa (Figure 1.2). The North West Province predominantly falls within two biomes namely the Savanna and Grassland Biomes. The study area is located in the Grassland Biome, specifically the Rand Highveld Grassland vegetation type (Mucina & Rutherford, 2006). More detailed information regarding the Rand Highveld Grassland vegetation type is given in Chapter 2, *Section 2.2.1: The Rand Highveld Grassland*. The North West Province contains approximately 3025 plant species, 138 mammals, 384 birds, 27 amphibians and 59 reptile species (NWDACE, 2008). An area of 67.8% of the North West Province consists of natural grasslands, thickets, woodlands and forests (NWDACE, 2008). Only 2.1% of the province consists of urban development which is predominantly concentrated in the eastern parts of the province, with the most population growth occurring in the Rustenburg, Klerksdorp, and Potchefstroom areas (NWDACE, 2008).

A total of 41% of the North West Province's population resides in urban areas (Stats SA, 2006). The rate of urbanisation in this province may be accounted for by the scarcity of employment opportunities in rural areas (NWDACE, 2008). New urban development usually occurs on the fringe of existing urban areas, thereby perpetuating urban sprawl, and often resulting in haphazard growth of the urban centre in areas which may be unsuitable for human settlement (NWDACE, 2008). Such unplanned and disorganised development exerts pressures on ecosystem goods and services (NWDACE, 2008).

Approximately 30% of the land cover of the North West Province has been transformed, of which approximately 1% of the area was converted to non-natural land uses between 1994 and 2006 and amounts to about 106 000 ha/year (NWDACERD, 2009). This may be a disturbing statistic when considering the direct implication that there will be no natural habitat left within the North West Province within 60 years if the common trend of land transformation continues (NWDACERD, 2009). Agriculture accounts for 73%, urbanisation for 24%, and mining for 3% of land use transformation in the North West Province (NWDACERD, 2009). The main drivers of biodiversity loss in the North West Province are the unsustainable usage of natural resources (such as overgrazing and water abstraction), land use transformation through urbanisation and agriculture, and subsequent invasion of exotic species (NWDACE, 2008; NWDACERD, 2009). There are 71 plant species in the North West Province recorded as invasive species, 42% of which are well established and already have a significant effect on natural ecosystems (NWDACE, 2008).

1.3.1 Selected grassland fragments

A total of 30 grassland fragments were selected (mean area = 27.56 ha, median = 4.14 ha, range = 0.59–179.41 ha) in and around Potchefstroom, situated in the Tlokwe Municipality, North West Province, South Africa (Figure 1.2).

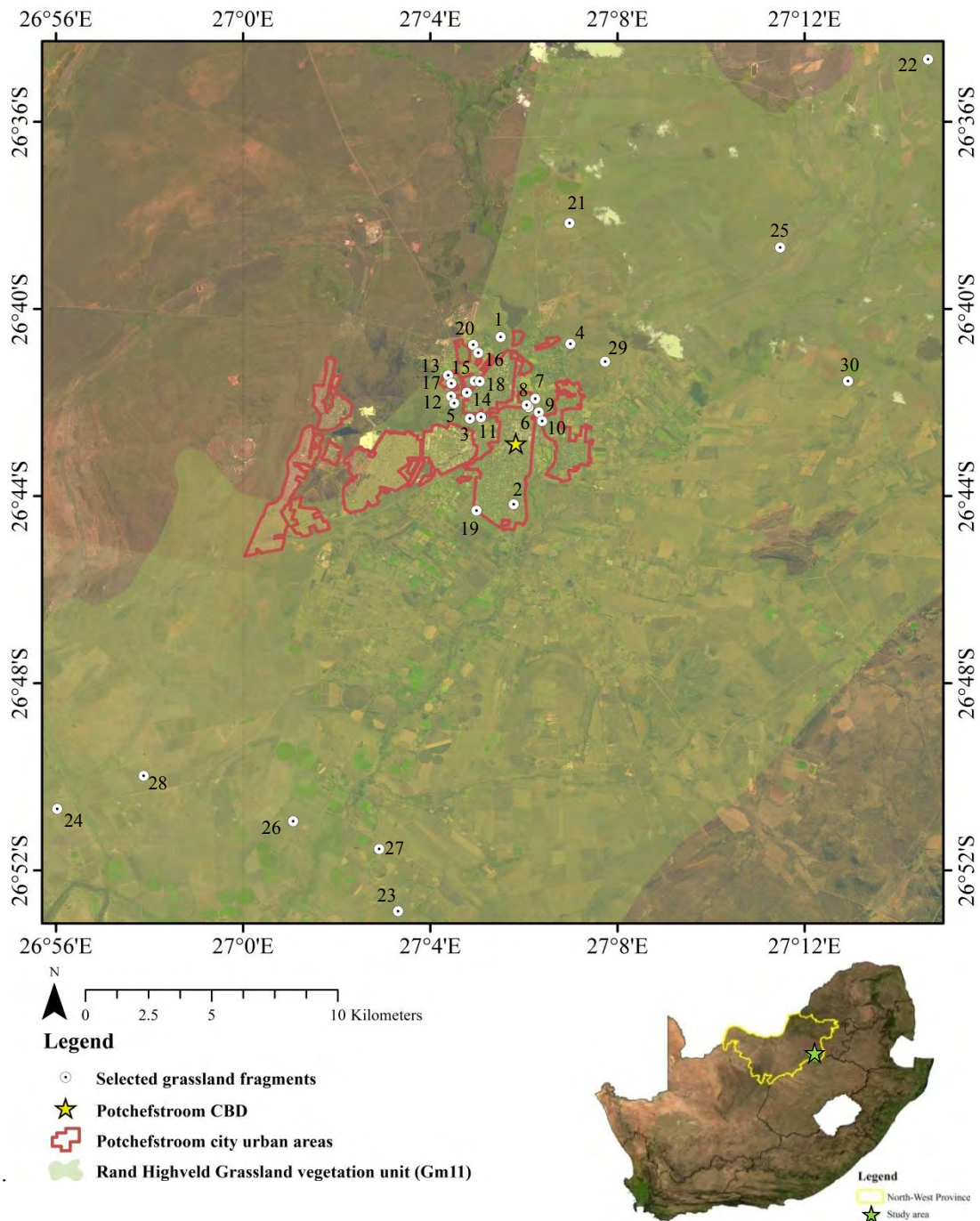


Figure 1.2: Map of the selected grassland patches in the study area in the Rand Highveld Grassland vegetation unit, situated in the Tlokwe Municipal area. The overview map (bottom right hand corner) indicates the location of the study area within the North West Province, South Africa.

The potential grassland fragments were first identified using SPOT 5 satellite images (CNES, 2007). These grassland remnants were subsequently explored to ensure that they met the criteria for selection of the grassland patches. The criteria for the selection of the grassland fragments were:

- All grassland fragments should be located within the Rand Highveld Grassland vegetation unit.

- The grassland patches must be fragments, separated and isolated from surrounding grassland areas by roads, urban development, or agricultural fields.
- *Themeda triandra*, one of the dominant grass species of the Rand Highveld Grassland, should be present.
- Grassland fragments should be selected in both urban and rural areas.
- Grassland remnants in rural areas may not be old agricultural fields or cultivated pastures.
- Patches should be minimally disturbed and as ‘natural’ as possible (i.e. no dumping has occurred, no old fields or planted pastures: grazing and mowing are permitted).

Although it was ideally endeavoured to include more than 30 grassland fragments in the study, the presence of grassland fragments within the Rand Highveld Grassland vegetation type in the Tlokwe Municipality were limited. Many of the grassland patches that were identified on SPOT5 images (CNES, 2007) were found during ground inspection to include old fields, planted grass pastures, or dumping sites. These did not fulfil the above mentioned criteria. The sizes of the selected grassland fragments varied greatly (size range = 0.59 ha – 179.41 ha). The number of sample plots per grassland remnant was determined by its size: 2 sample plots for grassland fragments smaller than 8ha, 3 for grassland remnants larger than 8 ha, and 5 sample plots for the largest grassland fragments exceeding 100 ha. The 30 selected grassland fragments and their attributes are listed in Table 1.1.

1.4 Exposition of dissertation

In this section a brief overview of the concepts and methods applied in this study is provided. The methods are elaborately discussed in the *Materials and methods* section of each chapter. A concise synopsis of each chapter is as follows:

Introductory chapters to this dissertation include a general overview of the study area (see *Section 1.3* of this chapter) and a literature review (*Chapter 2*) of the concepts of interest for this study.

Chapter 3 describes concepts of remote sensing and digital image classification. The classification of the SPOT 5 satellite image into five land cover classes (namely water, trees, grass, soil, and urban) using GIS techniques was the first step to further calculating urbanisation measures (*Chapter 4*) for the selected grassland fragments.

Table 1.1: The 30 selected grassland fragments under observation during the current study. The site name, location, size, and number of sample plots per fragment (plant diversity survey) are indicated. The presence of anthropogenic disturbances (specifically mowing and grazing) is also indicated.

Site	Site name	Location	Fragment size (ha)	No. of sample plots	Anthropogenic influence
1	Potch aerodrome	27°05'30.25"E 26°40'35.94"S	5.52	2	N/A
2	Cnr. Waterbok Ave. & Eland St.	27°05'46.91"E 26°44'10.33"S	3.84	2	N/A
3	Cnr. Louis La Grange St. & Fontein St.	27°04'50.72"E 26°42'20.48"S	18.13	3	N/A
4	Old drive in road	27°06'59.52"E 26°40'44.86"S	26.17	3	N/A
5	Chief Albert Luthuli St.	27°04'30.65"E 26°42'00.85"S	4.43	2	N/A
6	Cnr. Walter Sisulu Ave. & Spruit St.	27°06'6.064"E 26°42'05.84"S	6.26	2	Mowing
7	Cnr. Walter Sisulu Ave. & Mooiriver Ave.	27°06'14.67"E 26°41'55.16"S	2.36	2	Mowing
8	Cnr. Walter Sisulu Ave. & Chief Albert Luthuli Ave.	27°06'03.68"E 26°42'03.38"S	3.03	2	Mowing
9	Moorriver Ave.	27°06'19.40"E 26°42'12.32"S	7.27	2	N/A
10	Cnr. Burger & Buskus St.	27°06'23.43"E 26°42'23.72"S	1.63	2	N/A
11	Piet Bosman St.	27°05'05.12"E 26°42'18.52"S	2.29	2	N/A
12	Stan Jackson St.	27°04'26.67"E 26°41'52.08"S	2.13	2	N/A
13	Deppe St.	27°04'22.95"E 26°41'25.04"S	0.82	2	Mowing
14	Gunner's Memorial	27°04'47.07"E 26°41'47.17"S	0.74	2	Mowing
15	Old RAG Farm	27°4'56.966"E 26°41'32.24"S	1.74	2	N/A
16	Doelwit Rd. 1, Potch Army Base	27°05'01.41"E 26°40'56.15"S	3.42	2	N/A
17	Cnr. Michael Heyns St. & Oswald Pirow St.	27°04'27.26"E 26°41'35.61"S	1.03	2	N/A
18	Jan Smuts Ave.	27°05'03.51"E 26°41'32.80"S	0.65	2	N/A
19	Kruis St.	27°04'59.36"E 26°44'18.65"S	0.59	2	Mowing
20	Doelwit Rd. 2, Potch Army Base	27°04'55.06"E 26°40'45.88"S	2.99	2	N/A
21	De Beer Farm	27°06'58.53"E 26°38'09.56"S	11.54	3	Grazing
22	Lakeview Farm	27°14'38.31"E 26°34'39.64"S	9.49	3	Grazing
23	De Kok Farm	27°03'19.13"E 26°52'52.22"S	116.3	5	Grazing
24	New Machavie	26°56'02.17"E 26°50'40.57"S	3.76	2	N/A
25	Touchdown Farm	27°11'29.25"E 26°38'41.14"S	179.41	5	N/A
26	Thomas Farm	27°01'04.29"E 26°50'56.59"S	172.83	5	Grazing
27	Swart Farm	27°02'54.77"E 26°51'31.90"S	10.77	3	Grazing
28	Pelser Farm	26°57'52.65"E 26°49'58.61"S	19.85	3	Grazing
29	Fyfhoek	27°07'44.84"E 26°41'07.35"S	169.26	5	Grazing
30	Misty View Farm	27°12'55.67"E 26°41'32.42"S	38.69	3	N/A

The urban-rural gradient was quantified in *Chapter 4*. Eight urbanisation measures were calculated for the entire study area, followed by a Factor Analysis to determine the most suitable measures. The selected measures were subsequently calculated for a 500m radius matrix area surrounding the edge of each selected grassland fragment within the study area, to determine its position along the urban-rural gradient. Each selected urbanisation measure acted as an indicator for certain anthropogenic influences of importance for this study (e.g. urbanisation, percentage impervious surfaces, fragmentation, habitat loss).

Chapter 5 focuses on the plant species diversity and plant functional diversity. Vegetation survey techniques were performed in order to determine the plant species diversity. Certain functional traits were also described for each plant species to determine the functional diversity of each selected grassland remnant. The selected urbanisation measures (*Chapter 4*) were statistically correlated with plant species diversity and plant functional diversity data in order to determine whether certain anthropogenic disturbances influence these components of biodiversity.

Fine-scale biogeochemical landscape function was determined in *Chapter 6* by performing Landscape Function Analysis (LFA). The LFA field method (Tongway & Hindley, 2004) includes the recording of physical landscape patch attributes. Eleven Soil Surface Assessment (SSA) indicators were examined to reflect three main functionality parameters, namely stability, infiltration, and nutrient cycling. The LFA data (physical landscape attributes and soil surface function) were correlated with the selected urbanisation measures in order to express whether certain anthropogenic disturbances influence biogeophysical landscape function.

In conclusion, to determine the effects of urbanisation on the plant species diversity, plant functional diversity, and landscape functionality the focus was on two types of variables, namely (1) matrix variables and (2) intra-patch variables (Figure 1.3). Matrix variables are the urbanisation measures (*Chapter 4*) which are used to describe the matrix environment in which the selected grassland fragments are situated, and will also determine the position of the grassland remnants along an urban-rural gradient. Intra-patch variables are the variables that were studied within each grassland fragment, and included (1) plant species diversity, (2) plant functional diversity (*Chapter 5*), and (3) landscape functionality (*Chapter 6*) (Figure 1.3).

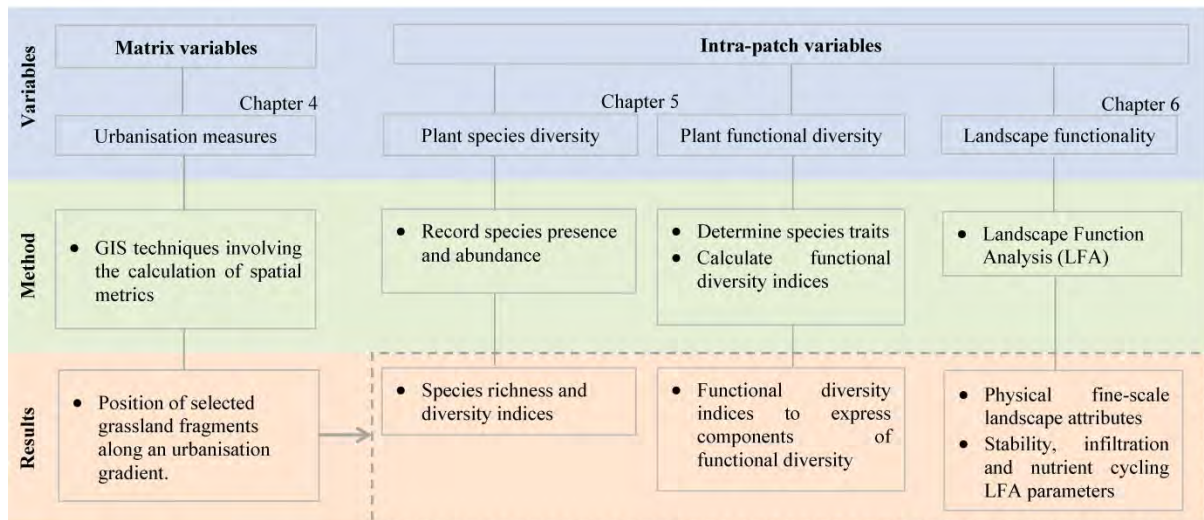


Figure 1.3: Summary of the elements constituting this study.

This dissertation is concluded (*Chapter 7*) by exploring relationships between all the data. Do plant species composition and diversity, and the range of functions they perform in a landscape, have any relationship with fine-scale biogeochemical landscape function, and what role does matrix quality and management practices play in affecting intra-patch variables? We also summarise the results, bring it into the context of the literature study (*Chapter 2*), identify possible shortcomings of this study, and make recommendations in terms of future studies, and management– and conservation practices.

1.5 References

- August, P., Iverson, L. & Nugranad, J. 2002. Human conversion of terrestrial habitats. (*In* Gutzwiller, K.J., *ed.* Applying landscape ecology in biological conservation. Springer. p. 198-224).
- Chapin, F.S., III, Walker, B.H., Hobbs, R.J., Hooper, D.U., Lawton, J.H., Sala, O.E. & Tilman, D. 1997. Biotic control over the functioning of ecosystems. *Science*, 277: 500-504.
- Chapin, F.S., III, Zavalenta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds. H.H., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. & Diaz, S. 2000. Consequences of changing biodiversity. *Nature*, 405: 234-242.
- Christensen, N.L., Bartsuka, A.M., Brown, J.H., Carpenter, S., D'Antonio, C., Francis, R., Franklin, J.F., MacMahon, J.A., Noss, R.F., Parsons, D.J., Peterson, C.H., Turner, M.G. & Woodmansee, R.G. 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. *Ecological Applications*, 6(3): 665-691.

- CNES. 2007. SPOT. [Web:] http://www.geoimage.com.au/geoweb/spot/spot_overview.htm. [Date of use: 20-26 Feb. 2012]
- Daily, G. 1997. Nature's services: societal dependence on natural ecosystems. Washington: Island Press.
- Fairbanks, D.H.K., Thompson, M.W., Vink, D.E., Newby, T.S., Van Den Berg, H.M. & Everard, D.M. 2000. The South African Land-cover Characteristics Database: a synopsis of the landscape. *South African Journal of Science*, 96: 69-82.
- Forman, R.T.T. & Godron, M. 1986. Landscape ecology. NY: John Wiley & Sons.
- Gibson, D.J. 2009. Grasses and grassland ecology. NY: Oxford University Press Inc.
- Henry, R.J. 2005. Importance of plant diversity. (In Henry, R.J. ed. Plant diversity and evolution: genotypic and phenotypic variation in higher plants. CAB international. p.1-6).
- Henwood, W. 1998. An overview of protected areas in the temperate grasslands biome. *Parks*, 8: 3-8.
- Hooper, D.U., Chapin, F.S., III, Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Hawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vendermeer, J. & Wardle, D.A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs*, 75(1): 3-35.
- Ludwig, J.A., Wilcox, B.P., Breshears, D.D., Tongway, D.J. & Imeson, A.C. 2005. Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. *Ecology*, 86(2): 288-297.
- Mason, N.W.H., Mouillot, D., Lee, W.G. & Wilson, J.B. 2005. Functional richness, functional evenness and functional divergence: the primary components of functional diversity. *Oikos*, 111: 112-118.
- McDonnell, M.J. & Pickett, S.T.A. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. *Ecology*, 71(4): 1232-1237.
- Mouillot, D., Villéger, S., Scherer-Lorenzen, M. & Mason, N.W.H. 2011. Functional structure of biological communities predicts ecosystem multifunctionality. *PLoS ONE*, 6(3): 1-9.

- Mucina, L. & Rutherford, M.C., eds. 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. Pretoria: South African National Biodiversity Institute.
- Niemelä, J., Breuste, J., Elmqvist, T., Gutenspergen, G., James, P. & McIntyre, N. 2011. Urban ecology patterns, processes, and applications. Oxford University Press.
- NWDACE (North West Department of Agriculture, Conservation and Environment). 2008. North West Province environment outlook. Mmbatho: North West Department of Agriculture, Conservation and Environment.
- NWDACERD (North West Department of Agriculture, Conservation, Environment and Rural Development). 2009. North West provincial biodiversity conservation assessment technical report, Version 1.2., March 2009. Mmbatho: North West Department of Agriculture, Conservation, Environment and Rural Development.
- Ojima, D.S., Galvin, K.A. & Turner, B.L., II. 1994. The global impact of land-use change. *BioScience*, 44(5): 300-304.
- Schulze, E.-D. & Mooney, H.A., eds. 1993. Biodiversity and ecosystem function. *Ecological Studies* 99. Berlin: Springer-Verlag.
- Stats SA (Statistics South Africa). 2006. Migration and urbanisation in South Africa. Pretoria: Statistics South Africa.
- Tilman, D. 2001. Functional diversity. (In Levin, S.A., ed. Encyclopedia of biodiversity. Academic Press. p. 109-120).
- Tongway, D.J. & Hindley, N. 2004. Landscape function analysis: procedures for monitoring and assessing landscapes: with special reference to minesites and rangelands. Canberra: CSIRO Sustainable Ecosystems.
- Tongway D.J. & Ludwig, J.A. 2006. Resource retention and ecological function as restoration targets in semi-arid Australia. *Restoration Ecology*, 14(3): 369-378.