
Land Use and Land Cover Change in the Western Cape Province: Quantification of Changes & Understanding of Driving Factors

Petronella Tizora¹, Alize Le Roux², Gerbrand Mans³, Antony Cooper⁴

¹Msc Geoinformatics Candidate
Department of Geography, Geoinformatics & Meteorology, University of Pretoria
Private Bag X20, Hatfield, 0028, South Africa
Tel:+27 (0)12 420 3243

²Senior Researcher, ³Senior Researcher, ⁴Principal Researcher
Built Environment, Council for Scientific and Industrial Research
P.O.Box 395, Pretoria, 001, South Africa
Tel: +27 (0)12 841 3242

Abstract

The Western Cape Province is currently faced with population growth, declining household sizes, increasing household numbers, high levels of migration, urbanization and escalating development pressures. These factors have consequently triggered changes in land use and land cover (LULC) and incited issues such as urban sprawl, marginalization of the poor, limited public access to resources, land degradation and climate change. This paper seeks to understand the most significant drivers of LULC change in the Western Cape Province. Focus is given to the major LULC changes which have occurred in the Province in past 24 years by integrating a desktop study of LULC changes using the 1990 and 2013-2014 South African National LULC datasets; document analysis; and expert opinion in the form of semi-structured interviews with municipal town planners. An adapted Driver-Pressure-State-Impact-Response (DPSIR) Framework is used to analyse and understand LULC changes in the study area. LULC changes are driven by political, economic, technological, demographic, biophysical and cultural factors that must be considered in strategies and policies in future planning to avoid detrimental impacts on the environment whilst maintaining socio-economic benefits.

Keywords

Land Use, Land Cover, Land Use Change, Drivers, DPSIR

1. Introduction

The State of the Environment Outlook Report for the Western Cape Province reveals that the Province is experiencing significant population growth, decreased household sizes, increasing household numbers, high levels of migration, urbanization, infrastructure development, mining pressures and agriculture expansion and intensification (Maree and Van Weele, 2013). These trends have consequently triggered changes in land use and land cover (LULC) and incited issues such as urban sprawl, marginalization of the poor, limited public access to resources, land degradation and climate change. Furthermore, the issues surrounding LULC in the Province emanate from past inequities in access to land coupled with unsustainable land use practices (Maree and Van Weele, 2013). This poses a challenge to the government which strives for a sustainable nation that safeguards democracy by providing basic access to services, managing limited resources and advancing effective and efficient integrated planning whilst maintaining ecosystem functions (DEAT, 2008). Understanding drivers of LULC change and articulating how various factors influence LULC is important in meeting this challenge.

2. Literature Review

To establish the theoretical basis for this research, this section will review literature on land, land use, land cover and drivers of land use change.

2.1 Land, Land Use and Land Cover

The Food and Agriculture Organization (FAO) Land and Water Bulletin 2, describes land as “a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)” (Sims and Sombroek 1997).

The terms land use and land cover though often used interchangeably, have different meanings. Land use is the purpose for which land is used whereas land cover refers to the physical characteristics of the surface of the land. The FAO describes land use as “the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it” (Di Gregorio and Jansen, 1998). According to Turner et al. (1994), “land cover is the biophysical state of the earth's surface and immediate subsurface.” Changes in land use patterns driven by various causes result in land cover changes that affect biodiversity, water, radiation budgets and other processes that collectively affect the climate and biosphere (Riebsame et al., 1994). Land use and land cover change detection and analysis is made possible by the availability of remote sensing technologies that provide land use and land cover data, together with GIS analytical technologies that can be used to understand LULC patterns (Dadhich and Hanaoka, 2011).

2.2 International Review of Drivers of Land Use Change

Land use change involves a conversion from one land use to another or intensification of the present or current land use (Turner et al., 1994). Changes in land use are determined by how individual landowners, communities and governments control land use and make decisions on how to use land. Such decisions are influenced by the interactions between socioeconomic factors such as population and biophysical factors which vary at different scales (Lambin and Geist, 2007). Briassoulis (2000) confirms this and further clarifies that biophysical drivers do not have a direct impact on land use change but impacts land cover change which in turn influences land managers decisions.

Land use change can therefore be modelled as a function of socio-economic and biophysical factors. These factors are often referred to as ‘driving factors’. The driving factors of land use change are categorized as either proximate or underlying, where the former are direct modifications by individuals at a local scale such as individual farms and the latter are indirect changes which occur at a regional scale (Lambin and Geist, 2007). Proximate driving factors are caused by human activities such as infrastructure and agriculture expansion whereas underlying factors are caused by complex interactions between social, political, demographic and biophysical variables (Lambin et al., 2001). Lambin et al. (2001) further maintains that proximate causes can be categorized into three broad categories of agricultural expansion, wood extraction and infrastructure expansion. Briassoulis (2000) describes underlying driving forces as socio-economic drivers which comprise of demographic, economic, institutional factors, technological and cultural or socio-political.

As ascertained above, international researchers have identified broad categories of drivers of LULC change. However, these drivers vary dependant on the context of the area under study and the scale of analysis. South African academic references on drivers of LULC change are very limited and therefore unable to fully explain LULC changes particularly in the Western Cape Province. Identifying LULC changes and their driving forces is crucial in understanding challenges, monitoring developments and mitigating the impacts of land use changes. Based on this premise, this study aims to investigate LULC changes and factors that drive these changes specifically in the Western Cape, thus contributing to the understanding of land use changes.

3. Research Objectives

The following were the objectives of the study:

- To quantify the changes in LULC in the Western Cape Province.
- To determine the driving factors of LULC change in the study area.
- To determine the economic, social and environmental impacts of LULC changes.

4. Approach & Methodology

4.1 Study Area

The study area for this research is the Western Cape Province (Figure 1), the fourth largest province in South Africa covering 10.6% (129 462 square kilometres) of the country's total land surface (Maree and Van Weele, 2013). The Province consists of five district municipalities (Cape Winelands, West Coast, Central Karoo, Eden and Overberg) and one metropolitan municipality (City of Cape Town).

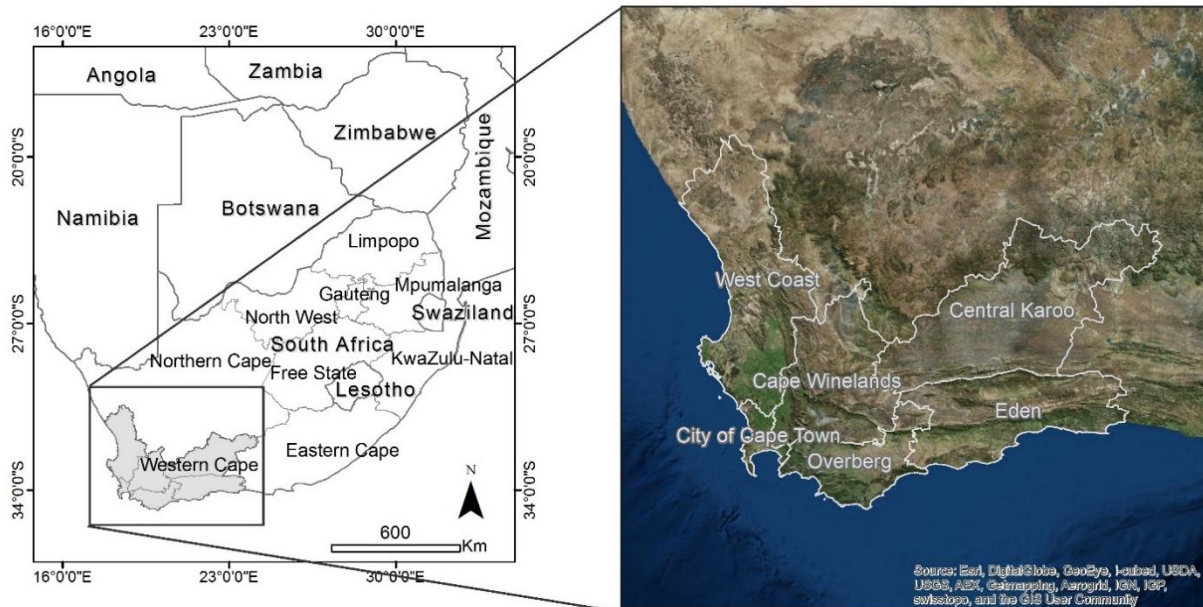


Figure 1: Geographical location of the Western Cape Province

4.2 Methods

This study was conducted using a mixed methods research methodology which integrated a quantitative and qualitative approach. Detection and analysis of LULC changes was conducted by a desktop study of LULC maps using Geographical Information Systems (GIS), interviewing municipality town planners, document analysis and adapting of the DPSIR framework. The desktop study of LULC maps was used to analyse LULC changes and this addressed the objective to quantifying changes in LULC in the Western Cape Province. Interviews with town planners accompanied with reviews of documents were the methods used to determine driving factors and their impacts. An adapted DPSIR framework was used to report and organize findings of the interviews into themes presented as components of the framework.

4.2.1 Remote Sensing derived LULC data

Analysis of LULC change in the Western Cape Province was based on LULC datasets of 1990 and 2013/14 obtained from the Department of Environmental Affairs (DEA). These datasets cover the whole country at a 30m spatial resolution and are known as the 1990 South African National Land Cover Dataset (35 Classes) and the 2013/2014 South African National Land Cover Dataset (72 Classes). These datasets were created by GEOTERRAIMAGE (GTI) and incorporate both land-cover and land-use data which are referred to as "Land-Cover" (GEOTERRAIMAGE, 2014). The 1990 dataset was derived from multi-seasonal Landsat 5 imagery which was acquired between 1989 and 1991 whereas the 2013/14 dataset was generated from Landsat 8 imagery acquired between 2013 and 2014. Land-use classes such as settlements, plantations, mines and cultivated land were acquired from other sources (GEOTERRAIMAGE, 2014).

LULC Data Processing

LULC change detection, quantification and analysis were performed in Land Change Modeler (LCM) 2 for ArcGIS. LCM requires input of LULC maps with matching classes, legend and characteristics.

These LULC maps must be byte or integer images with identical values and legends, where the legends begin with 1 and sequential. Furthermore, the maps must have identical rows and columns with X and Y extents. ArcMap 10.3.1 was therefore used to process the LULC datasets prior to analysis in LCM. The South African Land Cover Classification System for remote sensing applications was the adopted scheme in reclassifying the datasets.

LCM requires two LULC maps between two time periods in order to perform change assessments. After processing data in ArcMap, an assessment of LULC change was conducted using the processed 1990 and 2014 LULC datasets as input parameters. Three types of graphs between the two input LULC datasets were generated. The first graph gave an indication of gains and losses for each LULC class. The second graph showed net changes by category or class. This was calculated by adding gains and subtracting losses from the earlier LULC dataset (1990). The third graph examined the contributions to changes experienced by a single LULC due to other various LULC classes hence showing contributors to net change. All the maps were created using ArcMap 10.3.1 software by (ESRI, © 1999-2015) and graphs were produced using Land Change Modeler 2.0 for ArcGIS (Clark University, © 2005-2013).

4.2.2 LULC Change Qualitative Analysis

The research population for this study are municipal town planners in the Western Cape Province. Participants were selected per district municipality. In cases where a district representative was absent, a town planner with knowledge on past land use dynamics in the municipality was selected.

Data collection and processing

Annum (2015) refers to research instruments as tools used in collection of data, such as interviews, questionnaires, observations and document readings. Semi-structured interviews were conducted in order to gain knowledge of LULC issues in the study area and to collect primary data from interaction with planners. This method was selected as it allowed the researchers to explore issues relevant to the concerned municipality. The interviews were both face-to-face and telephonic and data was collected by transcribing and digital audio recording. Participants were informed of the nature of the research and a consent form was emailed and explained to them prior to the interviews. An interview guide (refer to Appendix 1) consisting of key themes was constructed.

Data collected from interviews was validated, corroborated and supplemented by relevant LULC change documentation. The Western Cape Provincial Spatial Development Framework (SDF), individual municipalities SDF's, Growth Potential Study of Towns, State of the Environment Reports and various legislation and policy documents related to land use e.g. Spatial Planning and Land Use Management Act (SPLUMA), were obtained from the internet and thoroughly examined in order to retrieve relevant LULC information.

4.2.3 Driver-Pressure-State-Impact-Response (DPSIR) Framework

The DPSIR is an analytical framework which can be used to organize, report and illustrate the effects of human activities on the environment. This framework was developed by the European Environmental Agency in the 1990s and has since been applied in environmental research projects to support planning decisions (Kristensen, 2004). The DPSIR framework was adapted in assessing LULC changes in the study area in order to present various aspects and issues which emerged from interviews and document readings.

5. Research Analysis & Findings

5.1 Desktop Quantitative Analysis of LULC Changes

This section presents the results of desktop quantitative analysis of reclassified maps of 1990 and 2014. These maps indicate LULC changes in the Western Cape Province (Figure 2). Individual district municipalities maps were also created based on clip extents of the municipality vector mask datasets. Table 1 shows the net area change in hectares and percentage changes for individual LULC classes between 1990 and 2014 in the Western Cape Province. The quantified results indicate that the Western Cape Province has experienced considerable changes in LULC.

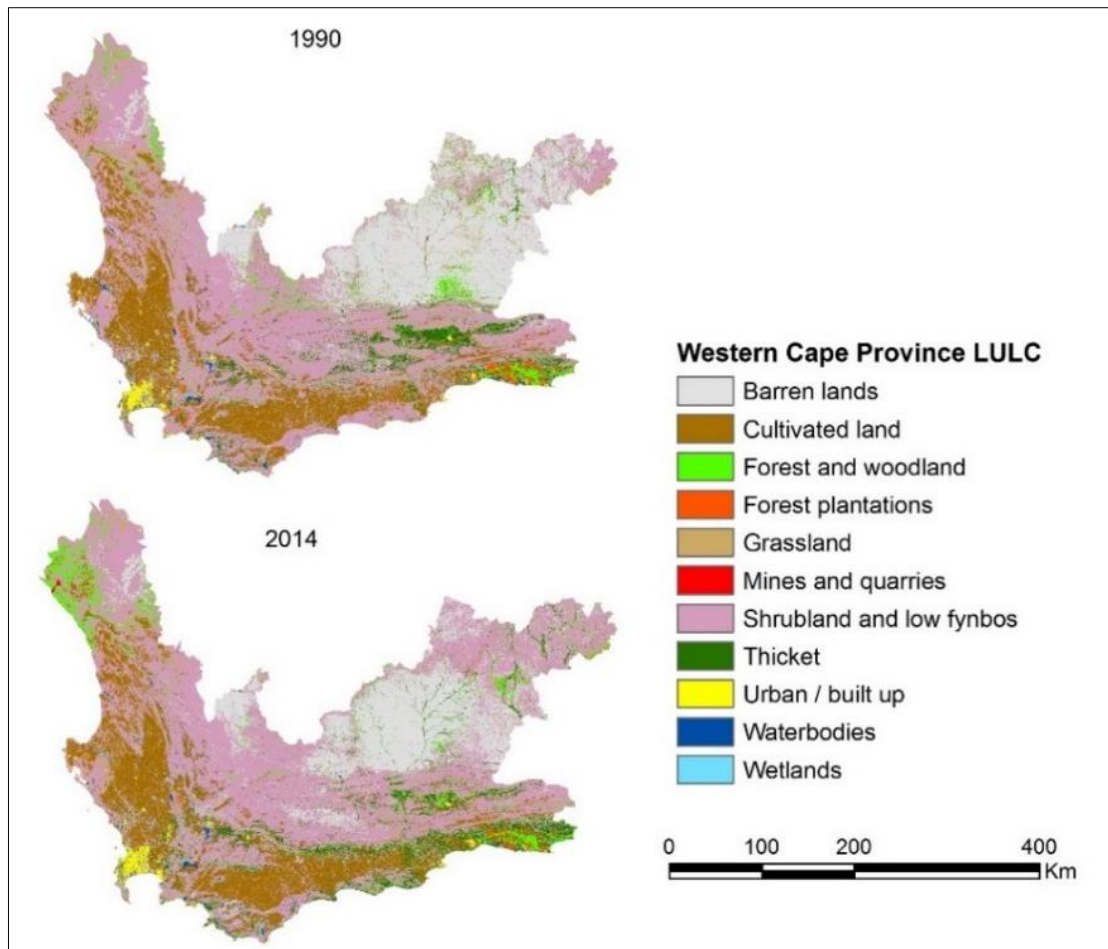


Figure 2: Western Cape Province LULC maps for years 1990 and 2014

Based on the LULC datasets used; there has been a considerable provincial decrease in forest plantations, grasslands, wetlands, and barren lands over the past 24 years. Contrary to these decreases, there have been increases in urban/built up, mines and quarries, water bodies, woodlands, thicket and shrubland.

Table 1: Western Cape LULC area, net change and percentage change between 1990 and 2014

Class Name	1990 Area (ha)	2014 Area (ha)	Net Change (ha)	% Change
Forest and woodlands	462 583.44	593 923.68	131 340.24	28.39
Thicket	590 777.55	794 971.53	204 193.98	34.56
Shrubland and low fynbos	6 143 518.44	6 610 854.06	467 335.62	7.61
Grassland	706 820.4	519 442.47	-187 377.93	-26.51
Forest plantations	120 180.51	81 228.42	-38 952.09	-32.41
Waterbodies	55 190.52	55 987.02	796.5	1.44
Wetlands	143 738.46	108 163.71	-35 574.75	-24.75
Barren lands	2 776 498.47	2 198 310.12	-578 188.35	-20.82
Cultivated land	1 949 069.34	1 969 208.91	20 139.57	1.03
Urban / built up	103 646.97	116 667.45	13 020.48	12.56
Mines and quarries	6 184.53	9 451.26	3 266.73	52.82

Analysis of the above statistics in LULC change is also presented in graphical form in Figure 3 where gains are green and losses in purple for each LULC category.

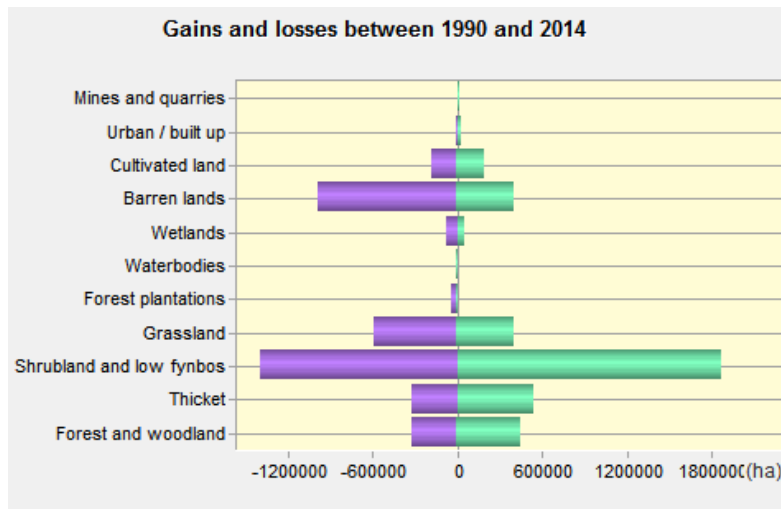


Figure 3: Western Cape Province gains and losses between 1990 and 2014

The highest percent gain is in mines and quarries although the Western Cape Province is generally not popular in mining, with mining activities mostly concentrated in the West Coast district municipality. Mining activities are predominantly characterised by sand mining resulting from construction pressures. The mining sector however has a low contribution to the Province's GDP and sand mines result in loss of surface productivity and undesirable visual impacts. Other net gains between the two time periods were in forest and woodland and thicket LULC classes. The net increase in thicket could be a result of mapping errors or inaccuracies due to spectrally similar woody vegetation classes such as indigenous forest, woodland and shrubland.

The highest net percent loss is in plantations LULC class, giving an indication that there has been a decrease in plantations over the past 24 years. The decrease in plantations in the Western Cape Province was mostly due to the Government's forestry exit policy and fires in the region. In 2001, the Cabinet decided to decommission about 44 793 hectares (ha) of forestry plantations in the Western and Southern Cape to convert the land to agriculture, human settlements and conservation within a 20 year period from 2001. The rationale behind this was that the plantations were not economically viable at that time; accompanied with concerns of plantations invasion of protected areas and catchments. Government however partially reversed 22 402ha back to plantation forestry following studies and recommendations by the Department of Water Affairs and Forestry in 2008 (Wilgen, 2015). There has been no significant increase in plantations since no initiatives were implemented following the reversal by Cabinet in 2008 (De Beer et al., 2014). An indication of the actual losses of forest plantations to other LULC classes between 1990 and 2014 is illustrated in Figure 4.

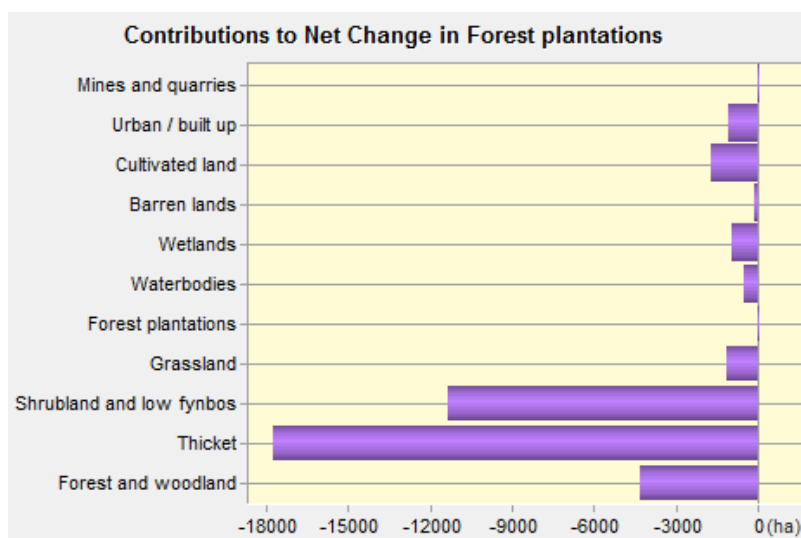


Figure 4: Contributions to net change in forest plantations by other LULC classes

The LULC change results also indicate that there has been a provincial increase in urban / built up areas with about 12% and a 1% increase in cultivation. An assessment of the individual district municipalities in the Western Cape Province however provides a clearer picture of the actual LULC changes and shows that the increase in urban areas in the past 24 years is concentrated in the Cape Metropolitan area and the adjacent Cape Winelands district municipality. Despite the 1% provincial increase in cultivation, the Cape Metro has experienced 3 728 hectares loss (-8.49%) in cultivation to other LULC classes.

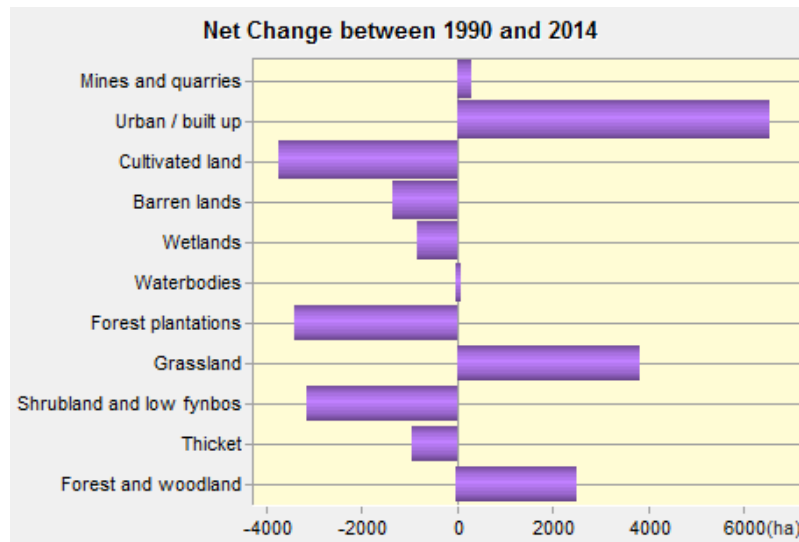


Figure 5: Cape Town Metro net change between 1990 and 2014

Further analysis of net changes in LULC in the Cape Metro indicate that the most increase occurred in the urban LULC class which experienced gains at the expense of cultivated land (216 ha), shrubland and low fynbos (5 315 ha) and plantations (463 ha). This increase is largely due to urbanization and migration amongst other factors which will be discussed in the driving factors section.

5.2 Qualitative Results & the DPSIR Framework

The following sections provide a summary of LULC change qualitative results based on components of the DPSIR framework (**Error! Reference source not found.**). Drivers are social, economic, demographic changes in societies, including consumption, lifestyle and production patterns. These forces lead to human activities and processes which exert pressure on land resources resulting in various states of the environment. The change in state of the environment has consequences which are indicated in the framework as impacts that elicit responses. Responses are actions by individuals, societies and the government to prevent and adapt to negative impacts (Gabrielsen and Bosch, 2003). The arrows between components of the DPSIR framework represent causal chains which show sequential processes that link causes of problems with their effects (Smeets and Weterings, 1999)

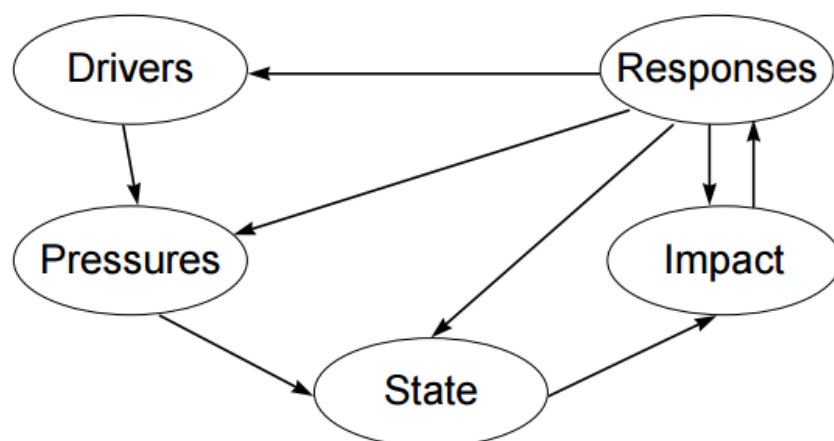


Figure 6: The DPSIR Framework Smeets and Weterings (1999)

The qualitative results of this study will be presented based on components of the DPSIR framework and will conclude with an adapted DPSIR LULC change framework for the Western Cape Province.

5.2.1 Driving Factors of LULC Change

- Political Factors

Various legislation and policies play a significant role in stirring LULC change in South Africa. The political apartheid history of South Africa is partially responsible for the current spatial patterns in the country. The Group Areas Act 41 of 1950 divided South Africans into different racial groups where a greater percentage of the land was for the white minority, whilst the majority blacks were confined to smaller homelands. The use of land in previous homelands has had significant impacts on LULC and livelihood options (Hoffman, 2014) and post-apartheid South Africa faces challenges which emanated from inequalities. Apartheid not only racially separated people, but also led to inequalities in housing, geographic location, environmental landscape and distribution of facilities (Spinks, 2001).

Post-apartheid policies and legislation were introduced with the aim of transforming apartheid spatial patterns into regions of “equity, integration and sustainability” (Rubin, 2008). However, Van Donk (2008) contends that past spatial patterns have been replicated by government’s incentives such as the Reconstruction and Development Program (RDP), which has seen settlement construction on the urban periphery with limited access to resources. He further asserts that this is due to the unavailability of affordable well located land and the need to address housing backlogs.

The South African Constitution of 1996 provides for the establishment of the three spheres of government as National, Provincial and Local (South Africa, 1996). These spheres are accorded legislative authority as described in Sections 43, 44, 104 and 156 of the Constitution. Section 40(1) states that they “are distinctive, interdependent and interrelated” (South Africa, 1996) and responsible for land use and spatial planning. Functional areas which are directly related to planning are listed in Schedules 4 and 5 of the Constitution of South Africa as provincial planning, municipal planning, regional planning and development and rural and urban development (Van Wyk, 2010). The Constitution however does not provide meanings of these functional areas, leading to inappropriate developments and conflicts between the three spheres. However, SPLUMA No 16 enacted in 2013 addresses this issue and clearly states the categories of spatial planning as municipal, provincial and national planning. Popular post-apartheid legislations that control land use in South Africa are listed in Appendix 2.

- Economic Factors

Economic factors are in the form of taxes, investments, access to capital, markets, cost of production and transportation, technology and subsidies (Barbier, 1997). Land managers are stimulated by these economic factors and motivated by profitability and feasibility of a particular land use. The Western Cape government intends to prioritize resources on high potential sectors of agriculture, tourism and industry as these promote job creation and inclusive growth (WCG, 2015).

Economic factors, combined with policies and institutional factors play a significant role in LULC change in the Western Cape Province. For example, giving farmers access to capital and markets and agricultural technology can encourage agriculture expansion and conversion of land. Interviews with town planners revealed the prevalence of pluriactivity, indicating strong links between sectors of agriculture and tourism.

- Technological Factors

The number of commercial farms in agriculture has declined from approximately 120 000 in 1950 to about 29 000 currently and there has been a corresponding increase in average farm size (DAFF, 2015). This has consequently led to less reliance on manual labour (leading to job losses) and an increase in capital assets such as mechanization. Farm worker issues have been reported in agricultural rural districts in the Cape Winelands as a result of job losses due to mechanization.

- Demographic Factors

It is not just the number of people that leads to pressure on land use, but aspects of population composition and distribution such as household size, migration and urbanization (Harrison and Pearce, 2000). The Western Cape Province experiences inflows of people from other regions through international, internal and temporary circular migration. Stats SA (2014) estimates internal or inter-provincial migration at 344 830 people into the Western Cape Province between 2011 and 2016. Internal migration into the province mostly originates from the neighbouring Eastern and Northern Cape Provinces and is due to perceptions of better employment opportunities, access to better health, education and other facilities. More than 80% of the population and economic activity in the province is concentrated in the City of Cape Town and the neighbouring Cape Winelands, characterized by rapid urbanization which leads to informal settlements expansion with high crime, poverty and basic services shortages (Maree and Van Weele, 2013).

Besides migration, declining household sizes also contribute to growth and land use issues. According to a study by UNISA, the average household size in South Africa declined from 4.48 in 1996 to approximately 3.69 in 2005 (Van Aardt, 2007). The number of households is increased by migrating youth and single mothers who contribute to the increase in shacks, which leads to increased pressure on infrastructure and services (Van Zyl et al., 2008).

- **Biophysical Factors**

Biophysical factors “define the natural capacity or predisposing environmental conditions for land use change, with the set of abiotic and biotic factors – climate, soils, lithology, topography, relief, hydrology and vegetation” (Lambin and Geist, 2007). The interactions between biophysical variables and human activities influence land use change e.g. relief, which determines the extent that machinery can be used and the rates of erosion. Steep slopes are difficult to operate modern farm machinery and also subject to erosion thus limiting exploitation. Changes in land uses such as agriculture are influenced by biophysical factors e.g. climate (rainfall, wind, temperature) and soil conditions.

The effects of climate changes are evident in the Western Cape Province where extreme weather conditions in form of droughts, heat waves and floods are prevalent. These conditions have consequently led to decreases in crop production and loss of jobs in the agricultural sector. The impact of climate change on the agriculture sector also adversely affects other sectors that rely on agriculture for key inputs. Furthermore, very hot and dry conditions in the Province trigger fires which are partially responsible for loss of plantations.

- **Cultural Factors**

Cultural factors encompass beliefs, attitudes and perceptions of land managers which have an impact on land use decisions (Lambin and Geist, 2007). The awareness of land managers on consequences of land use decisions depends on their personal histories and information available to them, and these are often linked to political and economic factors (Lambin and Geist, 2007). Interviews with municipal town planners revealed that land use decisions in the Western Cape Province are in the hands of the mayor, council, politicians, institutions, developers together with limited influence of the general public. Lack of awareness of impacts of land use change can adversely affect both the environment and economy.

- **Summary of Driving Factors**

Driving factors of LULC for the Western Cape Province were broadly categorised as proximate and underlying factors. Based on interview responses and document analysis, proximate factors that involve direct land use modifications at a local scale are infrastructure, agriculture and forestry changes. Underlying factors operate at municipality and provincial levels and were identified as political, demographic, economic, technological and cultural factors. Figure 7 summarises the driving factors of LULC change in the Western Cape Province.

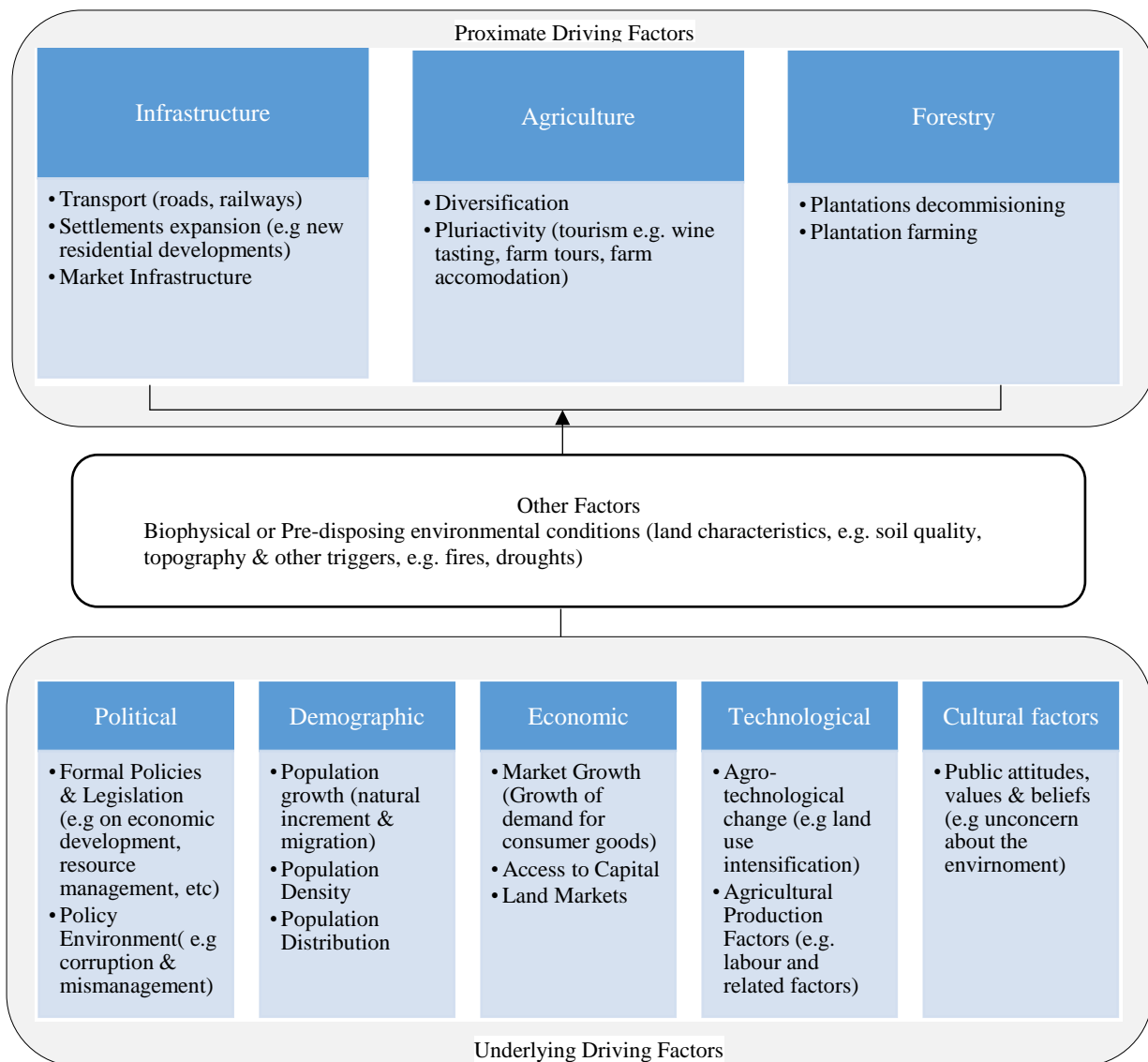


Figure 7: Driving Factors of LULC change in the Western Cape Province [adapted from Geist and Lambin (2002)]

5.2.2 Pressures

The factors discussed above lead to human activities which exert pressure on land resources. The most prominent pressures emerge from sectors with high economic development opportunities, which occur in the Cape Metropolitan, Eden and West Coast district municipalities. These sectors have been identified in the Provincial Environmental Review and Outlook as agriculture, tourism and industry sectors, which interact with other associated sectors and promote LULC change. Pressure from agriculture is in the form of land, water availability and chemicals. The agricultural sector attracts both inter-provincial and circular temporary migrants, thus exerting pressure on transport.

Development pressures in the province are also influenced by institution research projects and partnerships with the government. Examples are Agri-hubs by the Department of Rural Development and Land Reform (DRDLR); port developments by Transnet and the Department of Economic Development and Tourism (DEDT); and plantation decommissioning by South African Forestry Companies Limited (SAFCOL). Institutions conduct studies and make recommendations which push government to approve changes, especially if the impacts align with government objectives.

5.2.3 State

Land use change drivers coupled with pressures on resources affect the state of land. The change in state of land has clearly been demonstrated with the results presented from the desktop analysis which shows the changes that have taken place in LULC between 1990 and 2014. LULC maps also show that most infrastructure developments are concentrated along the coastline, in the City of Cape Town

and in core agricultural towns. Based on the interview respondents, most land use changes and associated impacts occur in agricultural, tourism and industry related areas.

Agriculture takes up the majority of land in the Western Cape Province (2.5million ha) and past trends indicate a decrease in croplands in the Central Karoo District with a contrasting increase in vineyards in the Western region (Maree and Van Weele, 2013). The decrease in agriculture is due to land capability and water availability where the latter is a common restraining factor in the Province. The increase in tourism has put a demand on residential, transport and other infrastructure, particularly in coastal areas where developments are taking place in the form of holiday homes, residential accommodation and tourism associated activities. Transnet and DEDT research on industrial opportunities has resulted in port developments and the initiation of the Saldanha bay Industrial Development Zone (IDZ).

5.2.4 Impacts

The change in state of land use has both positive and negative consequences. Agriculture promotes food security, job creation, economic stability, inputs to other industries amongst other advantages. However poor farming practices, overgrazing and land clearance can lead to erosion and land degradation. The conversion of plantations to other land uses has led to job losses and dried trees from clear-felling have fuelled fires leading to biodiversity loss. The perception of the Western Cape as a better province in terms of employment and access to basic services has led to in-migration leading to pressure on transport, accommodation and other essential facilities. This consequently leads to congestion, increased crime, informal settlements, backyard housing, urban sprawl, infrastructure developments and other issues which negatively impact the environment.

Pressure from the tourism industry has led to developments close to the coast and road upgrading to improve connectivity. The N1, N2 and N7 highways together with other roads will need upgrading to facilitate connectivity between tourism and other economic hubs. The Western Cape Province consists of three major ports i.e. Saldanha Bay, Cape Town and Mossel bay. The Saldanha Bay IDZ is expected to provide employment and various economic opportunities to different industries in future and Transnet has proposed iron-ore infrastructure expansion which will be an economic benefit and is also aligned with government infrastructure development goals (WESGRO, 2015). However the upgrading and expansion of iron ore terminal requires sediments dredging which leads to marine disturbance, pollution and coastal erosion (Clark et al., 2015).

5.2.5 Response

Responses are actions which societies or governments undertake as a result of detrimental impacts which can take place at stages between driving factors and impacts in the DPSIR framework. Such responses in the study area have been in the form of policies and monitoring projects. An example is the monitoring of the state and changes of ecosystem functioning of the Saldanha Bay and Langebaan Lagoon by the establishment of the Saldanha Bay Water Quality and Forum Trust (SBWQFT) (Clark et al., 2015). The SBWQFT produces annual reports on activities which affect the bay such as industrial development, dredging, and coastal erosion in order to identify and mitigate negative impacts to the environment (Clark et al., 2015).

5.2.6 Adapted DPSIR framework

LULC aspects and issues which emerged from interviews and document readings were presented in an adapted DPSIR framework consisting of themes of Driving Factors, Pressures, State, Impacts and Responses (Figure 8). This framework was developed to structure and subsequently summarise qualitative findings of this research.

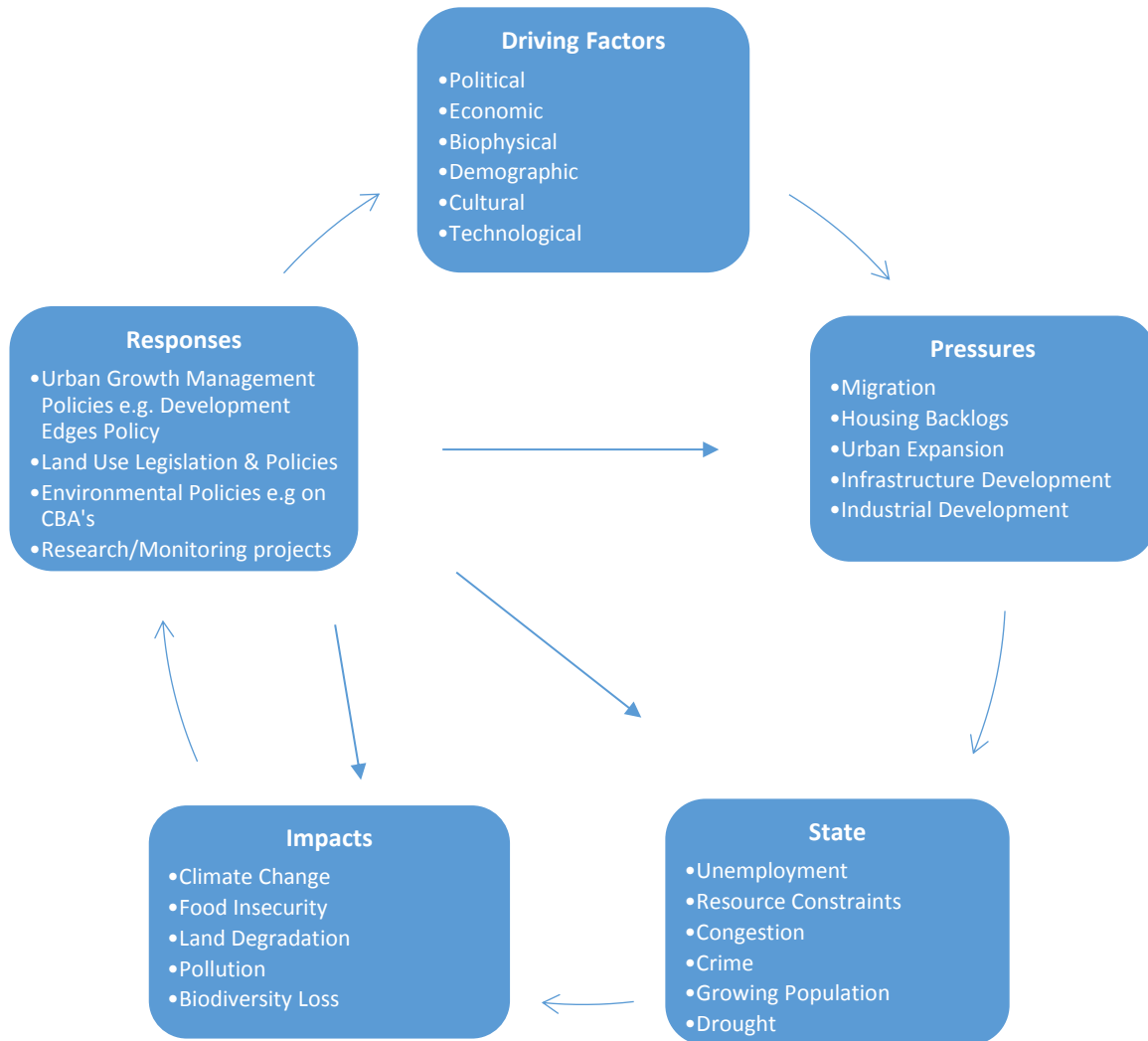


Figure 8: DPSIR Framework for LULC change in the Western Cape Province

6. Research Contribution

The identified driving factors of LULC change can be used to define transition rules in LULC change models. Such models have the ability to demonstrate and evaluate the impacts of driving factors by simulating possible scenarios. This paper therefore provides important knowledge which can be used in designing effective LULC change models that can analyse future scenarios and support planning. Planners can also use this knowledge in developing regional land-use strategies that recognize both short and long term impacts of LULC changes.

7. Research Limitations

One of the objectives of this study was to quantify changes in LULC by using pre-existing 1990 and 2013/14 National LULC datasets. The reliability of the LULC change statistical results is contingent on the accuracy of image processing, classification of input datasets and seasonal or climatic conditions from which the original source imagery was acquired.

8. Further Research

The results of this study provide an opportunity to explore the impacts of land use decisions by implementing land use change models. Models are used to simulate land use changes and hence assist policy makers in making well informed decisions.

9. Discussion and Conclusion

This study aimed to quantify LULC changes and to understand drivers of changes in the Western Cape Province. This was achieved by using GIS software to analyse LULC maps derived from remote sensing imagery, interviewing town planners to obtain deeper insights on LULC change dynamics and adapting of the DSPIR framework. The LULC quantitative analysis results indicate that there were significant LULC changes between 1990 and 2014 characterised by declines in forest plantations, grasslands, wetlands, and barren lands. In contrast, urban/built up, mines and quarries, water bodies, woodlands, thicket and shrubland classes exhibited increases. Mines and quarries had the highest increase (52.82%) mostly due to the demand of sand from the construction industry. The highest loss was in plantations (-32.41%), owing to the government's exit policy which saw the decommissioning of plantations. The LULC change results also show that there has been a provincial increase in urban / built up areas with about 12% and 1.03% increase in cultivation. However, analyses of individual district municipalities LULC changes reveal that the increase in urban areas was concentrated in Cape Metropolitan area and the adjacent Cape Winelands at the expense of cultivated land, shrubland and low fynbos and plantations. Increase in urban areas is due to rising infrastructure demands generated by population growth and the tourism industry.

Qualitative results of this study indicate that LULC changes in the Western Cape Province are a result of diverse interrelated factors that operate at different scales. At a provincial scale, changes emerge from political factors through legislation and policies aimed at poverty alleviation, promoting access to basic services, reducing inequalities and promoting economic growth. Patterns of LULC changes are consistent with nodes of economic growth which occur in the Cape Metropolitan, Eden and West Coast district municipalities. The agriculture, tourism and industry sectors in these municipalities attract foreign investments leading to net in-migration from other provinces. Migration coupled with natural increase results in population growth which increases the amount and intensity of pressure exerted on resources and consequently changes the state of land. Driving factors of LULC change were grouped into proximate and underlying causes as proposed by Geist and Lambin (2002). Based on interviews and document analysis, proximate causes were identified as infrastructure, agriculture and forestry changes and underlying causes as political, demographic, economic, technological and cultural factors. To understand these drivers, the DPSIR framework was adapted to show how driving factors lead to human activities which exert pressure on resources resulting in various states of the environment which have significant impacts and require responses. Strategies and policies based on responses to major drivers of LULC and their impacts are therefore recommended to avoid undesirable impacts of changes in LULC.

10. Acknowledgements

This study formed part of a Masters Research project supervised by Ms Alize Le Roux, Mr Gerbrand Mans and Mr Antony Cooper. Their constant guidance is highly appreciated. The DRDLR officials, District and Local Municipality town planners in the Western Cape Province are acknowledged for their participation in this study.

11. References

- Annum, D. G. 2015. *Research Instrument for data collection* [Online]. Available: <http://campus.educadium.com/newmediart/file.php/1/giilmadstore/UgradResearch/ThesisWrit4all/files/notes/resInstr.pdf> [Accessed 2 February 2016].
- Barbier, E. B. 1997. The economic determinants of land degradation in developing countries. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 352, 891-899.
- Briassoulis, H. 2000. Analysis of land use change: theoretical and modeling approaches.
- Clark, B. M., Massie, V., Laird, M., Biccard, A., Hutchings, K., Harmer, R., Brown, E., Dun, a. O. O., Makunga, M. & Turpie, J. 2015. The State of Saldanha Bay and Langebaan Lagoon 2015. Anchor Environmental Consultants.
- Clark University © 2005-2013 Land Change Modeler for ArcGIS. 2.0 ed.: Clark University.
- Dadhich, P. N. & Hanaoka, S. 2011. Spatio-temporal urban growth modeling of Jaipur, India. *Journal of Urban Technology*, 18, 45-65.

- DAFF 2015. 2015/16 to 2019/20 Strategic Plan. *In: DEPARTMENT OF AGRICULTURE FORESTRY AND FISHERIES (ed.)*. Pretoria.
- De Beer, M. C., Cori, H., Längin, D. W. & Theron, F. 2014. The socioeconomic impact of the phasing out of plantations in the Western and Southern Cape regions of South Africa. *Southern Forests: a Journal of Forest Science*, 76, 57-64.
- DEAT 2008. A National Framework for Sustainable Development in South Africa
- Di Gregorio, A. & Jansen, L. J. 1998. Land Cover Classification System (LCCS): classification concepts and user manual. *FAO, Rome*.
- ESRI © 1999-2015 ArcMap 10.3.1. ESRI Redlands, CA.
- Gabrielsen, P. & Bosch, P. 2003. Environmental indicators: typology and use in reporting. *EEA, Copenhagen*.
- Geist, H. J. & Lambin, E. F. 2002. Proximate Causes and Underlying Driving Forces of Tropical Deforestation *BioScience*, 52, 143-150.
- GEOTERRAIMAGE 2014. 2013-2014 South African National Land-Cover Dataset. Data User Report and Metadata.
- Harrison, P. & Pearce, F. 2000. *AAAS atlas of population & environment*, Univ of California Press.
- Hoffman, M. T. 2014. Changing Patterns of Rural Land Use and Land Cover in South Africa and their Implications for Land Reform. *Journal of Southern African Studies*, 40, 707-725.
- Kristensen, P. The DPSIR framework. Workshop on a comprehensive/detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach, 2004. 27-29.
- Lambin, E. F. & Geist, H. J. 2007. *Causes of land-use and land-cover change* [Online]. Available: <http://www.eoearth.org/view/article/51cbcd2f7896bb431f6905af> [Accessed 20 January 2015].
- Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G. & Folke, C. 2001. The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change*, 11, 261-269.
- Maree, G. & Van Weele, G. 2013. State of Environment Outlook Report for the Western Cape Province.
- Riebsame, W. E., Meyer, W. B. & Turner II, B. L. 1994. Modeling land use and cover as part of global environmental change. *Climatic change*, 28, 45-64.
- Rubin, M. 2008. LAND MANAGEMENT AND DEMOCRATIC GOVERNANCE IN THE CITY OF JOHANNESBURG. Urban Landmark.
- Sims, D. & Sombroek, W. G. 1997. Negotiating a sustainable future for or land-Structural and institutional guidelines for land resource management in the 21st Century.
- Smeets, E. & Weterings, R. 1999. *Environmental indicators: Typology and overview*, European Environment Agency Copenhagen.
- South Africa 1996. Constitution of the Republic of South Africa Act No. 108 of 1996.
- Spinks, C. 2001. *A New Apartheid?: Urban Spatiality, (fear Of) Crime, and Segregation in Cape Town, South Africa*, London School of Economics and Political Science, Development Studies Inst.
- Stats SA 2014. Mid-year population estimates. Statistics South Africa.
- Turner, B., Meyer, W. B. & Skole, D. L. 1994. Global land-use/land-cover change: towards an integrated study. *Ambio (Sweden)*.
- Van Aardt, C. 2007. Population and Household Projections for South Africa by Province and Population Group, 2001-2021. Bureau of Market Research, University of South Africa.

- Van Donk, M. 2008. *Consolidating developmental local government: Lessons from the South African experience*, Juta and Company Ltd.
- Van Wyk, J. 2010. Parallel planning mechanisms as a " recipe for disaster". *PER: Potchefstroomse Elektroniese Regsblad*, 13, 214-234.
- Van Zyl, J., Cross, C. & Donovan, M. 2008. Overview of the extent and nature of the unbundling of South African households and the implications thereof. *Paper Commissioned by The Presidency, South Africa*.
- WCG 2015. Provincial Economic Review and Outlook 2015. *In: TREASURY, W. C. G. P.* (ed.). Cape Town.
- WESGRO 2015. 2015/2016 INVEST IN WESTERN CAPE A PERSPECTIVE ON INVESTMENT OPPORTUNITIES IN THE WESTERN CAPE.
- Wilgen, B. W. v. 2015. Plantation forestry and invasive pines in the Cape Floristic Region: Towards conflict resolution. *South African Journal of Science*, 111, 1-2.

Appendix 1

Interview Guide Questions

What are the most significant land use changes that have occurred in this municipality in the last 20years?

Where did these changes occur and why in those particular locations?

When did the changes occur and why then?

Who is responsible for these changes?

What are the main reasons for these changes in land use?

Have government policies played a role in land use change?

What are the potential economic, social and environmental impacts of land use changes?

What measures are being implemented or considered by your municipality to address these potential impacts?

Does your municipality use any population or economic growth projection tools; if so, is it in its own capacity/ consultants are hired to do it?

What do you think this municipality will look like in 10years?

Appendix 2

Post-apartheid legislation that control land use in South Africa

Constitution of South Africa No 108 of 1996

Municipal Systems Act No 32 of 2000

Development Facilitation Act No 67 of 1995 (DFA)

Spatial Planning and Land Use Management Act no 16 of 2013 (SPLUMA)

Housing Act No 107 of 1997

National Environment Management Act No 107 of 1998 (NEMA) and associated acts i.e.

- NEM: Protected Areas Act, 2003
- NEM: Biodiversity Act,2004
- NEW: Air Quality Act, 2004
- NEM: Integrated Coastal Management Act,2008
- NEM: Waste Act, 2008

National Heritage Resources Act No 25 of 1999

Social Housing Act of No 16 of 2008

National Land Transport Act 5 of 2009

Authors Profile

Petronella Tizora is a registered GIS Technologist working as a Cartographer in the Unit for Geoinformation and Mapping, Geography Department at the University of Pretoria. She is currently in the process of acquiring her Masters in Geoinformatics, focusing on modelling land use changes in the Western Cape Province.