Assessing Changes in Land Use and Land Cover using Remote Sensing:

A Case Study of the Umhlanga Ridge Sub - Place

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Abstract

Land has proven to be a key component in the development of the human population and is viewed as one of the most significant natural resources currently available. This observation brings into question the recent debates surrounding the pressures people tend to impose on the land, which have resulted in transformations in its physical landscape and usage. Mans impact on the earth in terms of the transformations in land cover and land use have rapidly increased over the years. However, as a result of these continuous land transformations, planning and designing sustainable urban development has become challenging due to the additional fact that the available mapped resources of the land can be outdated or of very poor quality. One of the main methods of depicting the significant changes in land cover or land usage is through the utilization of remote sensing and its key application of change detection. Change detection enables the user to analyse the transformations of land use and land cover as it is able to provide consistent coverage at short intervals.

One of Durban's greatest cases of land transformations is change which has occurred in Umhlanga and its surrounding areas. Umhlanga started out as an area of tremendous agricultural value to the South African economy by producing substantial amount of sugar from its vast lands of sugarcane. Over time however, Umhlanga began to develop its coastline and gradually it expanded the transition until it became a central hub of social and urban development. Therefore, this research endeavour focuses on depicting this above mentioned land transformation from fields of sugarcane to the presently expanding area of suburban development in Umhlanga Ridge.

The aim of this study is to assess and analyse the land use and land cover changes that have occurred in Umhlanga Ridge using remotely sensed data and to further understand the socio – economic implications of these changes. Utilising the change detection method of image differencing, the remotely sensed data provided by the South African National Space Agency (SANSA) was analysed to identify the changes that have occurred between the years 2006 and 2012.

The results yielded from this research endeavour have proved that within Umhlanga and specifically that of Umhlanga Ridge, major land use and land cover transformations have occurred. The most dominant and evident change was found in the larger extent of the Transport and Urban land cover classes by the year 2012. While classes such as the forest and woodland, cultivated Land, grassland and the barren land cover experienced significant drops in their land cover extent, the results generated from the analysis showed that most of these land covers were taken over by the development of urban features.

Furthermore, this study reported profound socio – economic implications which occurred due to widespread land use and land cover changes. While many implications were documented, one of the main implications of this nature was found to be the significant number of employment opportunities that became available as a result of the expanding urban landscape. As the urban landscape of this area is continuing to change and expand, it is important to highlight that as a direct consequence of this action, the extent of the naturally occurring environment is being depleted. Therefore, with the urban development now being Umhlanga's dominant land cover class, additional and supporting data has revealed that the Tongaat Hulett Company and Development sector strives to maintain a balanced with its ecological surroundings by ensuring that suitable sustainable methods are used in the development process and in the maintenance of the area.

To conclude, in accordance to the research produced from this study, it is evident that the urban development in Umhlanga and Umhlanga Ridge has grown tremendously and will continue to expand at a steady rate in the future, with the intention of meeting the demands of the area's visiting tourists and permanent residents. However, while these continuous land use and land cover changes are taking place and expanding, it is imperative that a balanced relationship between man and nature be taken into consideration.

Preface

All the work stipulated in this dissertation was conducted in the Discipline of Geography in the School of Agricultural, Earth and Environmental Sciences at the University of KwaZulu-Natal, Durban (Westville). This research was carried out from February 2014 to November 2015.

Undertaken through the supervision of Dr. Michael Gebreslasie (School of Agricultural, Earth and Environmental Sciences) this study represents original work of the author which has not been submitted in any other form - in part or whole - for any degree or diploma to any University. Where the use of other works has been made, it has been duly noted in the text.

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December 2015

Declaration

I, as the researcher of this study, declare that...

(i) The research reported in this project, except where otherwise indicated, and is my original work.

(ii) This project does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons

(iii) This project does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

  a) Their words have been re-written but the general information attributed to them has been referenced

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(iv) This project does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the References sections.

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Abbreviations *(In alphabetical order)*

ANN	Artificial Neural Networks
CD	Change detection
CVA	Change Vector Analysis
DTC	Decision Tree Classifier
EIA	Environmental Impact Assessment
EMS	Environmental Management Systems
EO	Earth Observation
FAO	Food and Agricultural Organisation
GCPs	Ground Control Points
GPS	Global Positioning System
ID	Image Differencing
IRPTN	Integrated Rapid Public Transport Network
LULC	Land use and land cover
NASA	National Aeronautics and Space Administration
PCA	Principle Component Analysis
PCC	Post Classification Comparison
RMSE	Root Mean Square Error
SEDAC	Socioeconomic Data and Applications Centre
SANSA	South African National Space Agency
SASI	South African Sugar Industry
SD	Sustainable Development
SPCA	Selective Principal Component Analysis
SVM	Support Vector Machines
TDRSS	Tracking and Data Relay Satellite System
TID	Temporal Image Differencing
TIR	Temporal Image Ratioing
TM	Thematic Mapper
UHI	Urban Heat Island
USGS	United States Geological Survey
URNTC	Umhlanga Ridge New Town Centre
WGS	World Geodetic System

Chapter One: Introduction

1.1 Background

As one of the most significant natural resources available, land has proved to be a key component in the development of the human population. Land and its resources are able to provide man with numerous necessities such as food, water and shelter (Foley et al., 2005; Wu, 2008). In addition, land's versatile and adaptable characteristics have resulted in it being considered as one of the most unique resources in the process of production to both rural and urban populations on a global basis (Kivell, 1993; Meyer and Turner, 1994; Wu, 2008). From a historical perspective, land is said to yield a significant source of wealth, power, status and furthermore, from within the South African context, the colonial and Apartheid struggles have resulted in vastly skewed land ownership patterns and exacerbated disputes over the legalities of the land use (Beall et al., 2009; Bob, 2010).

However, being in a state of fixed supply, the availability of land is quickly becoming a scarce resource due to the rapidly increasing world population. Over the years the rising world population has had a significant impact on the functionality of urban and rural areas; leading to the questioning of the balance of supply and demand with regards to resources and usage of land (Ramankutty et al., 2002). This observation brings into question the recently occurring debates surrounding the pressures people tend to impose on the land which have resulted in transformations in its physical landscape and usage. According to a document released by the Food and Agriculture Organisation (FAO) in 1999, it was stated that migration of people from the rural to urban areas have reduced the pressures on the land for agricultural purposes. However on the other hand, expanding urban areas will mean a significant decrease in the total land available for agriculture to generate enough produce to sustain the increasing demands of the population (Food and Agricultural Organisation, 1999).

Urbanisation, the process whereby individuals from the rural areas make a transition to the urban sector, is regarded as one of the most irreversible forms of human activity on the land and has an immense impact on the environment at both local and global scale (Cowgill, 2004; Liu et al., 2005; Seto et al., 2012). This process gives rise to changes in land cover, threatens the biodiversity, effects ecosystems through habitat loss, affects the hydrological systems, influences the consequences of climate change, damages agricultural lands, gives rise to urban encroachment, substandard living environments as well as increased traffic congestion (Cowgill, 2004; Seto et al., 2012). For the purpose of this study, focus will be placed on understanding the role that the process of urbanisation has in contributing to the transformations of land use in the urban area of Umhlanga. This phenomenon will be further discussed later on in the research, as it is vital that the concept of land use and land cover change is understood beforehand.

The concept of LULC change is said to be of a multidisciplinary nature and as a result a single concise definition for the concept has not been determined. Nonetheless when looked at critically, the term LULC can be divided into two; land use and land cover. According to various authors, land cover can be described as the type of features which occur on the earth's surface, such as water bodies, vegetation and man-made structures (Ellis, 2013; Lillesand et al., 2008).

On the other hand, land use can be described as the human activities which take place on the surface of the earth or on the land including, agriculture, forestry and even expanding to the context in which the land is managed (Ellis, 2013; Lillesand et al., 2008). However, a common factor which links these concepts together is the idea that their occurrences are due to humans' impact on the earth and its surface (Lambin and Geist, 2006).

As mentioned previously, the impact of human activities on the earth's land cover and land use have rapidly increased over the years and as a result of these continuous land transformations, planning sustainable urban development becomes challenging. A further challenge experienced is that the available mapped resources of the land are either outdated or of very poor quality (Aspinall and Hill, 2007; Beall et al., 2009; Westendorff and Eade, 2002). With this lack of available information, it has become crucial to, "develop uniform systems of monitoring, changing patterns and growth of human settlements," (Westendorff and Eade, 2002: 306).

As a response to the above mentioned need for updated information on the earth's surface, a modern application of science termed Earth Observation (EO), was implemented in order to study the earth's transforming environment with the use of various remote sensing tools including satellite imagery and aerial photography (Westendorff and Eade, 2002). It is through the acquisition of remotely sensed imagery that locally and globally generated data from these systems or models are currently being developed in to the form of understandable maps in order to aid in documenting the LULC transformations that have taken place over the years.

1.2 Use of Remote Sensing and Change Detection

One of the main methods of depicting the significant changes in land cover or land uses is through the utilization of remote sensing. Remote sensing is considered to be, "the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand et al., 2008: 1). With the increasing ability to quantify and monitor the expansion of urban environments, remote sensing offers users a set of spatially consistent data, greater spatial precision and an overall higher resolution when compared to that of existing aerial imagery (Richards and Richards, 1999; Rogan and Chen, 2004; Xiao et al., 2006).

Combined with the use of Geographical Information Systems (GIS) and Global Positioning System (GPS) tools, remote sensing is able to generate better results for detecting LULC changes (Weng, 2002; Xiao et al., 2006). Remote sensing technologies have been previously used in various studies yielding effective results for both urban land use expansion modelling and land use change detection (Chen et al., 2000; Fasona and Omojola, 2004; Sheoran et al., 2013; Singh, 1989)

Change detection is a key application of remote sensing that enables the user to analyse the transformations of LULC, as it attains consistent coverage at short intervals (Singh, 1989). Change detection systematically correlates and evaluates images that are captured of the same area at different times and as a result, depicts the various land transformations that have occurred (Harris, 2003; Lillesand et al., 2008; Shepard, 1964; Singh, 1989). Change detection allows for both short and long term land transformations to be depicted and in order to achieve this, the process utilises multiple multi-temporal datasets (Lillesand et al., 2008).

It must also be noted that there are a variety of methods to conduct change detection, such as image differencing, image rationing and image regression (Lillesand et al., 2008; Singh, 1989). In addition, Singh (1989), mentions that in order for most change detection methods to function correctly, the two images must be of the same spatial registration including, the same map projection and time of day in which the images were captured. This process is explained by proposing the following example of change detection as, "detecting the change in suburban developments near a metropolitan area using data obtained on two different dates," (Lillesand et al., 2008: 22).

1.3 Motivation for this study

Land is rapidly becoming a limited resource throughout the globe and as a result there is a need for more efficient land use planning, especially towards the implementation of sustainable agricultural practices. With the growth of the human population in conjunction to the rapidly occurring process of urbanization, there is increased competition and continuous conflict arising between different land users; ultimately this has the ability to threaten the functionality of surrounding ecosystems and societies (Nagendra et al., 2004). Over the years, the lack of appropriate and efficient land use and land cover monitoring systems has allowed for unexpected and unprecedented rates urban growth to occur at the cost of agricultural land needed for the survival of mankind and surrounding ecosystems (Weng, 2002).

While detection and monitoring of urban growth is imperative toward creating effective methods of sustainable urban planning to monitor urban development, there is a need to place greater attention on the management of the land's resources with regards to the increasing population in urban landscapes (Odindi and Mhangara, 2011). Land use and land cover analysis and the process of change detection have play a key role in evolving the manner in which sustainable urban planning and development is conducted. One of the most recognised examples of extensive land use change in KwaZulu – Natal to date is that of the Umhlanga suburban area. As a result, this study will aim to assess and analyse the land use and land cover changes which occurred in Umhlanga Ridge and to also understand the socio – economic implications of these changes on the area today.

1.3.1 Umhlanga Ridge

Dating back to 1931, the area of Umhlanga quickly became a popular holiday destination attracting people from throughout KwaZulu – Natal and South Africa. While development continued through the years, the area of, Umhlanga has managed to maintain its beauty and recreational aesthetical value, which is now attracting tourists from across the world to its coastline (Tongaat, 2011). As part of the development progress, Umhlanga Ridge has emerged as one of the main districts of Umhlanga.

Being a hub of residential and commercial activity, Umhlanga and its suburban environment of Umhlanga Ridge, thrives on its ability to attain an eco-friendly design to its development and illustrates a positive interaction between man and the environment (Tongaat, 2011). While various studies have taken place with regards to the ecosystems of the Umhlanga Ridge Centre and its greater surrounding areas, this specific study intends to observe the Umhlanga Ridge from a holistic perspective to identify how the LULC's have transformed since its creation.

1.4 Aim

The aim of this study is to assess and analyse the land use and land cover changes that have occurred in Umhlanga Ridge using remote sensing and to understand the socio – economic implications of these changes.

1.5 Research Objectives

- To identify the dominant land use and land cover changes that have occurred between the years 2006 and 2012 in Umhlanga Ridge.
- To evaluate the extent of the changes that has taken place in Umhlanga Ridge.
- To determine the future changes of Umhlanga Ridge.
- To examine the socio - economic implications of the current changes in Umhlanga Ridge.

1.6 Methodology

In order to conduct this research, remotely sensed images of the Umhlanga Ridge area will be collected from the South African National Space Agency (SANSA) at an estimated interval of 5 years from 1995 to 2010. This will allow for 4 images to be collected and then classified with the most appropriate and accurate classifier algorithm in order to identify the LULC transformations. Thereafter, accuracy assessments will be carried out on each of the produced land cover maps and the image differencing technique will be employed as the best suited change detection technique for the study (Lillesand et al., 2008; Lillestrand, 1972). Furthermore, interviews with at least ten members of the Tongaat Hulett Development sector will be conducted using the Snowball sampling method in order to understand the ideas behind the LULC transformation of Umhlanga, the emergence of the Umhlanga Ridge Town Centre development, the socio – economic implications of these changes and to establish the future changes that are currently planned for further development of the Umhlanga landscape.

1.7 Thesis Outline

The following research endeavour will consist of seven chapters. Chapter One is aimed at highlighting information surrounding the field of study, the motivation for this study as well as the main aim and associated objectives of this research. Chapter Two of this thesis is to provide a synthesis of the various concepts and theories that are related to the specific area of study. Therefore, this chapter will draw attention to how the concept of sustainability is included in the planning and development of urban areas and the direct relation between sustainability and urban growth.

The literature review is the third chapter of this study and will document the current and most recent literature related to the topic of LULC changes. Furthermore, Chapter Three of this research highlights why LULC changes occur, the impacts they impose on the environment and the surrounding human population. In addition, the chapter will look at the significance of remote sensing and how – along with change detection – LULC transformations can be analysed.

Provided in the Chapter Four of this study will be, the geographical context, a thorough history of the Umhlanga area and climatic information relating to the study area. The methodology of this study will be discussed in Chapter Five. Highlighting a detailed account of all land cover classes located in the study area, Chapter Five will also discuss how the field study was conducted, how all the data needed for this study was collected and furthermore, how the classification and post classification procedures were carried out.

Chapter Six provides all the results obtained for this study, as well as an in-depth analysis of the changes experienced within each land cover class and what socio – economic implications have occurred as a result of these changes. Chapter Seven is aimed at stating the overall conclusions from this study, the limitations experienced and any recommendations to solve these limitations and improve the study.

1.8 Summary

This chapter highlights the importance of land to both mankind and the natural environment. The profound human activity of urbanisation has inflicted immense pressure and strain on the environment and remote sensing is utilised as the most successful tool to identify and monitor LULC changes in any given area. Therefore, this research endeavour is aimed at assessing and analysing the LULC transformations that have occurred in Umhlanga Ridge by using remotely sensed imagery and to further understand the socio – economic implications of these changes.

Chapter Two: Conceptual Framework

2.1 Introduction

A conceptual framework aims to provide a synthesis of the various concepts and theories that are related to or surround the specified area of study or research and are able to provide a reason for phenomena that continue to occur under similar conditions (Jabareen, 2008; Rudestam and Newton, 2001). This chapter will therefore be focusing on synthesising sustainable development in general – the history behind the concept, its multidisciplinary nature and the way it is implemented in modern society. In addition, this study calls for an understanding of how sustainability plays a role in the planning and development of urban areas. Thus, this chapter will also include information on the direct relationship between sustainability and urban growth.

2.2 Sustainable Development

First used in the 1980 World Conservation Strategy but made popular by the publication of the Brundtland Commission in the year 1987, the broadly accepted concept of sustainable development (SD) has been said to be, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," (WCED, 1987: 43). However, concerns surrounding the acceptability of this definition soon began to arise after its introduction into policy documents, strategies and everyday dialogue, due to the fact that its meaning was found to be vague and exceptionally ambiguous (Giddings et al., 2002; Redclift, 2005).

Many critics have noted the concept's ambiguity and deceptive nature due to its numerous internal complications and overall incongruity however, its widespread implementation and use within various disciplines of local, national and global levels has resulted in an assorted interpretations and perceptions of the concept (Mebratu, 1998; Redclift, 2005). With its multifaceted nature, it is expected that debates surrounding the concept and definition would come up; one of these discussions that has been highlighted is the fact that the definition of SD allows for the prioritisation of anthropogenic needs over the other influencing factors of life and the environment (Giddings et al., 2002; Redclift, 2005).

Another concerning issue is that, when analysing the definition of SD it is important to note that the 'needs' mentioned in the definition will constantly be changing as the needs of the present are unlikely to be the same needs outlined by each of the future generations and their associated cultural beliefs and values (Redclift, 1993; Redclift, 2005). Furthermore, Redcliff (2005) emphasizes that the manner in which SD is defined within different cultures or traditional systems is of high importance, as highlighted in the following example, "if in one society it is agreed that fresh air and open spaces are necessary before development can be sustainable, it will be increasingly difficult to marry this definition of 'needs' with those of other societies seeking more material wealth, even at the cost of increased pollution," (Redclift, 2005: 213). This statement by Redcliff (2005) holds significant value in analysing the concept and definition of SD; because, it brings to light the unavoidable misinterpretations of SD within culturally different societies and is also seen as the fundamental reason behind the long standing debates currently occurring.

In order to attain a complete understanding of SD and all that it entails, models of SD need to be analysed. Models are able to help, "gather, share, and analyse information; they help coordinating work; and educate and train professionals, policymakers, and the public in general," (Jain et al., 2007: 12), in order to successfully achieve SD. With the process of SD requiring effective, efficient and transparent communication and production among all government or public entities involved; the two most popular and well known models to the SD discourse will be examined in closer detail (Blewitt, 2010; Jabareen, 2006; Jain et al., 2007; Pezzey, 1992).

2.3 Models of Sustainable Development

2.3.1 The Three Ring Model

As illustrated in Figure 2A, these three 'pillars' provide the details needed to explain the concept of SD (Dempsey et al., 2011; Elliott, 2006; Giddings et al., 2002). First presented by Barbier (1987) in the form of three interlocking circles, the depiction highlights the symmetrical interconnectedness through the means of equal sized rings; thus making the visualisation, understanding and analysis of this SD model fairly simple.

With reference to the model depicted in Figure 2A, the 'economy' sector of this SD model is said to be based on the idea of maximising the, "flow of income that could be generated while at least maintaining the stock of assets (or capital) which yield these benefits," (Munasinghe, 1993: 3). Expanded by Elliott (2006) and Waas (2011), the inclusion of the economic factor in the model of SD has said to influence the need to provide job opportunities in order to attain basic needs such as food, water, a sanitary place of residence and overall social security. Objectives comprising of reductions in poverty, the increased accessibility of resources and the provision of services is seen as important goals that are needed to be achieved in SD from an economic approach (Elliott, 2006; Ndah, 2015). Furthermore, it has been stated that the economic sector must minimise the risks that jeopardise the level of economic sustainability and rather work toward maintaining a level of institutional, environmental and social sustainability (Spangenberg, 2005).

On the other hand, the environment or 'ecological' sector focuses on maintaining a balance between the physical and biophysical systems of the environment. This is then further explained to state that this sector of ecology combines all elements of the biosphere; those naturally occurring and also those that are man-made (Munasinghe, 1993; Perrings, 1991). In addition it is important to highlight that preserving the biodiversity and its resilience by means of genetics and also biological productivity is crucial to the adaptation process as environmental changes – natural or synthetic – continue to influence the biosphere (Elliott, 2006; Munasinghe, 1993; Rogers et al., 2008).

While the 'economics' and 'ecology' disciplines were at the forefront of defining the concept of SD, the idea to include the third discipline of 'society' emerged through the work of most recently conducted studies and research (Elliott, 2006; Munasinghe, 1993; Rogers et al., 2008). The inclusion of the 'social' element as one of the disciplines in the SD model was the result of accepting that, although the environment is the key component behind the successes of all economic activity and the functionality of life, the idea of equitable growth – which is embedded in the achievement the social discipline – were also observed as an important aspect to increase economic efficiency (Elliott, 2006; Starkey and Welford, 2001).

The 'social' sector of this SD model aims to maintain a level of stability between both the social and cultural systems which, on a broader scale includes, being able to drastically reduce the environmentally and economically harmful conflicts from occurring (Munasinghe, 1993; Rogers et al., 2008). Furthermore, this sector houses the main objective of achieving social justice and quality in the distribution and accessibility of natural resources and opportunities between people; no matter their gender, social grouping or race (Waas et al., 2011). The social aspect of this SD model draw attention to the fact that, "intragenerational equity (especially elimination of poverty), and the intergenerational equity (involving the rights of future generations)," (Munasinghe, 1993: 3) are exceptionally important in being able to preserve the level of cultural diversity on a local and global scale. The indigenous knowledge-base of information and methods of sustainable practices from all cultures need to be attained and conserved in order to promote public and community participation, which will result in an effective and collectively agreed upon social sustainable development framework (Munasinghe, 1993).

Over the years, the three ring model for SD has been modified to include a fourth element; institutional change (Waas et al., 2011). As depicted in Figure 2B, this new dimension creates the 'Four Pillar Sustainable Development' model and brings to light the direct relationship between the ecological and economic sector through means of the decision making processes at regional, local and global levels (Ndah, 2015; Waas et al., 2011). Further reiterated by Waas (2011) and the WCED (1987), a greater responsibility in the decision making process regarding the utilisation of the environment must be given to societies, thus promoting community support, the identification of shared interests and overall public participation in maintaining natural resources.

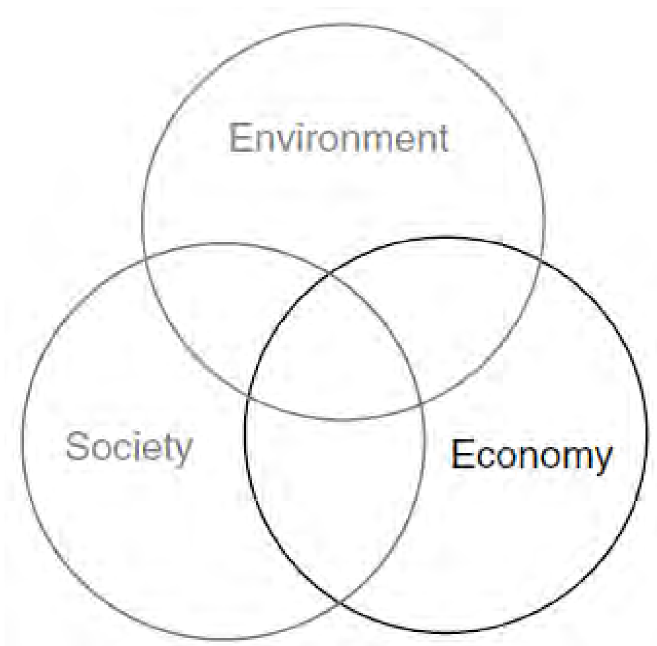

Figure 2A: *The Three Ring Model (Giddings et al., 2002: 189)*

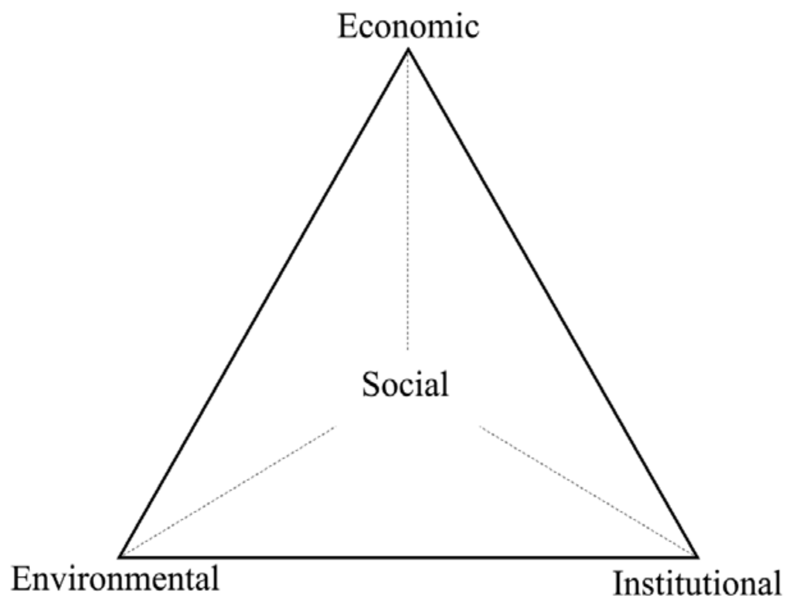

Figure 2B: *The Four Pillar Sustainable Model (Waas et al., 2011: 1651)*

2.3.1.1 *Challenges of the Three Ring Model*

The Three Ring model of SD is simplistic and easy to interpret – as evidence from the above discussion – however, some authors have found major flaws in this SD model (Giddings et al., 2002; Jenks and Jones, 2009; Waas et al., 2011). One of the most reoccurring and often mentioned flaws, is that this model compartmentalises the three different entities of SD and therefore underestimates the importance of the interconnected relationship between these entities (Giddings et al., 2002; Waas et al., 2011). In addition to the above, it has been stated that should these elements be looked at individually it would surely lead to, "a narrow techno-scientific approach, while issues to do with society that are most likely to challenge the present socio-economic structure are often marginalized, in particular the sustainability of communities and the maintenance of cultural diversity," (Giddings et al., 2002: 187). By separating these entities, each begins the fight for attention, thus causing a competing effect which has resulted in numerous 'trade-offs' between all of the relations.

According to Elliott (2006), trade-offs become an imperative necessity when trying to successfully attain SD, as it entails preferences being made, "at particular points in time and at particular scales as to what is being pursued and how, and sustainable development requires recognition of the costs involved for particular interests and for groups of people" (Elliott, 2006: 14). This is evident in the ongoing debates, especially those occurring between the 'economy' and 'environment' entities, as the 'economy' dimension has been said to be continuously favoured above all the other dimensions (Gibson et al., 2013; Giddings et al., 2002; Waas et al., 2011).

Another effect that has been noted as a result of a separating approach to this model has been the encouraged use of technical solutions in the economy within the economy to fix issues that arise from trying to achieve SD (Giddings et al., 2002). A simple example of this is the 'polluter-pays' principle which is a form of ecotax that, "implies internalizing costs for some, but responsibility of industrialized countries 'to pay' for their historical pollution for others," (de Sadeleer, 2014: 121). This control in pollution and trading of greenhouse gases are seen as ways in which the economy can work towards achieving SD. Reiterated in the following quote, this sectored observation of this SD model's elements, "can divert attention from asking questions that are important to getting to the core of sustainable development such as those about the nature of our society, what the policy priorities are, how decisions are made and in whose interest," (Giddings et al., 2002: 189).

In addition to the previously mentioned drawbacks, Waas et al. (2011) state that this specific SD model fails to incorporate humans within the environment sector. The environment is a crucial underlying element in man's survival and the success of the economy (Giddings et al., 2002; Redclift, 1993; Waas et al., 2011). From this SD model it is clear to see that although mankind is dependent on the accessibility to a healthy environment for its resources however, when looked at in the other direction it is evident that the natural environment does not need mankind or the overall society to function (Lovelock, 1995). This then proves the need to integrate humans into the natural environment, not for the sake of the natural environment, but rather to ensure mankind's survival. The previously mentioned point is confirmed with the statement that shows that including humans in the environmental sector, "expresses the duty of everyone to protect and restore the integrity of the planet, places decision making within these limits, and should be considered as a fundamental legal principle... its basic idea is on first determining the environmental limits and then establishing what development is feasible within those limits to achieve sustainable development... once the limits are agreed upon, the balancing and trade-offs between environmental protection and development issues still occur but within the carrying capacity of the planet," (Waas et al., 2011: 1652).

Giddings et al. (2002) and Elliott (2006) , highlight that while some believe that these elements are actually meant to be examined individually and that they each tend to occur at different spatial levels, the interconnectedness of these objectives is evident. The human existence is openly dependent on the survival of the environment, and thereafter the economy is highly reliant on the functioning of societies and communities in an effective and efficient environment (Elliott, 2006). Nevertheless, for all the flaws and drawbacks of the Three Ring SD model the Nested SD model is proposed as an improvement and therefore the more favourable model.

2.3.2 The Nest Sustainable Development Model

As the global economy is evolving, studies have shown the dominating nature of the economy over the environment and society sectors in the process of attain a sustainably developed status (Giddings et al., 2002; Korten, 1998). Influenced by large international corporations, organisations and the process of globalisation, a substantial growth of the economy remains at the forefront in being able to achieve SD (Giddings et al., 2002; Korten, 1998). In some developed countries such as Great Britain, being able to achieve a high economic growth rate is one of the prerequisites to being recognised as a sustainably developed state (Giddings et al., 2002).

Within the Three Ring model of SD a sectorial approach was adopted and as mentioned before, this gave the economy sector a significant amount of attention and consideration compared to the other sectors of the environment and the society which were both constantly taken advantage of in an exploitative manner – from a natural and anthropogenic perspective – and at times even being regarded as a, “sink where problems are dumped, whether unemployment, ill health or waste,” (Ndah, 2015: 6). However, as stated by Giddings et al. (2002) and Ndah (2015), the Nest model of SD – also termed the ‘materialistic reality’ – recognised the economy as being dependent on the society and the environment sectors and not being of an autonomous nature.

Observed as a corrective model to the Three Ring model of SD, the Nest model for SD (Figure 2C), depicts all three sectors –the economy, the environment and the society – as one entity ‘nesting’ within the process of SD (Giddings et al., 2002; Ndah, 2015; Rees, 1995; Rees and Wackernagel, 2008). As noted in the previous section, the environment is a crucial bank of resources for all societies and that the environment can continuously thrive without any association with the society, however this Nest model for SD accepts that the economy needs the society and the environment sectors to function, and that the society sector cannot exist without the economic sector (Giddings et al., 2002; Lovelock, 1995). Overall, this model of SD, “locates society within the environment and its limits... It is argued that such ‘nested’ models are more in favour of integration and holism, reducing the theoretical justification of trade-offs and encouraging the search for ‘integration’,” (Waas et al., 2011: 1652).

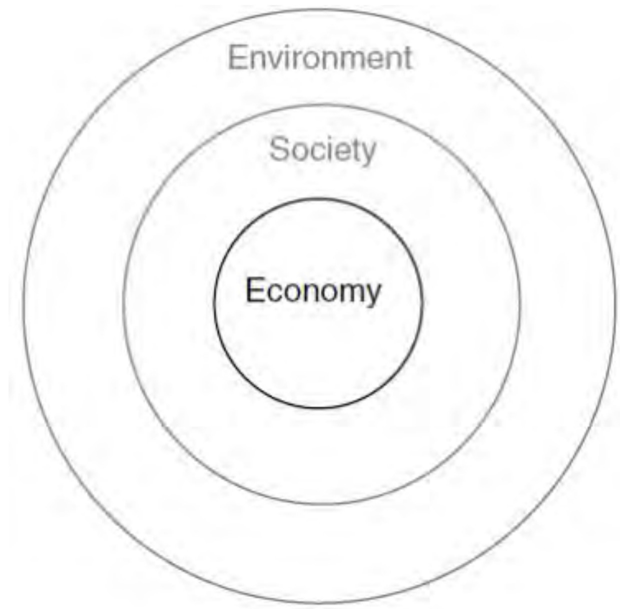

Figure 2C: *The Nest Sustainable Development Model (Giddings et al., 2002: 192)*

2.3.2.1 *Challenges of the Nest Sustainable Development Model*

As a functioning co-dependent relationship, the nested model of SD depicts how the economy sector moves to take its place a subset of the society sector, while both 'nest' within the confine of the environment sector (Ndah, 2015). Although this element of reliance is the differentiating factor when compared to other models the nested model of SD does have a few flaws in it composition and implementation. One of the most prominent issues with this model is that, each of the depicted concentric boundaries represent a form of restriction for each of the sectors and while it highlights the interdependence between each sector, it fails to provide a specific time dimension to the model and its different sectors (Thatcher, 2014).

It must be noted that while this model takes into consideration the environment and social limitations within the economic decision-making process, it results in a greater demand for a significant changes to be made within the organisation of society and also with regards to economic practices (Rydin, 2007). Consequentially, this highlights the problem of, " how contemporary routines of politics and policy can respond to such a radical agenda and, more broadly, the relationship between governance processes and sustainable development," (Rydin, 2007: 583).

2.4 Principles of Sustainable Development

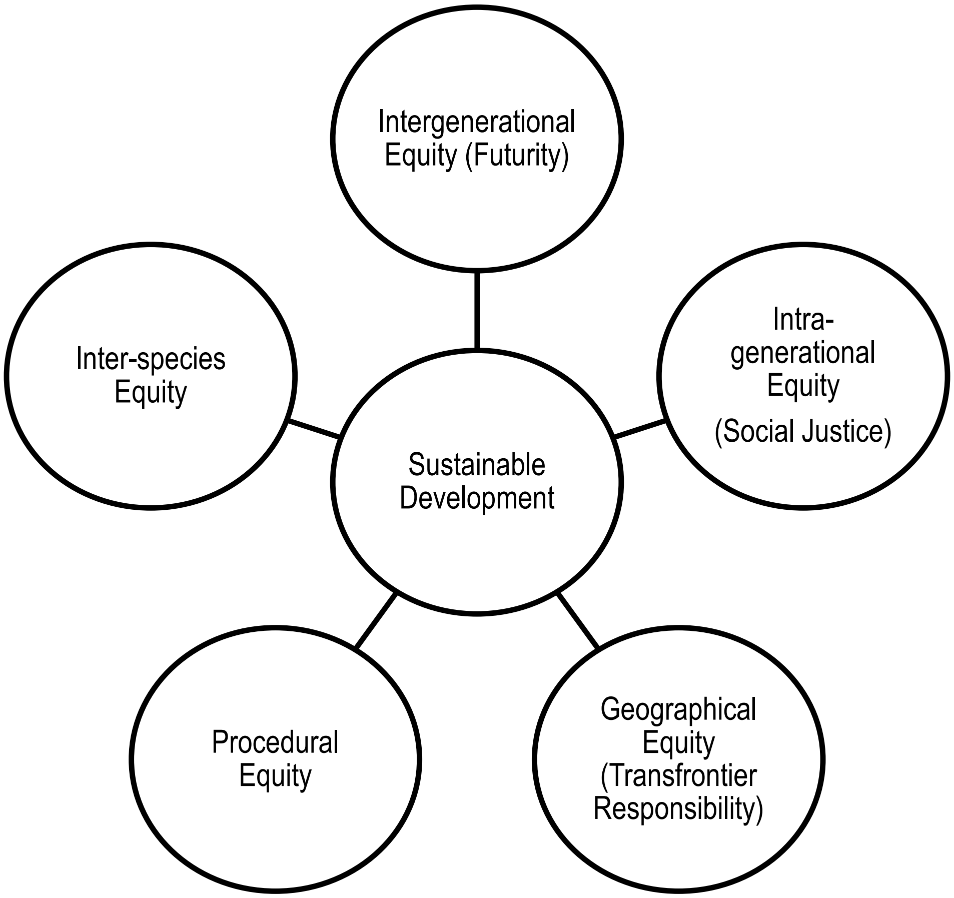

Figure 2D: *A depiction of the principles of Sustainable Development (Haughton, 1999)*

As established earlier in this chapter, the concept of SD is a difficult one to clearly define due to its multidisciplinary nature and its ability to be adapted and implemented in various fields of study (Blewitt, 2010; Elliott, 2006; Jenks and Jones, 2009; Rogers et al., 2008). As a result of not having a definitive or singularly accepted description of the concept, author Graham Haughton (1999) has derived five principles of equity (Figure 2D) which would be able to be applied to issues regarding the environment, society and economy sectors or even issues that are a mix of all three entities.

Further explained in the following quote which states that, "each of these equity principles represents contestable goals, since no clear definitive state of final achievement recognizable by all is ever likely to occur – it is the process of moving toward them, of changing human practices in their spirit, which is important, not some elusive readily quantifiable end-goal," (Haughton, 1999: 235), it is clear to see that this approach makes attaining goals of SD through anthropogenic efforts much easier to understand as opposed to having a specific model or step-by-step process in which to arrive at the state of being ‘sustainably developed’. Thus, by adhering to these principles, the state of SD can be achieved by altering the manner in which people conduct and maintain a level of development.

The first of the five principles that will be discussed is that of the ‘intergenerational equity’ principle. Also referred to at times as the ‘futurity’ principle, this element aims at reiterating the Brandtland Commission definition which states that SD is, “development that meets the needs of the present without compromising the ability of future generations to meet their own needs,” (Redclift, 2005: 213). This principle employs this specific definition as it highlights the necessitate to give consideration to the needs and availability of resources for future generations (Giddings et al., 2002; Haughton, 1999).

The second refers to the ‘intra-generational equity’ principle or rather the social justice principle. According to a discussion by Haughton (1999), it is stated that the concept of equity and justice are considered to be completely different elements, especially with regards to the perspectives of different people. Nevertheless, this principle focuses on achieving social justice by means of being able to address the root causes of social injustices, in the hope of eradicating its existence (Haughton, 1999). To expand on the above statement, this principle looks to attain social justice throughout the society, “regardless of class, gender, race, etc. or where they live and participation so that people are able to shape their own futures,” (Giddings et al., 2002: 194).

The ‘geographical equity’ principle is the third contributing factor to the process of achieving SD. Also considered as the transfrontier responsibility, this principle stipulates that due to the externally occurring impacts being constantly ignored while corporate environmental interests are put forward, “policies should be geared to resolving global as well as local environmental problems,” (Haughton, 1999: 236). Happening in all regions of the world – locally, nationally and globally – it is too often that polluters have a complete disregard for the effects that their detrimental actions have had on the environment and society (Counsell and Haughton, 2004; Haughton, 1999). Actions such as illegal dumping, environmental racism and the overall degradation of the natural environment are just some of the ways in which polluters affect the areas that are outside of their domain of influence, yet they still feel that they have no responsibility in rectifying the problem or to pay a compensation fee for the damage to the area (Giddings et al., 2002; Haughton, 1999).

Apart from being able to resolve issues regarding the degradation of the environment, policies should also include a high level of transparency, specifically with regards to the availability of environmental information and the manner in which non –renewable resources are utilised and consumed (Beatley, 1991; Haughton, 1999). Over and above this, efforts must be made to ensure that, “political or jurisdictional boundaries are not used to shield individuals, companies, and governments from the negative impacts of their activities,” (Haughton, 1999: 236).

The fourth factor needed to achieve SD is that of the ‘procedural equity’ principal. According to Haughton (1999), this principle requires that, “regulatory and participatory systems should be devised and applied to ensure that all people are treated openly and fairly,” (Haughton, 1999: 236). This principle is significantly related to the previous principle of ‘geographical equity’, as it also expresses concerns around the fact that polluters cannot continue to degrade the environment without paying for the consequences of their actions (Haughton, 1999; Haughton and Hunter, 2004). In addition to this, it also reiterates the need for the accessibility to information regarding activities that could be damaging to the environment and indirectly the society as well (Haughton, 1999; Haughton and Hunter, 2004).

Moreover, this principle – according to Haughton (1999) – is of exceptional importance as it includes the need for active public participation. Many studies have observed the implementation of public participation efforts and while some efforts help the situations, others tend to undermine and cause further problems to the situation (Webler et al., 1995). Nonetheless, public participation within this principle of SD is seen as being, “central to achieving effective and sustainable processes of regeneration, owned and mobilized by the general public as well as state authorities,” (Haughton, 1999). A ‘Bottom-Up’ approach must be embraced when trying to implement this principle in society as it will allow for the engagement with the public throughout all the decision-making processes at all regional levels (Haughton, 1999; Giddings et al., 2002).

The ‘inter-species equality’ principle is the fifth and final factor in the ‘check-list’ to achieving SD. This principle recognises the important role that the biodiversity and overall integrity of the environment has with regards to the functioning of society and all of mankind (Haughton, 1999). Overall, this principle states and argues that, “nature has certain rights, while humans also have obligations, to nature and to each other, to ensure that individual animal species and indeed whole ecosystems are not degraded to the point of non-sustainability,” (Haughton, 1999: 237).

2.5 Sustainable Development and Urban Areas

The process of urbanisation, as highlighted earlier in this study, was one of an unprecedented nature and in a similar manner, has led to the realisation of the destructive nature of associated anthropogenic activities (Bhattacharya, 2002; Lambin et al., 2001; Turner et al., 1994). Urbanisation has had detrimental effects on, “habitat, ecosystems, endangered species, and water quality through land consumption, habitat fragmentation, and replacement of natural cover with impervious surfaces,” (Jabareen, 2006: 38). With all these consequences of urbanisation occurring at such an alarming rate, the emergence of the SD concept has allowed for the introduction of an alternative way in which urban development can be constructive rather than more destructive while meeting the goals of SD. Reiterated by Haughton (1999) and Guy and Marvin (2001), the human species poses a significant threat the achievement of SD, as it is the only species that is trying to live beyond earth’s capacity while consequentially throwing off the balance of fundamental naturally occurring protective systems that are provided by the environment.

Prior to discussing the concept of SD with regards to urban zones or cities, it is important to note that ‘sustainable development and cities’ and ‘sustainable cities’ are two very different terms and have completely different meanings (Haughton and Hunter, 2004; Mitlin and Satterthwaite, 1996). With countless ongoing debates surrounding the division of these terms, it is crucial to identify a separation of these terms before continuing with to analyse how SD is implemented in cities or urban areas.

It has been suggested that ‘sustainable cities’, “implies that each city has to meet the resource needs of the population and enterprise located there from its immediate surrounds,”(Mitlin and Satterthwaite, 1996: 35) and in addition to this quote, it is said that the achievement of ecological sustainability is prioritised above all other sectors within SD. However, on the other hand, the notion of ‘sustainable development and cities’ refers specifically to the fact that, “the goals of sustainable development are the meeting of human needs within all cities (and all rural areas) with a level of resources use and waste generation within each region and within the nation and the planet that is compatible with ecological sustainability,” (Mitlin and Satterthwaite, 1996: 35).

With regards to SD and how it is implemented in cities or urban areas the important question to ask is: *what elements need to be considered in order to assess these area’s level of sustainability?* Jabareen (2011; 2006), suggests a thematic analysis method which identifies seven key criteria – later termed the Sustainable Urban Form Matrix (SUFM) - to observe the sustainability of different forms within the anthropogenic urban habitat (Figure 2E). According to Jabareen (2011), by utilising this SUFM and the, “the right scales of the proposed concepts we might be enabled to produce practically the most sustainable urban forms that contribute to the climate change adaptation strategies,” (Jabareen, 2011: 389).

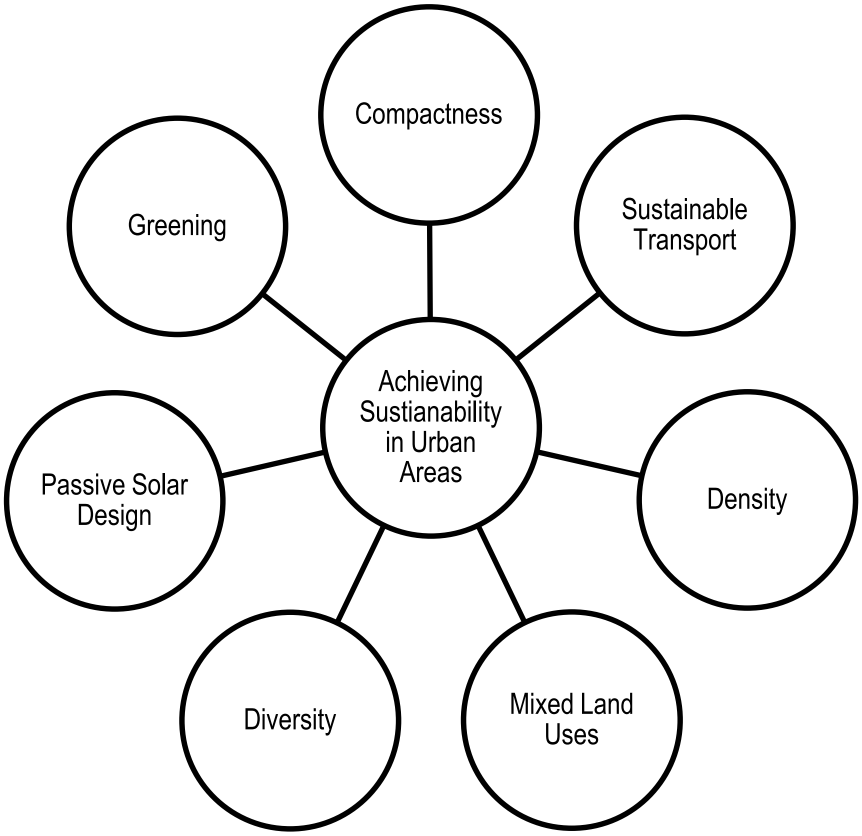

Figure 2E: *A depiction of the criteria of the Sustainable Urban Form Matrix (Jabareen, 2011; Jabareen, 2006)*

The first concept of the SUFM that will be looked at is that of 'compactness'. Considered to be the most globally accepted strategy to increasing the sustainability of urban areas or cities, the concept of compactness highlights the inclusion of urban contiguity and urban connectivity (Jabareen, 2006; Wheeler, 2000). In addition, this concept accepts that future urban formations should occur adjacent to the existing urban structures thus adding to the already present urban landscape (Hagan, 2000).

As mentioned in chapter two of this study the concept of intensification is important in the LULC transformation process, and similarly, it is seen as the foundational principle of the compactness strategy. It allows for the use of urban land by increasing the density of development and anthropogenic activities (Jabareen, 2011; Le Clercq and Bertolini, 2003). This also includes the, "development of previously undeveloped urban land; redevelopment of existing buildings or previously developed sites; subdivisions and conversions; and additions and extensions," (Jenks, 2000: 243). In order to achieve sustainability within the urban areas, city planners and designers adhere to the compactness strategy as it enables the city to be diverse, dense yet still remain highly integrated (Dumreicher et al., 2000).

The concept of compactness is said to be divided into four distinct themes in order to ensure that the sustainability of cities and the overall urban landscape is attained.

> "The first, probably the longest established and most common, is that a contained and compact city has a corollary of rural protection (McLaren, 1992). The second theme is related to the promotion of quality of life, including social interactions and ready access to services and facilities. The third is the reduction of energy consumption by providing building densities capable of supporting district heating or combined heat and power systems; and the fourth is the reduction of greenhouse gas emissions by minimizing the number and length of trips by modes of transport harmful to the environment," (Jabareen, 2006: 40).

From the above quote, it is important to note that compactness allows for urban spaces to eliminate the need to use transportation vehicles, private motor vehicles, and rather promote the ease of the walk-able distances to attain a variety of opportunities included in the maintaining of a wealthy urban lifestyle (Cervero, 2003; Elkin et al., 1991; Jabareen, 2011). Overall, Sherlock (1990) concludes that the strategy and goal of compactness is aimed at improving the liveability of urban residents and to reduce the methods used in commuting as it is a habit of wastefulness observed in current cities and urban areas.

When defining the concept of 'sustainable transport' – the second concept within the SUFM – there is much debate still occurring surrounding accepting a single description. On the one hand, the concept of sustainable transport can be considered to be, "transportation services that reflect the full social and environmental costs of their provision; that respect carrying capacity; and that balance the needs for mobility and safety with the needs for access, environmental quality, and neighborhood livability," (Jordan and Horan, 1997: 72).

While on the other hand, Duncan and Hartman (1996), put forward ideas toward a definition that states, "sustainable urban transportation system limits emissions and waste to within the area's ability to absorb; is powered by renewable energy sources, recycles its components, and minimizes the use of land; provides equitable access for people and their goods and helps achieve a healthy and desirable, quality of life in each generation; and is financially, affordable, operates at maximum efficiency, and supports a vibrant economy," (Jabareen, 2006: 40).

However, using the descriptions put forward by these authors, it is understandable that strategies and policies of sustainable urban areas need to include a requirement for the reduction in the need for movement and rather provide conditions in which travel needs are smaller and can be easily achieved by means of walking, cycling or energy-efficient public transport (Elkin et al., 1991; Jabareen, 2006).

The third concept of the SUFM is that of 'density'. In this instance, the concept of density takes into account certain limiting factor which states that, "at certain densities (thresholds), the number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable," (Jabareen, 2006: 41). As a result, the density concept refers to the number of people or housing units compared to the available land in the area (Jabareen, 2006).

Sustainability can be highly affected by density and the types of housing units available as each has its own different type of consumption with regards to land, energy and infrastructure (Walker and Rees, 1997; Parker, 1994) Reiterated by numerous authors, the provision of energy-efficient transport options and a limitation on the availability vehicle infrastructures within cities or urban areas will deter private motor vehicle ownership and furthermore, it will allow for significant land integration and promote the need to social interaction (Elkin et al., 1991; Jabareen, 2006; Newman and Kenworthy, 1989).

According to Jabareen (2006), the fourth concept of SUFM is that of 'mixed land uses', and plays a crucial role in being able to achieve SD in urban areas. By implementing mix of land uses within urban areas, there is a promotion of using land in a diverse manner, with the uses extending to the residential, industrial and the transportation sector (Jabareen, 2006; Jabareen, 2011). Parker (1994) and Thorne et al. (2003) reiterate the idea that mixed use land issues enable, "compatible land uses to locate in close proximity to one another and thereby decrease the travel distances between activities, encourage walking and cycling; and it reduces the probability of using a car for com-muting, shopping, and leisure trips, since jobs, shops, and leisure facilities are located nearby," (Jabareen, 2011: 390).

Currently, urban areas have been known to prohibit or limit the amount of mixed land use areas occurring and as a result, studies have proven that these cities have a reduced level of diversity in their communities, a limited level of safety and unappealing urban aesthetics (Jabareen, 2006; Newman, 1997). Even though the reduction in the use of motor vehicles will be able to curb the build-up of traffic and the other above mentioned consequences, it is seen as a motivation for the public to pursue face-to-face interactions, improve community communications and promote a sustainable urban environment (Bredell, 2012; Ewing et al., 1996; Jabareen, 2006).

Made acceptable in SD talks by Jane Jacobs (1961), the concept of 'diversity' is crucial to creating a liveable lifestyle within urban areas. Similar in some regards to the concept of mixed land uses, the concept of diversity is seen as a significant component if the SUFM and an essential factor to achieving SD in urban areas as it takes on the status of being a multidimensional phenomenon (Turner and Murray, 2001). It is said that the element of diversity promotes, "further desirable urban features, including greater variety of housing types, building densities, household sizes, ages, cultures, and incomes," (Jabareen, 2011: 390), which in turn encourages the development of urban areas that are attractive, aesthetically pleasing and the creation of differing urban landscape in terms of the architectural and housing styles (Yanns, 1998; Owens, 1992). Over and above this, the concept of diversity includes a social and cultural context thus abandoning the previously acceptable class and racial segregation of the urban landscape (Thomas, 2003; Wheeler, 2002).

The sixth concept in the SUFM is 'passive solar design'. The term 'passive energy' refers to the utilisation of solar or naturally occurring energy (Mazria, 1979). This type of energy is termed *passive* due to the fact that these systems require little effort in order to be attained and maintained, while in contrast, the active energy solar systems are used to generate electricity (Mazria, 1979; McMahon, 2015). Thus, utilising the passive solar energy systems is vital in achieving a sustainable urban area as it highlights the need to, "reduce the demand for energy and to provide the best use of passive energy in sustainable ways through specific design measures," (Jabareen, 2006: 42). This concept suggests that the manner in which the urban area or city is designed – in terms of its layout, landscape or location – can result in utilisation of renewable solar energy to help the functioning of the city, as opposed to relying on the more traditional non-renewable active energy systems (Owens, 1992; Thomas, 2003)

As mentioned in the previous chapter of this thesis, there is a clear difference in climatic conditions when looking at the urban, rural and countryside areas of a landscape. This is especially evident when the process of the urban heat island (UHI) is taken into account. The process of the UHI proves that cities or urban areas have a large surface area that is exposed to the naturally occurring solar energy, thus proving that it has a significant potential to attain high quantities of solar energy (Grimm et al., 2008; Mazria, 1979). However, this is largely dependent on the architectural structure and design of the city or urban area in question. Yannas (1998) ideally describes six ways in which the design of an urban area can improve and achieve sustainability:

> (1) *built form*—density and type, to influence airflow, view of sun and sky, and exposed surface area; (2) *street canyon*—width-to-height ratio and orientation, to influence warming

and cooling processes, thermal and visual comfort conditions, and pollution dispersal; (3) *building design*—to influence building heat gains and losses, albedo and thermal capacity of external surfaces, and use of transitional spaces; (4) *urban materials and surfaces finish*—to influence absorption, heat storage, and emissivity; (5) *vegetation and bodies of water*—to influence evaporative cooling processes on building surfaces and/or in open spaces; and (6) *traffic*—reduction, diversion, and rerouting to reduce air and noise pollution and heat discharge (Yanns, 1998: 43).

The above quote proves that there is indeed a direct link between the design of an urban area of city and the different energy systems. However, it is the responsibility of the public and also of urban planners to realise this and to highlight the importance of reducing the dependence on active energy and rather utilise the systems of passive solar energy in order to create a sustainable urban areas or city (Owens, 1992).

The last - and possibly the most important - concept to achieving sustainability in an urban area is that of 'greening'. The concept of greening aims to incorporate the element of nature within the city or urban area by adding to the aesthetical value and overall attractiveness of the city (Dumreicher et al., 2000; Nassauer and Faust, 2013). Besides being able to improve the sustainability of the urban area or city, greening helps create awareness around the struggle of achieving SD in such a highly consumptive area and it also gives the public and communities a reason to take pride in making a difference in their environment (Beer et al., 2003; Forman, 1995). Furthermore, greening in urban areas highlights the need to conserve the surrounding biodiversity, to live within the stated ecological limitations and improve the local, regional and national level of sustainability and the need to maintain a sustainable lifestyle for both the people residing in the area and as a community (Beatley, 2012; Niemelä, 1999).

2.6 Sustainable Development in Umhlanga Ridge

Advocated by the various theories associated with New Urbanism, the Umhlanga Ridge node recently introduced new development plans in order to influence the amount of public and private investments (ASM Consortium, 2008). These new development plans were all implemented and executed with the underlying framework of sustainability as dictated by the Coastal Policy Green Paper (CPGP) titled 'Towards Sustainable Coastal Development in South Africa' and published by the South African Department of Environmental Affairs and Tourism (1998). With a range of development goals which were considered in conjunction with the CPGP, the Umhlanga developments managed to maintain a balanced approach in the transformations made to the area and the adjacent coastal area (ASM Consortium, 2008; Department of Environmental Affairs and Tourism, 1998). Furthermore, after reviewing the SUFM as suggested by Jabareen (2011; 2006), it becomes easy to identify how the developments in the Umhlanga Ridge have integrated the principle and concepts to produce a sustainable area.

The document produced by the ASM Consortium company, explains how all of the Umhlanga Ridge developments were stated to be observed from a sustainable approach thus incorporating the naturally occurring environment into the urban area (ASM Consortium, 2008). This shows how the Umhlanga Ridge has included the SUFM concept of diversity within the developmental and implementation process in order to produce a sustainable urban area.

Another way in which the Umhlanga Ridge area has adhered to the SUFM is by ensuring that elements of compactness, mixed land uses and diversification are implemented in the process of development (ASM Consortium, 2008; Jabareen, 2006). The Umhlanga Ridge development process allows for this level of sustainability to be achieved as it gives the public an opportunity to live closer to all the amenities and work prospects while still allowing for an increased level of diversification of activities (ASM Consortium, 2008; Nomico and Sanders, 2003).

As highlighted throughout the SUFM, it was evident that minimising transport and promoting the ease of accessing goods or opportunities by means of walking is important (Jabareen, 2011). According to Allen, the prominent ‘car culture’ that has emerged over the years has evolved in terms of its material value. Further explained, it is stated that, “a car is no longer just a means of transport but a symbol of power and status. This has resulted in alienation between those who own private vehicles and those who don’t,” (Beires, 2010: 10) Similarly the Umhlanga Ridge development accepted the principles of the SUFM to shift the ‘car culture’ evolution by ensuring that the following are implemented:

> “pedestrian and non-motorised transport (NMT) maintains a 5 minute walking distance coverage to all major amenities and attractions within the core precinct area as well as the proposed internal public transport route ... A new internal public transport service to cover the core precinct area and provide linkages to the adjacent residential areas, precincts, pedestrian and NMT network, regional public transport interchange, centralized parking facility and provide easy walking distance to the various beach amenities,” (ASM Consortium, 2008: xviii-xix).

In addition to the above examples, the Umhlanga Ridge developments have introduced the idea of having a Central Park (ASM Consortium, 2008). The importance of this park or ‘green open space’ is crucial to and is reiterated in the concepts of greening and mixed land uses, as proposed by the SUFM (Jabareen, 2011). This park area will provide the much needed access to open and naturally occurring spaces which the public can utilise for recreational purposes (ASM Consortium, 2008; Jabareen, 2011).

Lastly, one of the most important aspects that have been included in the Umhlanga Ridge development which will ensure the sustainability of the area is that of the increased public participation and also the acknowledgement of the need for more public-private partnerships (Bredell, 2012; ASM Consortium, 2008; Yli-Pelkonen and Kohl, 2005). The eThekwini Municipality has placed emphasis on the need for the active and democratic participation between, “all stakeholders from the private sector (property owners and developers), public sector (municipality) and the community,” (ASM Consortium, 2008: xv). The acceptance of this mutually beneficial relationship will ensure that there is total transparency in the process and implementation of the developments, that all concerns – from all those involved – will be heard and that all committees – at local, regional and national levels – will be confident and proud of the move made toward a sustainable society (Beires, 2010; Nomico and Sanders, 2003).

2.7 Summary

From the above discussions, it is clear to understand the functionality of sustainability and the need to utilise it as an underlying principle when introducing developments in highly consumptive urban areas (Beer et al., 2003; Forman, 1995; Jabareen, 2011; Walker and Rees, 1997). With the use of the SUFM as a guideline to achieving SD, it is evident that the current developments of the Umhlanga Ridge area have adhered to all of the criteria for a sustainable urban area (Beires, 2010; ASM Consortium, 2008; Jabareen, 2011).

Chapter Three: Literature Review

3.1 Introduction

As mentioned previously and also further reiterated by numerous authors, the technology of remote sensing has played a key role in monitoring, depicting and analysing LULC changes throughout the globe (Lillesand et al., 2008: 596). With the rise in the accessibility and availability of information generated from remotely sensed images, there has been an increase in the number of change detection (CD) studies being performed. As a result, the detail, precision and specification of remotely sensed imagery are constantly being improved to provide the most accurate depictions of land changes that have occurred. As part of this study, this chapter will focus on understanding why LULC changes occur and the significant impact they impose on the environment and the surrounding populations. Furthermore, this chapter will discuss the significance and the manner in which remote sensing supports the process of CD analysis.

3.2 Land Use and Land Cover (LULC) Changes

As noted earlier, the concept of LULC changes is versatile within a variety of disciplines across the spectrum of academia and as a result, a holistic definition of the concept has not been determined. However, LULC changes can be further understood when separated into two factors – land use and land cover. It has been stated that the concept of 'land cover' can be described as the type of features which occurs on the earth's surface, such as water bodies, vegetation and man-made structures, while on the other hand, the term 'land use' is used to describe the human activities which take place on the surface of the earth or on the land including, agriculture, forestry and even expanding to the context in which the land is managed (Ellis and Pontius, 2007; Lillesand et al., 2008).

The use of the concept of LULC changes can be traced back to the early 1960's even though the processes of land change have occurred for many years prior to that (Meyer and Turner, 1992; Meyer and Turner, 1994). Sources have verified this statement by adding that the concept was only introduced as a combined term when the concerns over the usage of the depleting resources in relation to the rapidly growing population came to light (Leemans and Zuidema, 1995; Meyer and Turner, 1992). LULC changes became a popular field of study across numerous disciplines and soon the combined factors of 'land use' and 'land cover' could not be discussed independently and was found to be much more informative when considered in conjunction with each other.

Meyer and Turner (1992) further explain LULC changes in an ideal perception that concepts of 'land use' and 'land cover' fall within the parameters of its own hybrid category. As aforementioned notion, the authors clearly state that when separately looking at each concept, it is easy to understand that 'land use' represents how the human populations utilise and study the social aspects of this utilisation while, 'land cover' refers to the physical and biotic characteristics of the land surface (Meyer and Turner, 1992). Nevertheless, Meyer and Turner's (1992) idea of describing LULC changes as a uniquely occurring category encompasses the thought that LULC changes broadly focuses on the change of the land surface, its biotic cover and that human activities are the direct cause of alterations in the physical environment.

Similar to an article published in 1976, it was highlighted and stressed that each individual concept of 'land use' and 'land cover' is able to aid in the process of decision making on a local or national scale (Anderson et al., 1976). Yet, it must be acknowledged that in combining those factors and their respective information, it is of great importance to overcoming local and national concerns such as, "uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat," (Anderson et al., 1976: 3).

It can be said that together these terms can be used to describe the physical environment in relation to its transformations by anthropogenic activities or natural causes (Cihlar and Jansen, 2001). Accordingly, transformations in land uses – specifically anthropogenic – have had a direct influence on that of various land cover changes, however, the occurrence of LULC changes have also been noted to result in numerous harmful effects on the land and its residing populations (Jansen and Di Gregorio, 2004; Jansen et al., 2006; Lambin et al., 2001).

3.2.1 Driving Forces of LULC Changes

From previous discussions, the occurrences of LULC transformations are the indirect and direct consequence of the need for human populations to acquire fundamental resources (Ellis and Pontius, 2007; Cihlar and Jansen, 2001). In addition to this, Lambin and Geist (2007) consider that the causes of LULC changes can be separated into two categories; proximate and underlying. According to their study, proximate causes refers to the direct relationship the human population has to transforming LULC's on a localised level, while underlying causes of LULC changes focuses on the broader concerns that result in the causes happening at a local level (Lambin and Geist, 2007). Nevertheless, LULC changes are due to a culmination of interacting factors, especially those emanating from extensive human activities and use.

3.2.1.1 *Demographic Factors*

The unprecedented growth of the global population has had a significant impact on the LULC changes and also the overall increase of demand for resources such as food, timber, fuel and water (Lambin et al., 2003; Lambin et al., 2001; Ojima et al., 1994). Apart from exerting pressures on the land, growth in the population has caused a shift in household dynamics, the availability of labour, urbanisation and migration (Ellis and Pontius, 2007; Lambin and Geist, 2007).

According to examples put forward in numerous studies, as the population rapidly increases, the rate of urbanisation increases along with it, in turn opening up more job opportunities for those living in low-income areas (Lambin et al., 2003; Meyer and Turner, 1992). The shift in available labour and household dynamics is now evident with the above example because, as the men – the original heads of the household – migrate and leave for jobs in the urban area to maintain the households' economic status, the women then have to take on the men's responsibilities and work load at the household level (Meyer and Turner, 1992).

Migration is considered to be one of the most considerable demographic factor with regards to the transformation of LULC. Due to its diverse interconnection with matters such as the economy, government policies and resource consumption, the escalating rate of people migrating from the outer low-income areas into the urban city centres has meant a significant increase in the demand for resources and land in order to maintain the urban population (Schulz et al., 2010; Smith et al., 2010). Simultaneously, the processes of migration and urbanisation work hand-in-hand to become significantly determining factors in LULC changes, at regional, national and global scales (Lambin et al., 2003).

3.2.1.2 *Cultural Dynamics*

LULC transformations bring about concerns between both the urban and rural areas; such as the debate surrounding the respect and consideration for traditional or cultural values (Harris, 2003; Lambin et al., 2003). LULC requires extensive landscape transformations to not only the surrounding environments but also the rural or low-income communities in the surrounding areas (Verburg et al., 1999).

It is for this main reason that a community's, "cultural values, norms, and their preferences (lifestyles), and financial, temporal, and transport means," (Verburg et al., 1999: 127), must be taken into account prior to any land change action. Verburg et al. (1999) go on to explain that long established communities attain land that is sometimes of great value to urban developers due to its location or mineral wealth, however the historical value of that land must also be taken into consideration during the decision making process. Similarly, cultural factors – as mentioned above – tend to 'clash' with political and economic decisions of the ruling governments, especially with regards to decisions surrounding the accessibility of resources (Lambin et al., 2003; Verburg et al., 1999).

3.2.1.3 *Economic Globalisation*

The concept of globalisation is considered to be, "the worldwide interconnectedness of places and people through markets, information and capital flows, human migrations and social and political institutions," (Lambin and Meyfroidt, 2011: 3465). It must be noted that the concept and process of globalisation is not an actual driving force of LULC transformations but rather acts as a foundation for other driving forces of LULC changes (Ellis and Pontius, 2007). The associated concept of economic globalisation highlights the increasing influence and the control that large international agribusinesses have on smaller national policies and decision making processes (Ellis and Pontius, 2007; Lambin and Meyfroidt, 2011).

To further explain the idea behind economic globalisation and its involvement in the process of LULC change the following quote, "large agribusiness companies from countries rich in financial capital but poor in suitable land for agriculture are acquiring large tracts of land in countries with land reserves," (Lambin and Meyfroidt, 2011: 3467), clearly describes that although countries of a developed status are able to manufacture products and generate a profit, their inability to expand the area of production due to the lack of available land has caused a significant back-log in terms of meeting the demands of the population. As a result, developed countries begin to acquire trade deals with other less developed countries in order to use their land and labour power to produce the demanded products. This 'land grabbing' process has had a significant influence on the economy and the advancement of the less developed countries. It allows for the weakening of national connections, to further the increase of their interdependency on developed countries for imported products and gives a considerable disadvantage to the less developed country's ability to use their own land to progress and develop independently (Lambin and Meyfroidt, 2011; Smith et al., 2010).

3.2.1.4 *Technological Advancements*

Over the years, the development and application of new technologies has granted humans the ability to change, alter and adapt the environmental landscapes to the point of absolute degradation, in order to meet the populations increasing demands (Huston, 2005). Combined with economic freedoms and technological advancements, countries are able to quickly convert large forested areas or natural areas into areas needed for agriculture or urban settlement (Ellis and Pontius, 2007; Meyer and Turner, 1992; Mustard et al., 2004).

Although these advancements of technology are said to increase profits as a result of introducing large scale machinery for wide and extensive agricultural areas, it invites an unequal distribution of wealth between countries, regions, or households and can further influence an area's status of development (Ellis and Pontius, 2007; Huston, 2005; Lambin and Geist, 2007). According to Lambin et al. (2003), the demand and usefulness of a specific resource is able to dictate the development of new technology in order to extract that resource, and even though this may indeed bring an increased profit and the ability to secure more arable land to the community, it comes at significant environmental cost. A simple explanation of this is that with improvements to transport infrastructure including roads and bridges, the ease of access is given to previously inaccessible areas, thus increasing the range of natural resource exploitation and land degradation (Turner et al., 1994).

3.2.1.5 *Population Growth and Urbanisation*

As outlined by a number of authors, it has become understood that urbanisation is a key contributing factor responsible for LULC changes (Jansen and Di Gregorio, 2003; Lambin et al., 2001; Meyer and Turner, 1994). Often under-theorised and undefined, the concept of urbanisation is generally associated with the description, "by which individuals from the rural sector make a transition to the urban sector," (Cowgill, 2004: 527). However, from the perspective of a LULC analysis, the notion of urbanisation can be defined as the process whereby naturally occurring land or traditional agricultural land is changed into urban societies along with social and economic transformations (Cowgill, 2004; Liu et al., 2005). Nevertheless, the ongoing occurrence of urbanisation has sparked more severe conflicts between land users; especially between agricultural and non-agricultural users (Wu, 2008).

Population growth is viewed as one of the most influential factors with regards to the debate of LULC changes and more especially within discussions of the urbanisation process (Meyer and Turner, 1994). The increasing global population has caused a significant change in various aspects of the global environment, however the most considerable shift is found to be in the areas where people live (Verburg et al., 1999). As a result of the growing population, urban areas are rapidly becoming the preferred choice of residence for most people. With the constant flow of people into urban areas it is startling yet understandable that the spatial extent of cities has to expand in order to accommodate the growing population (Henriques and Tenedório, 2009; Verburg et al., 1999).

Over and above the urban area's rapidly growing population, cities are struggling to sustainably convert surrounding land to provide for the increasing population. Studies have shown that the quick manner in which the population is growing has led to poor land management and consequentially, an unsustainable urban design with damaging effects on the functionality of numerous ecosystems (Mohan et al., 2011; Mubea and

Menz, 2012). Subsequently, this lack of planning results in the emergence of urban fringes, whereby agricultural lands on the outskirts of cities are converted for urban uses (Fichera et al., 2012). This statement further confirms the ongoing competition and debate regarding the struggle for land between the agricultural and urban populations. In addition, urbanisation at such a rate causes numerous effects on the population and the environment, ranging from unsanitary living areas to excessive land degradation (Mohan et al., 2011; Mubea and Menz, 2012).

On the whole, it is clear to see that unprecedented urbanisation leads to immense changes of the LULC in an area, simply due to the fact that increasing populations create extensive demands on the environment in order to suit their needs (Mohan et al., 2011; Mubea and Menz, 2012; Olang and Kundu, 2011; Wu, 2008). Similarly stated by Foley (2005), the overall outcome of urbanisation will lead to the degradation of the environment to satisfy the needs of the human population.

3.2.2 The Consequences of LULC Change

Anthropogenic activities play a major role in shaping the biosphere and after considering the different causes of LULC changes, it is important to understand that there are direct and indirect consequences of LULC changes (Ellis and Pontius, 2007; Lambin and Geist, 2007). Over the years there have been many studies conducted to reveal a wide range of impacts associated with LULC changes and consequently it has made LULC research a priority, specifically with the fields of academia and policymaking (Ellis and Pontius, 2007; Foley et al., 2005; Pauleit et al., 2005). One such study noted that these impacts were often described as being interrelated rather than occurring in isolation (Schirmer et al., 2008). However, as proposed by Foley (2005), Ellis (2007) and Schirmer et al. (2008), the impacts of LULC changes must be examined individually before understanding its role in the chain reaction of consequences.

3.2.2.1 *Environmental Impacts*

With LULC changes happening at a rapid rate on a global scale, many studies have found commonalities surrounding the fact that the environment and its ecologies are one of the first areas impacted by LULC changes (Aspinall and Hill, 2007; Ellis and Pontius, 2007; Giannecchini et al., 2007). As a range of human activities have subsequently altered the earth's landscapes, it has also resulted in the disruption of various ecological processes and services with extensive and long term consequences (DeFries et al., 2004; Ojima et al., 1994; Wu, 2008).

3.2.2.1.1 *Forest Loss and Habitat Fragmentation*

The transformation of land which occurs during LULC changes tend to primarily utilize forest property and the use of these forest areas ultimately means a depletion of forest species (Ellis and Pontius, 2007). Studies have stated that the process of deforestation was greatly influenced by the support given from state programmes during the colonial period between the early 1960's and the late 1980's (Meyfroidt et al., 2013).

Presently, poor management, poor agricultural technology and expanding population demands are some of the main driving forces behind forest loss (Meyfroidt et al., 2013; Ojima et al., 1994). Angelsen and Kaimowitz (2001) and Geist and Lambin (2002) have stated that the occurrence of deforestation is now far more complex as it involves, "economic, demographic, technological, cultural and political factors acting at multiple scales, and influenced by geopolitical interests, governance, social and ethnic struggles," (Meyfroidt et al., 2013: 438).

In addition, Laurance (1999) and Echeverria (2006) have stated that the problem surrounding forest loss is further exacerbated due to the fact that forests host and sustain majority of the earth's animals and plant life. Habitat fragmentation is a direct consequence of LULC changes by means of the loss of forest area. According to Dale (1997), significant decrease in habitats occur when the newer or replacing land cover type does not support the former species of the area. This fragmentation has not only resulted in severe declines in available habitats, it has also caused a drop in animal and plant species richness (Dale, 1997; DeFries et al., 2004; Foley et al., 2005; Zhao et al., 2006).

Some studies have also noted an increase in competition among species in order to claim new areas as habitats, especially along forest edges (Dale, 1997; Yahner and Scott, 1988). One such study by Brittingham and Temple (1983) found that, "populations of neotropical migrant birds are being reduced by increases in cowbirds that parasitize nests of other bird species more frequently along forest edges, which are close to abundant food resources of agricultural areas and grasslands" (Dale, 1997: 761).

3.2.2.1.2 *Soil and Sediment Flow*

Soil erosion and sediment flow has been greatly increased as a direct consequence of LULC changes at both the global and local levels and, in addition, the impacts of LULC changes on soil have been said to go on unnoticed and tend to only appear at the point of no return. (Turner et al., 1994). Shangguan et al. (2014) proved this when they conducted a study on the soil pedodiversity of China and among other discoveries, found evidence that suggested, "that at least two dozens of soils have already gone extinct due to inadequate land use," (Tarquis and Medina-Roldán, 2014: 1). Although there have been vast improvements in agriculture as a result of introducing chemical inputs to minimise losses and increase profits from food production, it must be noted that these benefits are greatly outweighed by the consequences of LULC changes (Hartemink, 2006; Hartemink et al., 2008). Hartemink (2008) further explains that a major concern surrounding soil degradation is the fertility of soil and its drastic lack of nutrients from plants, which is only exacerbated as farmers clear more forest land to farm.

As noted in the previous chapter, urbanisation plays a key role as a driver of LULC change, especially on the environment. Soil erosion and its permeability becomes an increasingly pressing issue with urbanisation introducing, "increased impervious and hardened surface areas such as roads, parking lots, sidewalks and rooftops diminishes infiltration based processes and, consequently, recharge to the groundwater systems," (Olang and Kundu, 2011: 256). DeFries (2004) further reiterates this point by explaining that with water running off the impermeable urban surfaces rather than infiltrating the soil as it should, urban areas are more susceptible to flash flooding.

Lakes and rivers have been found to be the most affected ecological components with regards to massive inflows of sediment; especially areas that are located near forests and woodlands which now have been replaced with agricultural farm land (Olang and Kundu, 2011). Olang and Kundu (2011), describe how the rise of sediment flow into Lake Nakuru have greatly decreased the growth of blue-green algae – the main food source to the flamingo birds that visit this lake (Olang and Kundu, 2011). They go on to further explain that although the sediment inflows have diminished the income associated with the ecotourism of the area, "the ecological effect of this has been the loss of biodiversity through migration of the birds to other water bodies within the rift valley where complimentary food is available," (Olang and Kundu, 2011: 256). It is clear to see from the above quote that the transformation of land from its natural state to grazing or agricultural farm land has caused significant disruption to the hydrological drainage process (DeFries et al., 2004; Olang and Kundu, 2011; Turner et al., 1994).

3.2.2.1.3 *Hydrological Cycle*

When analysing the consequences that LULC changes have had on the hydrological cycle and its contributing processes, it is important to note that it refers to the impacts on both surface and groundwater sources (Turner et al., 1994; Meyer and Turner, 1992). With the world in a constant state of change, it is understandable that rapid LULC changes are also altering the earth's water cycle. The water cycle is in a state of continuous exchange between, "the atmosphere, the land, and the oceans, and its main components are precipitation on the land and the oceans, evaporation from the land and the oceans, and runoff from the land to the oceans," (Kuchment, 2004: 1).

However, by changing the LULC of an area for human activities, the water cycle is greatly impacted, especially with regards to the magnitude of evapo-transpiration rates (Sterling et al., 2013). One of the most profound anthropogenic activities which has demanded the use of large amounts of water is agriculture (Gleick, 2003). As a result of the large consumption levels needed to satisfy the demands of agricultural lands, there has been a noticeable decline in the groundwater table, a reduced flow rate of some rivers and also in some instances, the complete drying up of large rivers (Foley et al., 2005; Gleick, 2003; Meyer and Turner, 1992). Meyer and Turner (1992) further explain that although evidence has shown the rapid depletion of water sources – both above and below the earth's surface – the extent of human impact on a global scale is still unknown.

3.2.2.1.4 *Pollution*

With the increasing rate at which land is being transformed for anthropogenic activities, is difficult to keep track of the various impacts it has had on the environment (Foley et al., 2005; Meyer and Turner, 1992; Ojima et al., 1994). However, one of the impacts that have been most evident is the pollution of water sources, atmospheric quality and the fertility of soils. Through countless studies conducted over the years, a common element found was that pollution stems from two sectors; agriculture and urban development (Ojima et al., 1994; Wu, 2008).

Both sectors require the removal of naturally occurring vegetation of the land and as a result, soils become excessively eroded and are further eroded by means of exposure to elements such as water (in forms of rain, hail and snow) and wind (Ellis and Pontius, 2007; Kuchment, 2004). Ellis and Pontius (2007) expand on this to add that over and above the mentioned impacts, the degradation of soil fertility increases the amount of detrimental pollutants such as, "phosphorous, nitrogen, and sediments to streams and other aquatic ecosystems," (Ellis and Pontius, 2007: 1). Furthermore, modern agricultural practices pose a greater threat to the pollution of the earth's water systems by means of inputs such as herbicides and pesticides (Ellis and Pontius, 2007; Foley et al., 2005). Some studies have shown that these inputs – among many others – not only infiltrate the surrounding waters systems but can also remain in the soil and cause extreme contamination (Foley et al., 2005; Sterling et al., 2013; Wu, 2008).

Pollution of atmospheric conditions is also quickly becoming one of the most destructive consequences of LULC changes, as it continues to affect all social, economic and environmental aspects of daily life. Alterations in land use practices to have a direct influence on air quality by means of simply changing the rate of various emissions into the atmosphere (DeFries et al., 2004; Foley et al., 2005) As part of this discussion, it is important to note that as a result of rapid urbanisation, expanding industrial areas are seen as a key component behind the pollution of the natural environment and even human health (Houghton, 1994). For many years, emissions from the growing industrial sector have drastically altered the composition of the atmosphere and with evidence provided from numerous studies, it has been documented that this impact is only exacerbated by the increasing " concentrations of greenhouse and ozone – depleting gases, such as carbon dioxide and chlorofluorocarbon," (Ojima et al., 1994: 300).

Over and above the detrimental effects caused through industrial emissions, Ye et al (2000) conducted a study in Shanghai to examine the various health effects of vehicles in the city and reported that in association to the exceptional rate of the urbanisation process, there has been a significant increase in the number of vehicles being used in and around the city. Other authors have also reiterated the above mentioned point and further concluded that with the demands and needs of the growing human population, transformations of LULC and effects on all its associated components is inevitable (Grimm et al., 2008; Ramphal and Sinding, 1996; Zhao et al., 2001; Zhao et al., 2006).

3.2.2.1.5 *Climate Change*

The significant fragmentation of the Earth's land cover has changed the atmospheric gas concentration through agricultural land transformations and the process of urbanisation however, LULC transformations has an equally devastating influence on the changes in climate occurrences (Kalnay and Cai, 1991; Wu, 2008). LULC changes and the rise in anthropogenic activities have generated significant increases in the emissions of greenhouse gases, including the amount of carbon dioxide - the primary heat trapping gas – being released into the atmosphere and as a result, has caused adverse effects on global climate patterns (Dale, 1997; Ojima et al., 1994; Wu, 2008). Based on an article by Dale (1997), it is noted that three key gases are adversely affected due to the LULC changes; carbon dioxide, methane and nitrous oxide. While the initial explanation behind the increases of these gases is largely attributed to the rise of industrial activities, the emissions being released have only persisted with the increase in LULC transformations (Dale, 1997; Grimm et al., 2008; Zhao et al., 2006).

Alterations in the area's albedo (reflection of sunlight) due to changes in LULC have also been regarded as one of the key contributors to transformations in global and local climatic conditions (Dale, 1997). Studies have shown that areas experiencing drastic LULC changes such as areas of dense vegetation or agricultural land being cleared out for upcoming urban developments, have depicted significant changes in the balance of surface heating (Dale, 1997; Ellis and Pontius, 2007). According to Ellis and Pontius (2007), the earth's surface heat is further influenced by, "evapotranspiration from vegetation (highest in closed canopy forest), and by changes in surface roughness, which alter heat transfer between the relatively stagnant layer of air at earth's surface (the boundary layer) and the troposphere," (Ellis and Pontius, 2007: 1). Another realistic demonstration of observed changes with regards to climatic conditions and more specifically temperatures between rural and urban areas can be described using the urban heat island (UHI) effect.

In order to further understand the modifying impact that anthropogenic activities have on climate change, the UHI effect can be used as an example to explain this direct relationship. The UHI effect demonstrates the process whereby urban areas or cities tend to have a significantly higher air and surface temperature when compared to that of surrounding areas; mostly areas of rural status (Grimm et al., 2008). The formation of the UHI's are then affected due to aspects such as "land cover pattern, city size (usually related to urban population size), increased impervious surfaces (low albedo, high heat capacity), reduced areas covered by vegetation and water (reduced heat loss due to evaporative cooling), increased surface areas for absorbing solar energy due to multi-storey buildings, and canyon-like heat-trapping morphology of high-rises," (Grimm et al., 2008: 758). Reiterated in a study conducted in Shanghai by Zhao et al. (2006), the results indicated an obvious increase in surface temperatures as the city continued to expand, thus further proving a direct relationship between LULC changes and climatic conditions.

3.2.2.2 *Socio – Economic Impacts*

In recent years, land has proved to be an invaluable commodity, especially to all of the modern developments associated with human activities. Furthermore, land provides the foundation upon which all agricultural, economic and social benefits are maintained and in order for land to be utilised for these purposes, LULC changes become a given occurrence (Wu, 2008). Nonetheless, consequences of these changes have brought to light the urgency of this profound threat to the survival of mankind (Lambin and Meyfroidt, 2011; Wu, 2008). The following discussion will be focusing specifically on a few of the socio – economic impacts that have resulted due to transformations in LULC.

3.2.2.2.1 *The Battle for Land*

The competition for land and the extent of LULC changes have a direct relationship in the challenge of sustaining the global population. As numerous studies have documented the ongoing conflicts over the competition for land currently occurring between urban and agricultural zones, it is important to note that this debate has continued due to the demanding and expanding human population (Meyer and Turner, 1992; Smith et al., 2010; Wu et al., 2013). In terms of maintaining the human population during this modern era and in order to explain the competition for land, there are said to be two specific forms of production that are essential to the debate; the production of food and production of timber (Wu et al., 2013).

The production of these two necessities has become greatly compromised with the unprecedented growth rate of the global population, however, it has also been highlighted that along with the expanding population rates, there have been significant changes in the human population's food preferences, especially when examined in conjunction with the considerable advances in the standard of living due to processes such as urbanisation, modernisation and exceptional economic growth (Fekete-Farkas et al., 2005; Smith et al., 2010). Although it may seem inconsequential at first, but it is a fact that this simple change of the dietary intake is actually a key influencing factor behind sharp increases in both crop and meat production (Smith et al., 2010; Wu et al., 2013).

In order to meet the demands of this growing population, methods of 'extensification' and 'intensification' can be observed as normal occurrences during this period (Smith et al., 2010). Smith et al. (2010) go on to explain that the term 'extensification' describes the process of physically altering the natural environment and surrounding ecosystems with the purpose of attaining more produce. On the other hand, the 'intensification' process describes the practice whereby the production of the demanded products take place on land that is already used for agricultural or forestry purposes (Smith et al., 2010).

The implementation of both these terms brings in to question the availability of unused land which is specifically suitable for agricultural production, as compared to the land which has already been acquired and used for crop production. Other studies have noted that the battle for land that is both arable and accessible has only been exacerbated by the fact that, the only other potentially cultivatable land can be found beneath tropical forests. In light of recent mass deforestation and climate changes, tropical forests have been placed under the category of a protected area in order to further conserve the biodiversity (Bruinsma, 2003; Gregory et al., 2002; Smith et al., 2010; Turner et al., 1994). Similar to that of crop production, the growing population called for a further demand in livestock production which has only exacerbated the competition for land as livestock production meant the use of more land to cater for the livestock's growth, maintenance and the overall production process (DeFries et al., 2004; Smith et al., 2010).

Although factors such as the demand for timber, the demand for areas for recreational purposes and the overall commercialisation of land have caused a significant strain on the increasing need for land and other open natural spaces, it is the production of food that is seen to be the source of the problem when looking at the debate surrounding the battle for land (Fekete-Farkas et al., 2005; Smith et al., 2010). The anthropogenic dietary and nutritional shift over the last few decades has caused immense concerns surrounding the availability of productive land, and to further reiterate this point it has been stated that, "urban areas cover only a small percentage of the landscape, but the residents populations generate a food demand that alters land use over a much larger area," (DeFries et al., 2004: 250).

3.2.2.2.2 Urban Sprawl

The growth of urban areas and the simultaneous impact of anthropogenic activities have sparked global interest with its far reaching effects. Furthermore, the unprecedented rate of LULC transformations have depicted a significant evolution of society (Wu et al., 2013; Grimm et al., 2008; Wu, 2008). Over the years and with the improvements in technology, societies have modified their practices from being an agricultural or primary resource society to that of a modernised and industrialised society (Johnson, 2001; Wu et al., 2013). However, in order to sustain the demand from the growing population, increases in urbanisation and industrial development meant rapid urban expansions – specifically in terms of attaining more land (Grimm et al., 2008; Long et al., 2007; Wu et al., 2013).

As a consequence of rapid urban expansion, the occurrence of urban sprawl has allowed the boundary of urban areas to be expanded and to cause significant encroachment on rural areas (Hasse and Lathrop, 2003; Johnson, 2001; Wu, 2008). Even with numerous definitions, its diverse and integrating nature, the concept of urban sprawl can be broadly described as a, "type of uncoordinated development with impacts such as loss of agricultural land, open space and ecologically sensitive habitats in and around urban areas due to lack of integrated and holistic approaches in regional planning," (Mohan et al., 2011: 1275). In an example, Rahman (2007) explains the process of urban sprawl by describing how India, after its independence from the British rule, saw a significant influx of people migrating into the city of New Delhi and as a result overpopulation quickly led to the city expanding in an uncontrollable manner. This process has thus meant severe negative impacts on the city's population, particularly their productivity, health and overall socio-economic development (Rahman, 2007; Netzband and Rahman, 2007). The above mentioned process and the consequent impacts of urban sprawl can be viewed from two prominent perspectives; in terms of the encroachment on rural development and in terms of the suburbanisation process.

According to Robinson et al. (2005), growth spurts of urban populations found a significant increase in the housing density within the urban centre, as identified by the above mentioned example of India's city of New Delhi (Rahman, 2007). Consequently, this further encouraged the expansion of low-density housing as people sprawled from these city edges, moved from the urban facilities in search of improved standards of living and in doing so, began to encroach on the surrounding rural areas (Grimm et al., 2008; Lo and Yang, 2002; Robinson et al., 2005). The encroachment of urban areas on a rural landscape has caused a number of conflicts and debates between urban and rural populations (Wu, 2008; Wu et al., 2013). The expansion of urban areas have changed rural communities in terms of their traditional infrastructure, settlements, markets and also soil fertility (Grimm et al., 2008; Wu, 2008). The following quote, "urbanites and agencies have legitimate concerns about the use and condition of rural natural resources, just as rural populations have legitimate concerns about urban-based pressures on the natural world," (Wu, 2008: 7) further reiterates the debate occurring over the shared interests in the natural environment and the impacts they have economically, socially and politically. Some studies have highlighted that urban areas have encroached on rural areas to such an extent that some communities have become lost or absorbed in the surrounding urban areas of growth and as a result have abandoned their traditional ways of living (Schirmer et al., 2008; Wu, 2008).

In a study of land change on Southern Australia, Schirmer et al. (2008) noted how low-income settlements were significantly impacted by the expanding urban areas. With a wide range of sub-questions varying from employment and community interactions to water use, this study found and documented both the positive and negative impacts of urban encroachment on rural areas. The study identified that the negative effects far outweighed the benefits of urban sprawl (Schirmer et al., 2008). Some members of the rural community stated that while some farmers were able to sell crops that they produced at a higher price to the new found customer base, others abandoned subsistence agricultural farming methods to join the expanding commercial plantations or the industrial sector (Ottensmann, 1977; Schirmer et al., 2008; Wu et al., 2013).

In addition, Lopez et al. (1988) stated that by observing that the prices of vegetation produce were sold at a far higher price in urbanised areas as opposed to the prices in rural areas. The rural population also expressed how this abandonment created a breakdown in the community's interaction and overall cohesion as people begin to work long regimented hours leaving little time for communication and involvement in cultural or social activities with the surrounding community members (Schirmer et al., 2008). A common impact clearly highlighted as a result of these LULC changes through urban encroachment is that rural communities have lost their identity as a population and in turn have become absorbed in the urban area and lifestyle (Schirmer et al., 2008; Wu et al., 2013). On the other hand, as cities gain residents of a lower income status and lose residents of a higher income status due to processes such as the expansion of urban areas and the encroachment on rural areas, the increasing rate of suburbanisation rises dramatically (Wu et al., 2013).

The second form of urban sprawl which LULC changes has had a significant impact on globally expanding societies is that of suburbanisation. Considered to be the introduction of low-density residential developments and later 'edge cities', this form of urban expansion allows for an increase in social and economic activities along urban fringes (Irwin and Bockstael, 2004; Mohan et al., 2011; Nechyba and Walsh, 2004). With the increased rate of suburbanisation – an important component in the LULC change debate – studies have shown that although this process allows large benefits such as increased privacy and access to the aesthetically pleasing surroundings for the residents or 'suburbanites', it may also pose a number of costs to the social and environmental quality of life in the area (Kahn, 2000; Nechyba and Walsh, 2004).

According to Kahn (2000), it is evident that mileage of vehicles can stand to be an ideal indicator in determining resource consumption and also states that suburbanisation or the urban sprawl has contributed greatly to the increase in the number of operational vehicles. While suburbanites tend to consume more resources by living outside of the city centres, it has been highlighted that the implementation of public transport infrastructure in some of these areas are minimal thus resulting in suburban residents using private vehicles to travel (Kahn, 2000; Nechyba and Walsh, 2004; Ottensmann, 1977). Apart from the detrimental effects of air pollution generated as a result of additional vehicles being used, the increase in the use of private vehicles has subsequently led to the sharp rise in congestion within the suburban areas (Grimm et al., 2008; Kahn, 2000).

Other studies have noted that in conjunction to an increase in levels of traffic congestion experienced in the suburban areas, residents have to travel for a longer period of time and a farther distance in order to engage in specific activities in the city centre; especially if the residents attain employment in the city centre it ultimately means this would be a daily situation (Kahn, 2000; Mieszkowski and Mills, 1993; Ottensmann, 1977). Furthermore, suburbanisation has been found to cause a significant separation in both the suburbanites location of work and residence, which eventually means an added cost and strain for the suburban residents (Nechyba and Walsh, 2004). Similarly, with regards to the mobility and accessibility of resources for residents of the suburban areas, it has been stated that, “the separation of residential areas by vacant land leads to increased costs in providing utilities and other public services,” (Ottensmann, 1977: 389), thus bringing to light the challenges faced by the governmental body in order to ensure the required services and needs of the suburban societies are met.

In an article by Hasse and Lathrop (2003), it is stated that urban sprawl presents a way of easing the population pressures in the city centres, the process also has particularly damaging costs, specifically on the consumption of available land (open spaces) and resources in relation to the rapidly growing human population. As mentioned earlier, suburbanisation is regarded as an extension of development specifically for residential use; however, on the other hand, edge cities are considered to be newer cities created outside of the main or core city centre, and with its large amount of available space it is able to offer a variety of services such as job opportunities, low density housing, retail stores and other recreational activities to their residents (Henderson and Mitra, 1996; Mohan et al., 2011; Netzband and Rahman, 2007).

The evolution of suburbanisation to expanding edge cities has in turn drawn attention to the land consumption crisis currently being experienced (Kahn, 2000). Kahn (2000), Nechyba et al. (2004) and Irwin et al. (2004) have stated through their research endeavours that suburban households are consuming a far greater amount of land as opposed to that of the urban city centre. Similar to the effects of growing urban areas, the growth of edge cities are gradually converting land in order to sustain the demands of the increasing suburban population and consequentially, suburbanites find themselves in the familiar predicament of a lack of access to naturally occurring open spaces in order to take part in a wide variety of outdoor activities (Fekete-Farkas et al., 2005; Kahn, 2000; Smith et al., 2010).

Over and above the need for open spaces specifically for outdoor activities, these open spaces give developers an opportunity to provide the sprawling urban landscape a form of design, plan or pattern (Ohls and Pines, 1975; Ottensmann, 1977). Urban sprawl follows an exceptionally flexible growth pattern due to its uncontrollable manner of development, however recent studies have shown that, “the reservation of land for later development in more intensive uses, either residential or commercial, could produce an urban pattern that may be more efficient in the long run,” (Ottensmann, 1977: 389). It is important to understand that once an area is developed the implications of reversing that development or urban landscape is damaging to both the surrounding environment and inconvenient for the people who reside in the area, thus with development decisions being of such an irreversible nature, the reservation of land by government allows for proper negotiations and the necessary environmental impact assessments (EIA's) to take place prior to the start of development (Irwin and Bockstael, 2004).

Urban sprawl is continuously growing at a rapid rate and it is at the same rate that the cost and benefits of LULC transformations are becoming more evident. As the income of urban residents grow, they become increasingly concerned with the fact that their new financial status could allow them to reside in areas that are of low-density suburban locations with lower crime and better public school facilities; thus resulting in the increase in rates of urban sprawl (Kahn, 2000). However, as a result of urban sprawl, studies have shown that one of the key societal costs of urban sprawl and also overall LULC changes – specifically on rural areas – is that of increased levels of disparities between people and their financial statuses (Wu, 2008).

3.2.2.2.3 *Social and societal disparities*

One of the greatest injustices resulting in the occurrence of LULC changes is that of the various disparities and forms of segregation among the people of communities according to their financial status or social class (Wu, 2008). Numerous studies have identified that with the exceeding growth of urban sprawl, the income and economic segregation between urban and suburban communities have rapidly intensified (Ottensmann, 1977; Wu, 2008). A difference in the types of income plays a major role in causing a lack of social cohesion in both the urban and suburban communities as people who earn a high income can afford housing in a location that is appropriate to lead a healthy and comfortable lifestyle as opposed to staying in the city centre which is overcrowded with unsanitary conditions (Kahn, 2000). In order to highlight the above mentioned disparities the concept of housing affordability will be further discussed.

With more people striving to earn a better income they continue to work toward being able to live in the idealistic conditions provided in suburban areas, however governments have begun to realise that this would mean expanding the amount of suburban land developments in areas that could be used for further industrial growth (Wu, 2008). Subsequently, governments have introduced strict land use regulations on the public in the hope of slowing down the development of suburban areas and as a result, the population of lower-income residents in the city centres seem to gradually grow while the amount of higher-income residents staying in the suburban areas either remain stagnant or tend to decline (Wu, 2008; Wu et al., 2013).

According to Wu (2008) and Wu and Cho (2007), it has been found that that the imposed land use regulation enforces a higher price on suburban housing, thus making it more difficult for people of the low, middle and even high-income status to afford buying a house in the area and continue paying the needed rates for maintenance of the area. By introducing the land use regulation, governments deter people from the idea of being able to live in the suburban areas thus decreasing the demand and the supply for housing developments in these areas (Wu and Cho, 2007).

However, with emerging edge cities, studies have identified the gradual move of companies and firms to locations in the suburban areas in order to be closer to high-income clients who are able to pay for their given services (Mieszkowski and Mills, 1993). With more companies moving or opening up a branch in the 'elitist' suburban area, the suburbs began to grow in terms of being able to improve and sustain their accessibility to basic resources while the residents of city centres continue to struggle to gain access to basic needs, job opportunities and also maintain a good quality livelihood (Kahn, 2000; Ottensmann, 1977; Wu, 2008). It is here that the disparities, segregation and clear lack of social interaction of people are particularly evident.

3.3 LULC Change in South Africa

Urbanisation is the key driving force in the transformation of LULC (Jansen and Di Gregorio, 2004; Lambin and Geist, 2007; Lambin et al., 2001). With majority of the more experienced urbanised areas being situated in developed countries, it is understandable as to why most of the studies have focused on these cities and not those in developing countries; much like South Africa (McCusker and Carr, 2006; Odindi and Mhangara, 2011). While a few researchers and even fewer research efforts focused on the task of explaining and analysing the transformation of South African cities, South Africa has experienced rapid and extensive urban expansion throughout the country within the last decade (Giannecchini et al., 2007; Turok, 2012).

An important factor to take into consideration when assessing South Africa's development and landscape transformation is the historically prominent era of Apartheid. The Apartheid regime caused a great fracture in South Africa's unity, however over and above this, the fragmentation of the population based on racial differences meant a significant suppression and delay in the country's overall development (Atkinson and Marais, 2006; Cherry et al., 2000). With such a segregated population occurring due to acts such as the 1951 'Prevention of Illegal Squatters Act', there was a further drawback as governments held the authority to demolish houses and evict individuals and their families from the urban areas if they did not fall within the required racial category of the area (Odindi and Mhangara, 2011). It was only after the fall of the Apartheid regime that the transformation of South Africa's landscapes gradually began to change from that of a rural to urban status (Atkinson and Marais, 2006; Odindi and Mhangara, 2011).

According to a study by Grobler et al. (2006) in the South African province of Gauteng, it was found that grassland vegetation communities or self-sustaining communities found in open spaces throughout the province have been highly fragmented as a result of the expanding urban landscape. Another study by Ololade et al. (2008) in the South African city of Rustenburg indicated an immense transition of cultivated land to that of built up or urban lands within a space of four years.

Nevertheless, looking at the greater eThekwini Municipality area and where it stands in the transformation of the LULC, it is evident that South Africa is still in a process of developing. However, the urban areas of both South Africa and the eThekwini Municipality are currently growing faster than the current size of the country's population (Roux, 2009). This trend is detected through the emergence of significantly large built up city core centres while the smaller surrounding cities on the periphery are a combination of 'township' communities or low-income settlements (Turok, 2012). According to Turok (2012), the emergence of this fragmented urban arrangement can be further supported by the lack of government policies and strategy plans yet to be implemented and carried out in order to control the urban growth while still being able to improve public infrastructure and to provide those currently living in rural or low-income settlements with access to basic services. Turok (2012) goes on to explain that even though South Africa's mix of spatial forms are unique to the landscape and the overall process of LULC alterations, efficient and effective planning methods need to be adopted by the government and implemented with the correct follow-up procedures to manage the growth and expansion of the urban areas at a reasonable rate.

Many LULC change studies have taken place in South Africa and most have come to similar conclusions regarding the expansion of the urban landscape. In a recent study conducted by Musaka and Van Niekerk (2013), Stellenbosch, the second oldest city in South Africa had a significant 28% increase of the urban landscape within a space of ten years. Similarly, Odindi and Mhangara (2011) carried out a study in the South African city of Port Elizabeth. The study produced results which indicated a 9.8% increase in the urban land cover and associated features over a period of five years (1995 - 2000). Furthermore, this study discovered that the expansion of the urban extent was at the expense of other land cover classes such as open, naturally occurring spaces and vegetated areas which subsequently experienced a drastic 8.46% loss of its overall extent (Odindi and Mhangara, 2011)

In order to successfully monitor LULC changes and the growth extent of urban and suburban areas, government and urban planners continually call for precise and temporally appropriate information on the spatial dynamics of different areas of interest (Giannecchini et al., 2007). One of the most proficient, effective and widely used methods of examining LULC changes is that of remote sensing. The utilisation of remote sensing allows the user the ability to access a vast basis of data and to identify change in various landscapes over areas of different extents in extreme detail (Lillesand et al., 2008; Mas, 1999; Otunga et al., 2014; Rogan and Chen, 2004).

3.4 Use of Remote Sensing in LULC Change

Described as, "the science and art of obtaining information about an object, areas, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation," (Lillesand et al., 2008: 1), remote sensing has been implemented in countless fields of study with vast ranging success rates. With remote sensing's impressive achievements and technological advancements in urban land mapping and land management, it is clear to see why researchers have utilised remotely sensed data and remote sensing techniques in order to detect transformations in LULC studies (Anderson et al., 1976; Harris, 2003; Henriques and Tenedório, 2009; Rahman, 2007). Rogan and Chen (2004) have further noted that the evolution in technology in remote sensing and LULC research endeavours has been specifically due to the introduction of a different group of sensors operating at a variety of imaging scales.

In addition, it has been stated that the three key driving factors of significant advancements in remote sensing are, "(1) advancements in sensor technology and data quality, (2) improved and standardized remote sensing methods, and (3) research applications," (Rogan and Chen, 2004: 304), however Franklin (2001) has highlighted the fact that remote sensing's implementation in research is still severely lacking and needs to be improved upon. The occurrence of LULC change is quickly increasing at an unprecedented rate and the implementation of remote sensing has aided in the visualisation of the transformation of one land cover type to another (Geist and Lambin, 2002; Lambin et al., 2001; Meyfroidt et al., 2013). Although this has been the case for many instances where remote sensing has been utilised, some studies have found that through remote sensing processes, there are more modifications to land cover types as opposed to the complete conversion of the land (Coppin et al., 2004).

Urban landscapes remain one of the most difficult surfaces to analyse using remote sensing due to its extensive complex surfaces (Mubea and Menz, 2012). Urban areas are considered to be a multifaceted landscape as they consist of various artificial and natural surfaces such as widespread impervious surfaces, water bodies, vegetation, soils and rocks (Henriques and Tenedório, 2009; Lu and Weng, 2007; Mertens and

Lambin, 2000). Due to the expanding occurrence of impervious surfaces in the urban areas, there has been a significant reduction of the natural infiltration process of soils and as a result, this has caused a continuous change in the observation of land cover (Olang and Kundu, 2011).

Nevertheless, the process and procedure of implementing remote sensing in LULC change assessments has been noted to have flaws and faults where it can be improved upon. Some authors have identified that one of the significant drawbacks of remote sensing is the difficulty in distinguishing between some of the land cover classes that often share similar spectral signatures (Mas, 1999; Mubea and Menz, 2012). An example of this is the lack in the ability to tell the difference between disturbed forest areas and undisturbed forest areas or even the difference between natural grasslands from that of pasture grasslands (Mas, 1999). On the other hand, remote sensing has a wide range of benefits that range from being able to map, monitor and analyse areas at both a regional and global level, being able to attain imagery and the associated data for areas which were previously inaccessible and expensive. Above all, remote sensing enables the researcher to easily convert, understand and critical analyse changes in various landscapes as it provides multispectral and multi – temporal data (Jansen and Di Gregorio, 2004; Mas, 1999; Nelson et al., 2005; Sedano et al., 2005; Weng, 2002).

As the importance of remote sensing and its accessibility of information is quickly increasing with the need to analyse and evaluate LULC transformations - especially for urban and town planning developers or land managers - the use of CD techniques are isolated as the ideal manner in which to identify these LULC alterations by means of ground-based, atmospheric and Earth – orbiting sensors (Lillesand et al., 2008; Rogan and Chen, 2004).

3.5 LULC and Change Detection Analysis

Although there are numerous forms of definitions with regards to the concept of CD, an ideal explanation has been noted to be, “the use of multitemporal data sets to discriminate areas of land cover change between dates of imaging,” (Lillesand et al., 2008: 595). Numerous studies have since expanded on this definition to include that such areas of interest can be of either a short or long term phenomena (Harris, 2003; Lillesand et al., 2008; Liu et al., 2005). The process and associated procedures of CD is said to be successful with the, “data acquired by the same (or similar sensor) and be recorded using the same spatial resolution, viewing geometry, spectral bands, radiometric resolution and time of day,” (Lillesand et al., 2008: 595).

With the previously mentioned concept, it must be noted that for many years the use of aerial imagery or photographs were previously utilised in the CD analysis and the overall assessment of LULC transformations. However according to various studies, the introduction of newer technology has enabled the use of satellite images which stand as an alternative to the photograph method, thus allowing for the cartographic and geographic databases to be digitally updated and sustained much more efficiently (Al Bakri et al., 2001; Bauer and Steinnocher, 2001; Rogan and Chen, 2004; Treitz and Rogan, 2004). This availability of satellite imagery has dramatically improved the results of studies conducted in the areas of CD analysis especially the detail and precision of the generated results due to the high resolution imagery being utilised (Rogan and Chen, 2004).

The implementation of CD and the associated analysis has several advantages to local and global efforts focusing on monitoring LULC change, such as the fact that it includes all the relevant features with the electromagnetic spectrum, it is able to identify the location, type and manner in which the LULC transformations are occurring and lastly, it has relatively low operational costs (Jansen and Gregorio, 2002; Nackaerts et al., 2005). However, although some studies have brought to light that the CD analysis results are ideal in order to monitor land conversion, Rashed et al. (2005) explain that many a times the process of CD fails to identify changes that have occurred within specific classes but is rather suited to assessing whether change has occurred or not. Other studies have noted that the LULC transformations that take place in developing countries specifically, occur at a gradual rate and as a result, drastic LULC changes are not easy to identify (Olang and Kundu, 2011).

It is important to note that the type of method chosen for the specific study or research endeavour is able to directly determine the resulting data or maps (Coppin et al., 2004; Nackaerts et al., 2005). Even though there are a wide variety of CD methods which are available in order to assess LULC changes, it must be noted that prior to selecting a method suited to the specific research or study there are two prominent factors that need to be taken into consideration.

First, it is important to identify the intention of the research or study with regards to remote sensing and the CD process. To further explain this, Jensen and Gregorio (2002) state that LULC transformations can happen in two ways; the complete conversion of land from one category to another and the complete modification of a specific land category. This means that the conversion of land cover results in a clear change while modifications result in a small change in the land cover (Jansen and Gregorio, 2002). Similarly, the process of remote sensing and CD are able to detect conversions of LULC transformations due to it being noticeable, while modifications are subtle and therefore difficult to notice – more especially at a global level (Jansen and Gregorio, 2002; Lambin and Geist, 2006). The second and most significant factor that must be considered when choosing a suitable CD method is, being able to identify the remote sensor system, the environmental characteristics and the spatial, temporal, thematic and spectral constraints (Coppin et al., 2004; Lu et al., 2004). Once these above mentioned factors are taken into consideration with regards to the research, a specific CD method will be easy to identify as suitable for the study and will thereafter be implemented in the assessment procedures.

3.5.1 Pixel – Based Change Detection Techniques

The use of pixel-based methods tend to employ techniques that utilise the spectral information that is contained within the individual pixels to create the required and relevant land cover classes (Aguirre-Gutiérrez et al., 2012; Lu et al., 2004). Within the group of the pixel-based method, there are numerous techniques that can be utilised in order to successfully conduct a CD assessment. Some of the techniques that are related to the pixel-based method will be further discussed in this section are, temporal image differencing (TID), temporal image ratioing (TIR), principle component analysis (PCA), change vector analysis (CVA) and lastly the post classification comparison (PCC).

According to authors such as Coppin et al. (2004) and Aguirre-Gutiérrez et al. (2012), any method or technique of CD modelling will require a prerequisite process whereby change extraction and change separation takes place, however the pixel-based CD methods use processes or algorithms for change extraction and combines it with processes needed to achieve change separation. It must be further noted that although the techniques that fall within the pixel-based methods generate large amounts of repeatable information, it is able to follow a more calculated approach to CD than other methods due to its quantitative nature (Desclée et al., 2006).

2.5.1.1 *Temporal Image Differencing*

One of the most frequently utilised pixel-based CD techniques is that of the temporal image differencing (TID) technique. Explained by Lillesand et al. (2008), the procedure of TID involves the subtraction of the digital numbers of two images on a pixel by pixel basis. The following quote further reiterates the above mentioned process of TID by stating that the, “registered images acquired at different times are subtracted to produce a residual image which represents the change between the two dates,” (Mas, 1999: 143) in which the LULC transformation has taken place. Many studies have employed this approach very often due to its simplicity and that it allows for the generated data or maps to be assessed, critically analysed and interpreted with ease (Hussain et al., 2013; Lu et al., 2004; Weng, 2002). This was reiterated by Weng (2002), who conducted a study on the Zhujang Delta in China and in order to assess the changes that occurred to surface runoff over a specific timeframe and its overall impact on LULC transformations of the environment and in order to successfully achieve this, the TID technique was utilised.

Riordan (1980) however stated that when using the TID technique, it failed to consider the start and end location of a specific pixel in the featured space. Explained by the following statement, "an agricultural pixel with a radiance value of 190 in band 4 on one date and 160 on the second date showed a change of 30 digital counts ... despite this substantial change relative to other types of change, the pixel may still represent an agricultural pixel," (Singh, 1989: 993), it is evident that in its simplicity, the TID technique might be inadequately equipped to manage factors within detecting changes in a natural space.

3.5.1.2 *Temporal Image Ratio*

The technique of temporal image ratio (TIR) is considered to be another easy and accessible method of CD analysis as it involves the computing of a ratio for images which are from different dates (Lillesand et al., 2008; Lu et al., 2004; Singh, 1989). Clearly described by numerous authors this process utilises the ratio of remotely sensed images on a pixel to pixel basis and once conducted, the pixel that has not changed will obtain a ratio value of 1, while the areas that have experienced change will now have values higher or lower than 1 (Coppin et al., 2004; Coppin and Bauer, 1996).

Some CD critics of TIR have mentioned that although it has the capacity to handle calibration errors from the angles of the sun, shadows and topographical impacts much more effectively and efficiently, it can only provide information based on changes that have or have not occurred, more specifically in the form of binary data (Hussain et al., 2013). Furthermore, it has been stated that TIR has generated better results in terms of enhanced detail and exceptional precision of the LULC changes (Chi et al., 2009).

3.5.1.3 *Principal Component Analysis*

Not always a preferred or frequently used CD method, the principal component analysis (PCA) or the selective principal component analysis (SPCA) technique is nevertheless included as a type of pixel-based CD. In this technique, "two (or more) images are registered to form a new multiband image containing various bands from each date," (Lillesand et al., 2008) and thereafter the uncorrelated principal components which are joined from the combined data set can as a result be linked to areas of significant LULC changes.

Most commonly utilised for the purpose of multi-temporal CD analysis, this technique is also best suited for coarse resolution imagery including that of Landsat imagery (Ehrlich and Bielski, 2011). Rogan and Chen (2004) further reiterate the drawbacks of this technique by stating that it is exceptionally limited in its applicability when detecting changes occurring at different times over different areas and above this, they highlight the fact that this technique is purely based on a statistical approach. Lillesand et al. (2008) have also stated that the information generated from this technique can often be difficult to interpret and analyse, especially since the technique finds difficulty in identifying the nature of a specific LULC transformation that has happened.

3.5.1.4 *Change Vector Analysis*

The CD technique of change vector analysis (CVA) offers the user the capability to determine the trajectory of the change and also define the threshold on the magnitude of the change occurring in a specific space (Baker et al., 2007; Lu et al., 2004; Mas, 1999). CVA is said to be rapidly growing in terms of its popularity among researchers due to the above mentioned potentials and also due to the fact that when running the CVA procedure the changes occurring in all layers of data are analysed as opposed to an assessment of only a few selected spectral bands (Baker et al., 2007). As stated previously, one of the main attractions of this technique is that the user is able to identify the trajectory of the LULC transformations; however this element has a significant drawback as it requires imagery or data from the same phonological period in order to successfully proceed with the analysis (Baker et al., 2007; Hussain et al., 2013; Lillesand et al., 2008).

3.5.1.5 *Post Classification Comparison*

The post classification comparison (PCC) technique makes use of a 'pixel-by-pixel' comparison method in order to detect areas of LULC transformations (Bauer and Steinnocher, 2001; Coppin and Bauer, 1996). Over and above this, PCC enables the process of comparative analysis of the satellite imagery obtained in a time series to occur after the previous independent classification (Mas, 1999). In a study conducted by Fichera et al. (2012), the technique of PCC was implemented because it was identified as the only CD technique that allowed for the classes to be calculated based on how each pixel had been changed from each of the relevant classes. Furthermore, other studies have added that the PCC technique enables the researcher to easily identify previously imperceptible changes; it also provides information on the types of changes that have occurred in each class and compensates for majority of the vegetation variations and the atmospheric conditions that happen between the two dates in question (Kamusoko and Aniya, 2009; Pabi, 2007).

3.5.2 Object – Based Change Detection Techniques

The object-based CD technique is said to be very similar to that of the pixel-based CD technique and its associated methods, however the single areas where these object-based CD technique differs is that the image is not classified by each individual pixel but rather first through the segmentation of all the object's combined pixels and thereafter running the classification on those objects (Lillesand et al., 2008; Walter, 2004). The above mentioned actions – image segmentation and image classification – are the two important steps that are crucial to that of the object-based CD technique and as a result incorporates spatial neighbourhood properties when being considered in the technique (Blaschke, 2010; Esbah et al., 2010).

The object-based technique has been frequently adopted in a number of studies with highly successful results ranging from a decrease in the variances found within each class, a more effective classification process especially when using multispectral imagery and that the related algorithms were simple and ease to utilise (Duro et al., 2012; Esbah et al., 2010). Similarly, studies that have utilised pixel-based techniques and then compare their results to that of the results generated by the object-based technique have found that the object-based technique outperforms the previous methods, specifically with regards to the overall accuracy of the classification in a variety of environmental and urban settings (Duro et al., 2012).

3.6 Challenges of Change Detection in Remote Sensing

Although there have been significant advancements in technology and in the need to improve the existing methods and techniques for remote sensing; there have been considerable drawbacks which have occurred with regards to the currently available methods and techniques. The most common flaw found upon review of the different techniques is that CD techniques are difficult to understand and perform successfully without the proper data and know-how (Coppin et al., 2004).

Other studies have reiterated the fact that while these techniques are widely used throughout different facets of study and is able to generate successful results, the techniques fall short by not being able to precisely identify the variation which occurs within land cover classes with similar spectral characteristics (Fichera et al., 2012; Lu et al., 2004; Nackaerts et al., 2005). A clear example of this is the inability to still be able to successfully detect changes in land cover with specific regards to urban and suburban environments (Xian and Crane, 2005).

In terms of accuracy, the techniques and their individual ability to provide detailed and precise results is called into question. To highlight this fact, an example from Hussain et al. (2013) depicts that the shadow effect associated with higher resolution images has led to deviations in the accuracy of the results and the generated imagery. The CD analysis needs to take place in an efficient and effective manner and the one known way in which that can be achieved is if the CD methods utilised can integrate and increase the inter-date variance of the images by making use of both the spatial and spectral domains (Rogan and Chen, 2004).

3.7 Summary

From the above review of the currently available literature surrounding the concepts of LULC changes and remote sensing, it is obvious that there is a direct relationship between the two concepts. It is evident that factors such as demography, culture, economic globalisation and technological advancements are just a few of the driving forces of LULC transformations, however the main force of influence is definitely the occurrence of urbanisation. As countries and their populations strive to compete for a place in the global economy, their need to develop drives the growing rate of urbanisation. This in turn has resulted in the unprecedented rise in LULC transformations, as larger tracts of land are constantly being cleared and adapted to serve the anthropogenic demands. Remote sensing plays a fundamental role in the ability to map this unprecedented growth of LULC changes. The availability of satellite sensors has enabled a greater scope for the detailed mapping of urban and natural areas while also providing other detailed information regarding the surrounding environment. This review has also taken into account the numerous CD methods and techniques available in order to provide accurate and detailed maps depicting the transformation of LULC.

Chapter Four: History and Geographical Context

4.1 Introduction

The following chapter will focus on describing and understanding the geographical dimensions of the specified area of Umhlanga Ridge. Situated in KawZulu – Natal's eThekwini Metropolitan Municipality (Figure 4E), it is important to note that Umhlanga refers to the greater area in question with Umhlanga Ridge located within the boundary of Umhlanga and specifically situated on a hill top to provide the ideal viewing point of the Indian Ocean and coastline. In addition, this chapter will provide a brief history of the Umhlanga area as a necessary foundation to demonstrate the transformation that has taken place. Furthermore, with the use of various sources of data, such as aerial photographs and maps, the change of the Umhlanga Ridge area can be depicted and will allow for a short explanation of the areas topology and climatic characteristics.

4.2 Historical Background of Umhlanga

4.2.1 The Developmental Transformation of Umhlanga

Throughout the colonial era, coastal plains along the African continent were seen as the most ideal sites for the development of settlements, with one such location being that of Umhlanga Rocks. Situated on the eastern coastline of South Africa approximately 20 kilometres north of Durban and meaning *'the place of reeds'* in the local language of isiZulu, Umhlanga was founded and owned by Sir Marshall Campbell of the Natal Sugar Estates company from the late 1850's (Nomico and Sanders, 2003).

Being an entrepreneur and industrialist, Campbell identified and understood Umhlanga's topology and climate, and in turn allowed for the intensive sugarcane cultivation to take place in the area (Tongaat Hulett Development, 2011; Urban Improvement Precinct, 2014; Van Vuren, 2014a). However, prior to establishing the sugarcane plantations, Umhlanga's first landmark was that of a beach cottage named the Oyster Lodge. Built in 1863 by Sir Marshall Campbell's son, William Alfred, the lodge started out as a quaint holiday resort for the mill workers, family and friends, however, it quickly grew in popularity and soon after became a well sort after getaway (Morrison, 2011; Van Vuren, 2014a).

Although the Oyster Lodge attracted a vast number of tourists from throughout South Africa, Umhlanga's first hotel was only established in the early 1920's. Built by Virginia – daughter of Sir Marshall Campbell –and named The Victoria Hotel, it was the first official development in the area (Morrison, 2011; Nomico and

Sanders, 2003; Umhlanga Tourism Information Centre, 2012). As the Oyster Lodge's reputation continued to grow, further developments were made to improve and provide for the visiting population, with smaller shops being introduced in 1950 (Morrison, 2011; Nomico and Sanders, 2003).

It must be highlighted that the Oyster Lodge's uniquely reflective roof was said to have been a form of guidance for ship captains to navigate a safe distance away from Umhlanga's rocky shoreline (Urban Improvement Precinct, 2014; Van Vuren, 2014a; Van Vuren, 2014b). With the lodge later being converted in 1930 to the currently known Oyster Box Hotel, the year of 1953 saw the construction of a lighthouse sporting red and white to warn passing ships of the surrounding rocks and to also ensure that ships do not mistake the Umgeni River mouth for the start of the Durban harbour (The Oyster Box, 2014; Urban Improvement Precinct, 2014; Morrison, 2011).

Rapid developments such as the Beverly Hills Hotel in 1964 soon made Umhlanga's transformation from being a popular tourist destination to achieving a township status thus leading to the area officially being named the Borough of Umhlanga in the year 1972 (Urban Improvement Precinct, 2014; Nomico and Sanders, 2003). Due to the 'Group Areas Act' from the Apartheid regime, the Borough of Umhlanga was known for being populated by strictly white people only and being the politically dominant race during this era meant easy access to extensive luxuries (Nomico and Sanders, 2003). In order to maintain its patronage, the Borough of Umhlanga continued its development in 1980 by providing large up-market apartments, hotels and a large residential sector which expanded westwards from the coastline (Morrison, 2011; Nomico and Sanders, 2003; Tongaat Hulett Development, 2011).

4.2.2 The Emergence of the Tongaat Hulett Company

The Campbell family and the Natal Sugar Estates played a pivotal role in Umhlanga's involvement in the South African Sugar Industry (SASI) and also in Umhlanga's initial development phase (Bunn, 2005; Tongaat Hulett Development, 2011; Urban Improvement Precinct, 2014). However, it is important to highlight the connection of the Tongaat Hulett Company to that of the Umhlanga area.

Having the most notable and profound influence on the SASI, Sir James Liege Hulett arrived in Durban in 1857 and acquired 600 acres of land by the year 1860, which he later named Kearsney (Sinegugu, 1999; Tongaat Hulett Sugar, 2014). After much agricultural trial and error, Hulett finally established a tea estate on the Kearsney property which was later known to be the foundation of the JL Huletts & Sons Company (Sinegugu, 1999; Tongaat Hulett Sugar, 2014). This company soon merged with other farms and tea estates which had been previously owned by his four sons and with the objective, "to carry on in Natal or elsewhere, the business of tea growers, farmers or any other business or matter concerned with agriculture in any form, shape or way that the company deemed necessary (Tongaat Hulett Sugar, 2014: 1), the JL Huletts & Sons Company were seen as a formidable force in the agricultural sector.

As the demand for sugar grew in South Africa, the government in operation at the time called for a large refinery to be built in 1910 and located in the city of Durban in order to process the raw sugar generated from all mills in the SASI; including that of the Hulett mills (Tongaat Hulett Sugar, 2014). This then prompted Hulett to extend the current state of his company between the years of 1903 till 1911 to include four sugar mills and a large refinery, all while maintaining the profitable two factories that focused on tea production (Tongaat Hulett Sugar, 2014). According to sources, this successful extension of the Hulett company resulted in the development of the company's own railway track, in order to more efficiently transport tea and sugar supplies or products to numerous destinations across the coastline (Sinegugu, 1999; Tongaat Hulett Sugar, 2014).

After Sir James Liege Hulett's passing in 1928, his son Albert Hulett assumed chairmanship of the company, while in 1948 he was succeeded by his own son, Guy Hulett, who took on the role of both chairman and managing director of the JL Hulett & Sons Company (Tongaat Hulett Sugar, 2014). In 1962 Guy Hulett made one the most significant and memorable take-over bids for the Campbell's Natal Sugar Estates (Clarke, 2013; Lincoln, 1988; Tongaat Hulett Sugar, 2014). Studies and research conducted around this bid agreed that it was a long, bitter and frantic exchange battle between the companies which eventually resulted in the JL Hulett & Sons Company winning control of the Natal Sugar Estate (Clarke, 2013; Tongaat Hulett Sugar, 2014).

However, prior to this take-over, a deal was made between the Natal Sugar Estates and the CG Smith Group and its five other milling affiliates which included the Crookes Brothers and the Tongaat Sugar Group (Clarke, 2013; Tongaat Hulett Sugar, 2014). According to an explanation provided by Clarke (2013), the deal allowed for the CG Smith Group to launch a counter – take-over bid for the JL Hulett & Sons Company. Approximately twenty two days later from the initial take-over, the CG Smith Group and the Tongaat Sugar Group emerged successful as the new owner of the JL Hulett & Sons Company (Clarke, 2013; Lincoln, 1988; Tongaat Hulett Sugar, 2014).

It was after the take-over of 1962 that the headquarters of the Hulett Corporation was moved from West Street in Durban's city centre to the ridge of Umhlanga overlooking La Lucia (Tongaat Hulett Sugar, 2014).

The second take-over that occurred with the Hulett Corporation was in 1980, when the Barlows Company took over the CG Smith Group and joined with the Tongaat Sugar Group to control the Hulett Corporation (Tongaat Hulett Sugar, 2014). According to studies, this take-over did not last long due to a conflict of interest within the Barlows Company (Lincoln, 1988; Tongaat Hulett Sugar, 2014). As a result, the already common shareholder to both the Tongaat Sugar Group and the Hulett Corporation, Anglo American, took over the Barlow Company shares and influenced the merge of the two remain companies (Clarke, 2013; Tongaat Hulett Sugar, 2014). This merge became effective from April 1982, resulting in the emergence of the new company named the Tongaat Hulett Group Limited (Tongaat Hulett Sugar, 2014).

At present, the Tongaat Hulett Company is said to hold the status of being both an agricultural and agri-processing business, which has branched out to include components such as the management of land and property developments (Tongaat Hulett Development, 2011; Tongaat Hulett Sugar, 2014). The company is comprised of three sectors; the Tongaat Hulett Sugar, Tongaat Hulett Starch and Tongaat Hulett Developments.

According to the company website, the sugar and starch sectors of the company utilise sugarcane and maize in order to generate a wide range of refined carbohydrate products (Tongaat Hulett Development, 2011; Tongaat Hulett Sugar, 2014). On the other hand, its development sector has, "established a reputation for excellence as one of South Africa's leading private land conversion developers, having planned and developed more than 2000ha of serviced land for residential, commercial, industrial, resort and mixed-use purposes," (Tongaat Hulett Development, 2011: 1).

It must be noted that in the late years of 1980, the Tongaat Hulett Company created the Tongaat Hulett Planning Forum, which was a public-private partnership formed to make a plan and strategy to implement the development in the area north of Durban (Michel and Scott, 2005; Nomico and Sanders, 2003). Furthermore, the Moreland Developments was established as an addition to the Tongaat Hulett Company's property sector with the purpose of, "converting agricultural land on the urban periphery to urban real estate," (Michel and Scott, 2005: 106). With the Tongaat Hulett Planning Forum's strategy of development being accepted by the Durban Council, the Moreland Developments were granted permission to start the development process and the overall decentralisation from the Durban CBD (Michel and Scott, 2005; Nel et al., 2003; Tode, 2002). One such area of development that the Tongaat Hulett Company and its associated Moreland Developments is currently overseeing is that of the Umhlanga Ridge. As previously mentioned, this project was successful in creating, "a protected coastal area orientated towards tourism, coupled with an inland corridor more focused on industrial development," (Tode, 2002: 91).

The need to implement developments that are of a sustainable nature is highly important to the Tongaat Hulett Company. According to sources, the use of renewable energy or 'green methods' within all three of the sectors is viewed as an underlying component to all the development and projects taken on by the company (Tongaat Hulett Development, 2011; Tongaat Hulett Sugar, 2014). In addition, the Tongaat Hulett Company prides itself in their ability to partner with of local communities when introducing and implementing any initiatives in the area in question, thus ensuring that local communities are able to voice their opinions, help the development and provide overall empowerment and sustainability to their community (Tongaat Hulett Development, 2011; Tongaat Hulett Sugar, 2014).

4.3 Umhlanga Ridge

At this point it must be noted that Umhlanga consists of a number of sub-communities within its boundary. According to the images provided from the Tongaat Hulett website (Tongaat Hulett Development, 2011), the study area for this research is comprised of two elements; residential and commercial. Looking closely, Figure 4A depicts the districts that are within the company's residential portfolio and for the purpose of this study, the area marked as number 10 (Umhlanga Ridge Town Centre) will be utilised. Similarly, Figure 4B illustrates the company's area of commercial development and for this particular study, the district marked number 05 (Umhlanga Ridge) will be focused on. Looking at both the specified regions (numbers 10 and 05) and both figures holistically, it becomes clear that the Tongaat Hulett Company dominates a significant amount of the land ownership and has full control with regards to its usage.

With majority of its land conversions and developments occurring from 1996, it was the years prior to this that found Umhlanga's small tourist town surrounded by extensive stretches of underdeveloped, agricultural land planted with sugarcane (Michel and Scott, 2005). Currently, the Tongaat Hulett Company is expanding and continuing to extend the range of developmental projects in the area. According to an online article published in 2013, the Tongaat Hulett Company released approximately forty-two hectares of prime Umhlanga Ridge land for transaction to any interested investor or consortium to establish and assemble a real estate base in the location of one of KwaZulu-Natal's most sort after properties (Hancock, 2013; SA Commercial Prop News, 2013). While the existing development in the Umhlanga Ridge area has already attracted real estate investments worth over R50-billion, the Tongaat Hulett Company's chief executive officer, Peter Staude mentioned that, “the timing was right for this mega property transaction initiative to be undertaken to boost investment and further increase the pace of development in the region, building on the investment platform already created,” (Hancock, 2013: 1).

Being created under the Apartheid regime, the previously strict ‘whites only’ area of Umhlanga was comprised of upper class suburban developments and luxury tourist facilities all along the northern coastline of Durban (Michel and Scott, 2005; Nomico and Sanders, 2003; Van Vuren, 2014b). On the west of the coastline was the sugarcane farming belt with the towns of Phoenix, Verulam and Tongaat situated just beyond the belt and being used to house the Indian population who worked the sugarcane farmlands (Michel and Scott, 2005). Then in the area situated south west of Umhlanga was the significantly larger African townships of KwaMashu, Ntuzuma and Inanda (Michel and Scott, 2005). From the above description of Umhlanga’s location from a historical perspective, it is clear that Umhlanga was viewed as an island of wealth being surrounded by a sea of severe poverty (Kitchin, 2003; Michel and Scott, 2005).

Umhlanga, from a broader perspective, has embraced the need for mixed land uses in all areas of its development. In doing so, both areas – Umhlanga Ridge and the Umhlanga Ridge Town Centre (URTC) – are designed on the underlying principles of sustainability, safety and convenience for all working, residing or visiting the area (Bredell, 2012; Tongaat Hulett Development, 2011; Van Vuren, 2014c). By incorporating a mixed land use approach to its urban landscape, Umhlanga has allowed itself to become known as one of the Tongaat Hulett Company’s most successfully developed areas. Covering land uses such as medical, educational, residential, commercial and also recreational activities, this area is able to entertain and accommodate a range of income groups (Tongaat Hulett Development, 2011; Van Vuren, 2014c). With Umhlanga being planned on the previously mentioned underlying principles, the area has ensured that all the developments are connected through a variety of pedestrian-friendly roads, parks and public spaces which are further designed to allow the easy flow of traffic throughout the suburb (ASM Consortium, 2008; Bredell, 2012; Tongaat Hulett Development, 2011). The above mentioned factor is one of the prominent reasons for the high demand of property in the Umhlanga area.

Figure 4A: *The Tongaat Hulett Company's Residential Portfolio (Tongaat Hulett Development, 2011)*

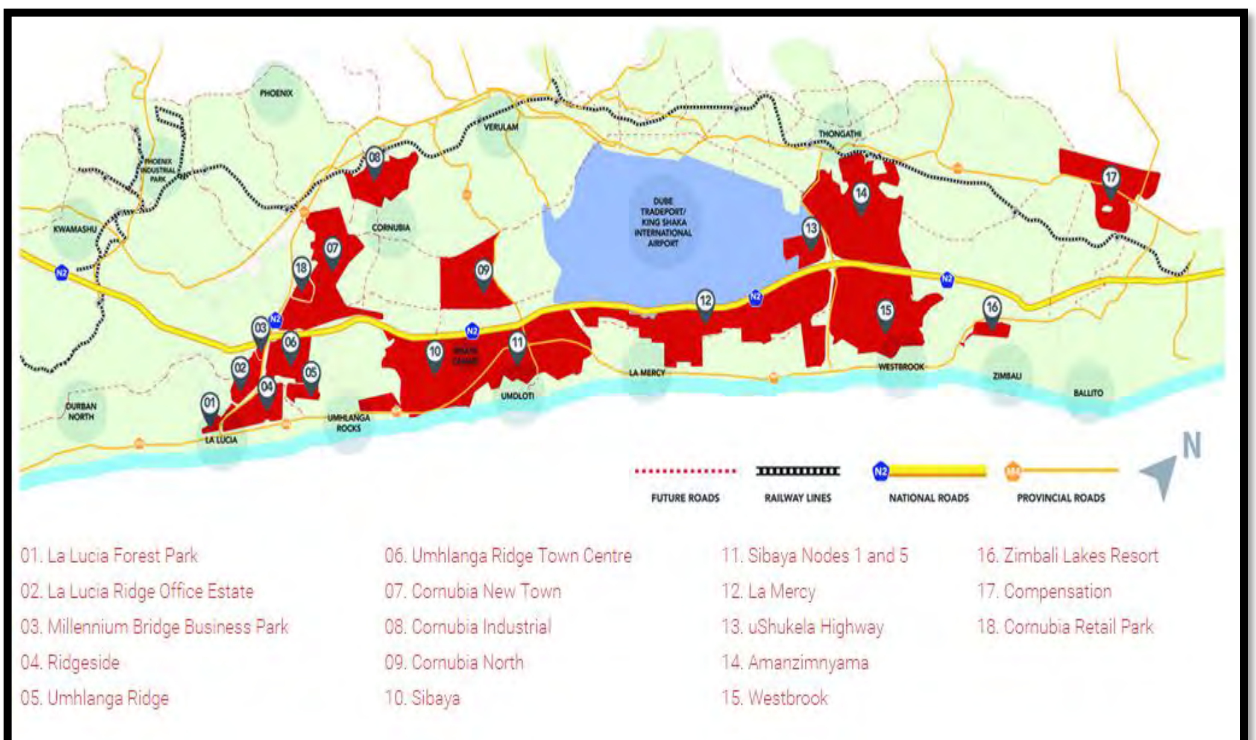

Figure 4B: *The Tongaat Hulett Company's Commercial Portfolio (Tongaat Hulett Development, 2011)*

4.3.1 The Gateway Shopping Centre

As highlighted in the previous sections, Umhlanga was once an area dominated by agriculture, farming of sugarcane and minimum development, however, as evident from the above discussions development of the Umhlanga Suburb has allowed Umhlanga to become a much sort after commercial, residential and tourist destination (ASM Consortium, 2008; Michel and Scott, 2005; Tongaat Hulett Development, 2011; Wood, 2008). With the Tongaat Hulett Company and its Moreland Developments sector focused on the conversion and development of former agricultural land to urban land use, the emergence of the Gateway Shopping Centre was seen as one of the prominent developments in Umhlanga (Kitchin, 2003; Michel and Scott, 2005).

Being the first significant development of the modern era to the Umhlanga area, the Gateway Shopping Centre was situated in the ideal area to allow a constant flow of energy into the surrounding developments (Bredell, 2012; Michel and Scott, 2005). Utilising ideas from already developed shopping centres such as the Mall of America and the West Edmonton mall in Canada, Gateway is said to be the largest shopping mall in Africa (KznDurban, 2011). Many environmentalists had protested against the development of Gateway shopping centre due to its size; the fact that the presence of the shopping mall has led to a severe loss of agricultural land in the Umhlanga areas and with further land being used for the construction of roads and other commercial and residential sites surrounding the shopping mall (Yusuf and Allopi, 2004).

4.4 Climatic Conditions of Umhlanga

Positioned on the eastern coastline of South Africa, Umhlanga is regarded as an ideal tourist destination due to its constant warm waters from the Indian Ocean (CCBusiness, 2011). As evident in Figure 4C and Figure 4D, the coastline experiences an overall warm subtropical climate, while the summers are known for being hot and humid with temperatures ranging between 23 and 30 degrees Celsius (CCBusiness, 2011; Umhlanga Tourism Information Centre, 2012). On the other hand, the season of winter is popular among tourists and is regarded as the perfect time from a climatic perspective with temperatures averaging 23 degrees Celsius during this time. These conditions allow for swimming weather to continue all year long (CCBusiness, 2011; Umhlanga Tourism Information Centre, 2012).

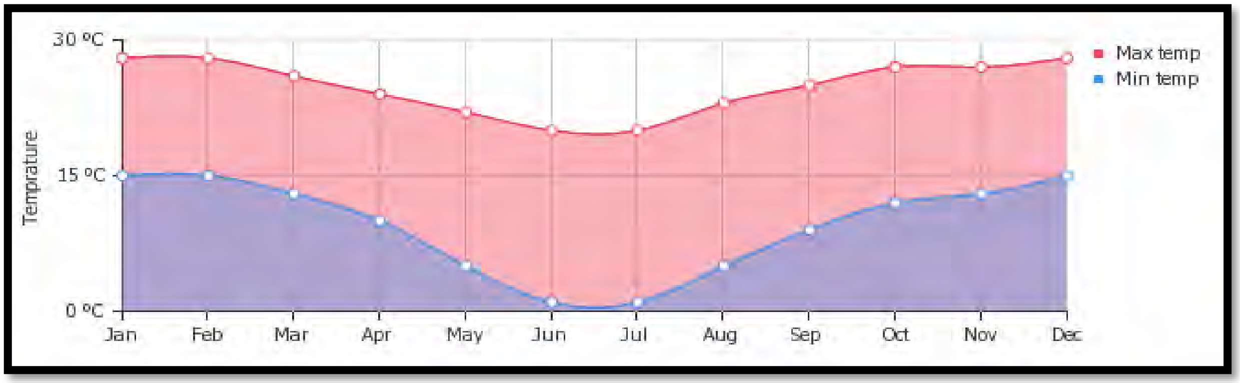

Figure 4C: *The annual average Maximum and Minimum temperatures experienced in Umhlanga (WWCI, 2014)*

Figure 4D: *The annual average level of humidity experienced in Umhlanga (WWCI, 2014)*

4.5 Location of the Study Area

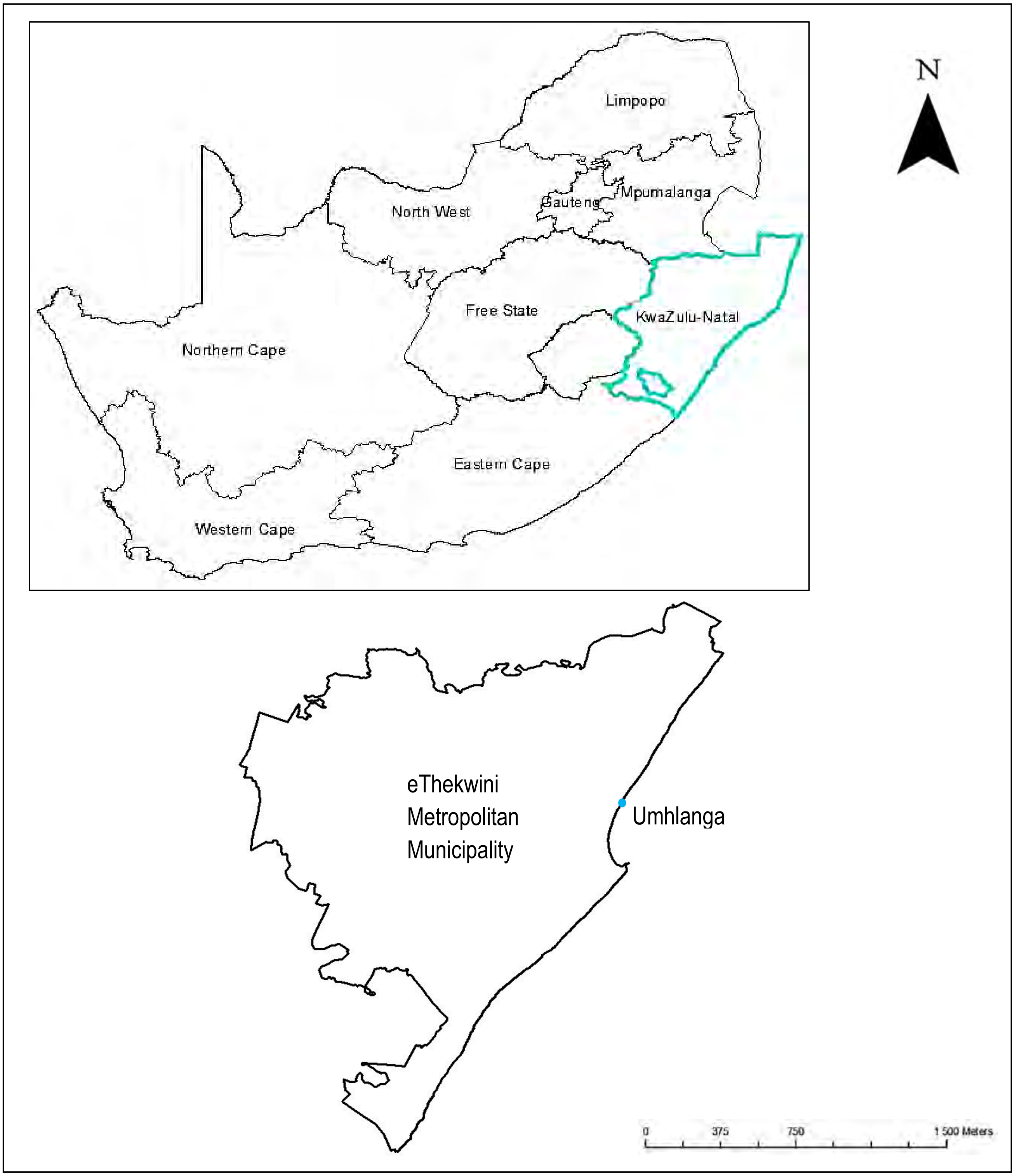

Figure 4E: *The location of Umhlanga within South Africa (inset) and the KwaZulu – Natal Province*

4.6 Summary

This chapter has focused on the value of Umhlanga including its geographical and historical worth to South African and its agricultural industry. From existing research, it is evident that the Tongaat Hulett Company and the associated development projects have greatly influenced the socio-economic and recreational status of the widespread Umhlanga area. With pleasant climate conditions and terrain available all year round, Umhlanga has immense potential to contribute to South Africa's economy; especially in the production and tourism sectors. Furthermore, these unique characteristics have allowed Umhlanga to become a much sort after holiday destination and a prestigious area to either live or work in.

Chapter Five: Methodology

5.1 Introduction

When conducting research, there are a variety of factors that need to be taken into consideration, especially with regards to the manner and adopted approach to the process of collecting the data. This specific chapter is aimed at providing a detailed account of all the methods and materials that were employed while carrying out this research. In order to achieve this, the following chapter will first highlight the exact land cover classes that were utilised for this research endeavour. Secondly, this chapter will detail the process of collecting the data needed for the purpose of this study, including a comprehensive account of the process and associated challenges that were faced while acquiring the data. In addition, the various processing techniques that were carried out on the obtained satellite imagery will also be discussed.

5.2 LULC Classification Schemes

With the wide scope of data and information provided by the remote sensing process, determining changes or transformations in LULC has become increasingly easy, cost efficient and more importantly, a source of reliable information (Alphan, 2003; Lowry et al., 2007). However, the act of mapping these changes requires that the land in question be divided into specific land cover classes (Alphan, 2003; Anderson et al., 1976; Lowry, 2005; Lowry et al., 2007). To accomplish this, LULC studies require a generalised LULC classification scheme which will help provide the desired consistency needed for LULC mapping and analysis (Lillesand et al., 2014; Thompson, 1996).

At the moment, there is no single universally acknowledged LULC classification scheme due to the fact that classification schemes tend to differ according to the country, organisation and also to the researcher's preferences. However, one of the most commonly used land cover classification system was devised by the United States Geological Survey (USGS) in the mid-1970's (Anderson et al., 1976; Lillesand et al., 2014). The USGS Land Cover Classification System is noted as the basic structure of numerous land cover classification schemes; even for those classification systems which have been able to offer a more detailed and specialised mapping of land classes in recent studies (Lillesand et al., 2008).

It has long been foretold that the integration of LULC data should not take place especially on a single map; however, studies have proven that by combining the various remotely sensed data the map becomes more reliable and resourceful in its use (Lillesand et al., 2008; Lowry et al., 2007; Thompson, 1996). The intermixing of LULC data, studies conducted by Thompson (1996) and Lillesand (2008) noted that when generating and analysing LULC maps, it is crucial to acquire additional or supplementary data.

With data being generated from different sources, collecting supplementary data to provide improved accuracy to a remotely sensed map can range from processes such as site visits and the use of other updated maps (topographical or cadastral maps) (Dewan and Yamaguchi, 2009a; Lowry et al., 2007). By combining and integrating data of different types and from different sources, the maps generated are of a more accurate, reliable and constant quality. Furthermore, it is important to note that by using data which can be geometrically registered to a common geographic base; it increases the potential for greater information extraction (Dewan and Yamaguchi, 2009a; Dewan and Yamaguchi, 2009b).

There is no singular accepted land cover classification system due to the diversity of the landscape in question, however, a land use and land cover classification scheme was adapted from Thompson's (1996) article '*A Standard Land-cover Classification Scheme for Remote Sensing Applications in South Africa*' for the purpose of this research. This classification scheme suggested by Thompson (1996) is designed specifically to meet the needs of the South African user, while still being able to adhere to the condition set by international standards.

5.2.1 Identification of each LULC Class

As noted in previous chapters, differentiating between 'land use' and 'land cover' is increasingly difficult and has often resulted in the two being mistaken for each other due to their ability to interchange (Jansen and Di Gregorio, 2003; Jansen and Gregorio, 2002). In addition, "most conventional methods of assessing land-cover change only identify transitions between classes, while neglecting change within classes due to land-cover modification ... usually results in significant error, potentially underestimating the total area experiencing land-cover change and the magnitude of that change," (Powell and Roberts, 2010: 185).

Using Thompson's suggested scheme, it is also stated that the classification is based upon three hierarchical levels (Figure 5A), which enables the researcher to take broad level classes (Level I) and further the detail and specifics in each land cover class (Level II). Therefore, for the purpose of this research, the adopted land cover classification scheme consists of both Level I and Level II cases.

Level I:	12 broad land-cover types that can be identified off high-resolution satellite imagery, such as LANDSAT TM and SPOT, without the use of ancillary data.
Level II:	23 subclasses that can be identified from remote sensing (RS) data, without the use of ancillary data, if the data format is suitable (i.e. digital, print, scale, season, band combinations, etc.).
Level III:	flexible, user-defined subcategories developed by individual planners, RS analysts, etc., specific to their own requirements or resource management disciplines, beyond the scope of the broad CSIR generic framework. It incorporates subclasses defined with the use of additional non-RS data, such as edaphic or climatic parameters (i.e. GIS modelling), or the linkage of land-use parameters (e.g. agricultural management practices or intensities: 'subsistence-level temporary crops').

Figure 5A: *The Three Level Hierarchy (Thompson, 1996)*

In order to ensure that the correct land cover classes were used for this research endeavour, data such as Google Earth imagery and the eThekwini Municipality's online aerial photographs were utilised to outline potential land cover classes prior to conducting the required field work. Although this process may seem tedious, it allowed for an overall visual assessment of the study site and permitted a shortlist of land cover classes to be identified with the area in question. As a result, the following land cover classes were identified for this specific study: Forest and Woodlands, Barren lands, Cultivated lands, Urban/Built-up lands and Grasslands.

Table 5A: *The Land Cover Classification Scheme utilised in this study*
[Adapted from (Thompson, 1996)]

Abbreviation	Class Name	Description of the Land Cover Class
F & W	Forest and Woodlands	This land cover class includes areas that are composed of greater than 10% tree cover, as well as areas encompassed with woody plants that occur greater than 5 metres in height.
B	Barren Lands	This land cover is composed of all non-vegetated lands, or areas that consist of minimal vegetation. This class is composed of areas that are made up of

		coastal dunes, Aeolian dunes and beach sands.
C	Cultivated Lands	This area is composed of lands that have been ploughed and/or prepared for the raising of various crop, however it excludes timber production. Included are crops, fallow lands, or lands that are prepared for planting.
U	Urban/Built-up Lands	All areas composed of buildings and urban development; this includes residential, commercial, industrial land cover as well as that of communication systems.
T	Transport Networks	Roads and other transport derived routes, subclass of urban.
G	Grasslands	Areas composed of grasslands that have primarily less than 10% of tree or shrub canopy cover but which has greater than 0.1% of the total vegetation cover present. It is composed of the dominant grass like, non-woody as well as rooted herbaceous plant species.

5.3 Field Survey

Obtaining reference data is crucial when utilizing remotely sense imagery. It has been stated that reference data, “involves collecting measurements or observations about the objects, area, or phenomena that are being sensed remotely,” (Lillesand et al., 2008: 38) and can be attained from a number of sources. The main reason for collecting reference data using field surveys is to firstly verify the information being extracted from the remotely sensed image and to support the overall analysis and interpretation of the acquired data (Lillesand et al., 2014). In addition to collecting reference data, training data is vital for any classification of remotely sensed imagery and the post-classification accuracy assessment (Aguirre-Gutiérrez et al., 2012; Foody, 2002; Hubert-Moy et al., 2001).

The training data set is retrieved by the collection of ground truth information in the form of Ground Control Points (GCPs) (Landgrebe, 2003; Mather and Koch, 2011). It has been a long-established process to have GCPs collected using a global positioning system (GPS) device, however advanced technology has allowed for the easy availability of ortho-imagery and topographic maps which provide similar information (Jensen, 1996; Lu and Weng, 2007).

Many have reiterated the point that although conducting field surveys in this particular manner (by collecting GCPs) is often regarded as tedious and labour intensive, it provides a far greater level of accuracy compared to other methods and can be conducted timeously and efficiently – especially if the area in question is smaller (Chen and Stow, 2003).

The field work for this particular study was conducted on the 25th and 26th of July 2015 in ward 35 of Umhlanga (eThekwini Municipality). Overall, 60 GCPs were collected for the purpose of this research from various locations throughout the study area in order to document each differing land use and class. The GPS handheld device utilised for the field work of this study was a Magellan Meridian and had a Root Mean Square Error (RMSE) of less than one metre.

5.4 Data Collection

For the purpose of this study two specific forms of data were acquired and utilised in order to successfully carry out the research. The following section will be detailing the acquisition of the remotely sensed satellite imagery and the process behind acquiring the necessary key informant interviews from the Tongaat Hulett Company's development sector. In addition, Figure 5B will summarise the complete methodological process conducted in this research.

5.4.1 Acquisition of the Satellite Imagery and related information

While some researchers prefer the use of aerial photographs with high resolution, the use of remotely sensed images is generally accepted for mapping and detecting changes in LULC (Crespi and De Vendictis, 2009; Kuenzer et al., 2015; Xian, 2015). As a basic requirement for LULC change detection studies, remotely sensed imagery must be acquired from sensors with similar spectral, spatial, radiometric and temporal solutions (Crespi and De Vendictis, 2009; Powell and Roberts, 2010). Landsat 5 TM imagery were available from sources such as SANSA and also the USGS archives but due to the low spatial resolution of these images, the integrity, accuracy and overall results of the study would have been compromised.

For the purpose of this research, high resolution SPOT 5 imagery was obtained from the SANSA archives. Launched on the 3rd of May 2002, the SPOT 5 satellite has three specific instruments; the high resolution geometric (HRG) sensor, the high resolution stereoscopic (HRS) sensor and a vegetation sensor (Lillesand et al., 2008; Lillesand et al., 2014). With the HRG and HRS sensors providing high spectral resolution and high resolution to the panchromatic imagery respectively, it was an ideal source of data for this particular study.

Looking back at the research objectives that were stipulated in the first chapter of this study, it was stated that this assignment was to identify the dominant land use and land cover changes that have occurred through time in Umhlanga Ridge with specific reference to the years 2006 and 2012. However, after further research and extensive communication with SANSA, it was decided that the images with the best clarity and least amount of cloud coverage was to be selected. With SPOT 5 images made readily available and easily accessible from SANSA's archives, images from as early as 2006 (July) and as late as 2012 (April) were obtained. Ideally it would have been preferred to have attained images from a similar month in each of the mentioned years however; these images from those particular months provided the best visible detail and clarity of the study area.

5.4.2 Acquisition of Additional Data

For the purpose of this research endeavour, key informant interviews were conducted in order to attain information regarding the Tongaat Hulett Development sector's involvement in the transformation of Umhlanga and the Umhlanga New Town Centre, as well as to identify the plans that the company has made for the future of Umhlanga's urban landscape. Key informants are considered to be, "individuals who possess special knowledge, status or communication skills, who are willing to share their knowledge and skills with the researcher, and who have access to perspectives or observations denied the researcher through other means," (Crabtree and Miller, 1999: 73).

Consequently, it became evident that in order to gain information regarding Umhlanga's transformation, specific members of the Tongaat Hulett Development sector needed to be interviewed. However, when selecting a key informant it is important to note that they are not chosen by means of a random sampling method (Parsons, 2008). While random sampling assumes that each particular entity in a study is represented equally in the research; the selection of key informants is rather the opposite (non-random), with the preferred choices being purposeful, strategic and based on an information rich sample (Crabtree and Miller, 1999).

As a result, Mr Andile Mnguni (Development Executive at the Tongaat Hulett Development sector) was selected as the first key informant for this study. From this point onward a snowball sampling method was employed in order to complete the research's sample group. According to the theory supporting a snowball sampling, the method makes use of *referrals* to increase the overall sample size until the desired sample size is reached (Blanche et al., 2006; du Plooy-Cilliers et al., 2014; Kumar, 2014). Thereafter, Mr Mnguni suggested that Mr Rory Wilkinson (Urban Planning Director for the Tongaat Hulett Development sector) as an ideal candidate to participate in this study and consequently led to the selection of the participant, Ms Karen Petersen (Developments Director of the Tongaat Huletts Development sector) be included in the study as a key informant. Similarly, Ms Petersen identified, Mr David Jollands (Director of the Tongaat Hulett Development sector).

However, the most significant flaw that was experienced during this sampling processing was the lack of people being suggested to participate in the study by those who have already been interviewed. When questioned for an appropriate participant suggestion, Mr Jollands stated that the four already documented interviewees were the most suitable individuals as they were most actively involved in the initial and current transformation of Umhlanga. Although the original sample size was meant to be a maximum of ten participants, the four people who participated in this study were able to provide information for this research initiative. Furthermore, this remained in compliance with the snowball sampling method, which stated that the process of collecting the referrals into the sample group must continue, "until the required number or saturation point has been reached, in terms of the information being sought," (Kumar, 2014: 208).

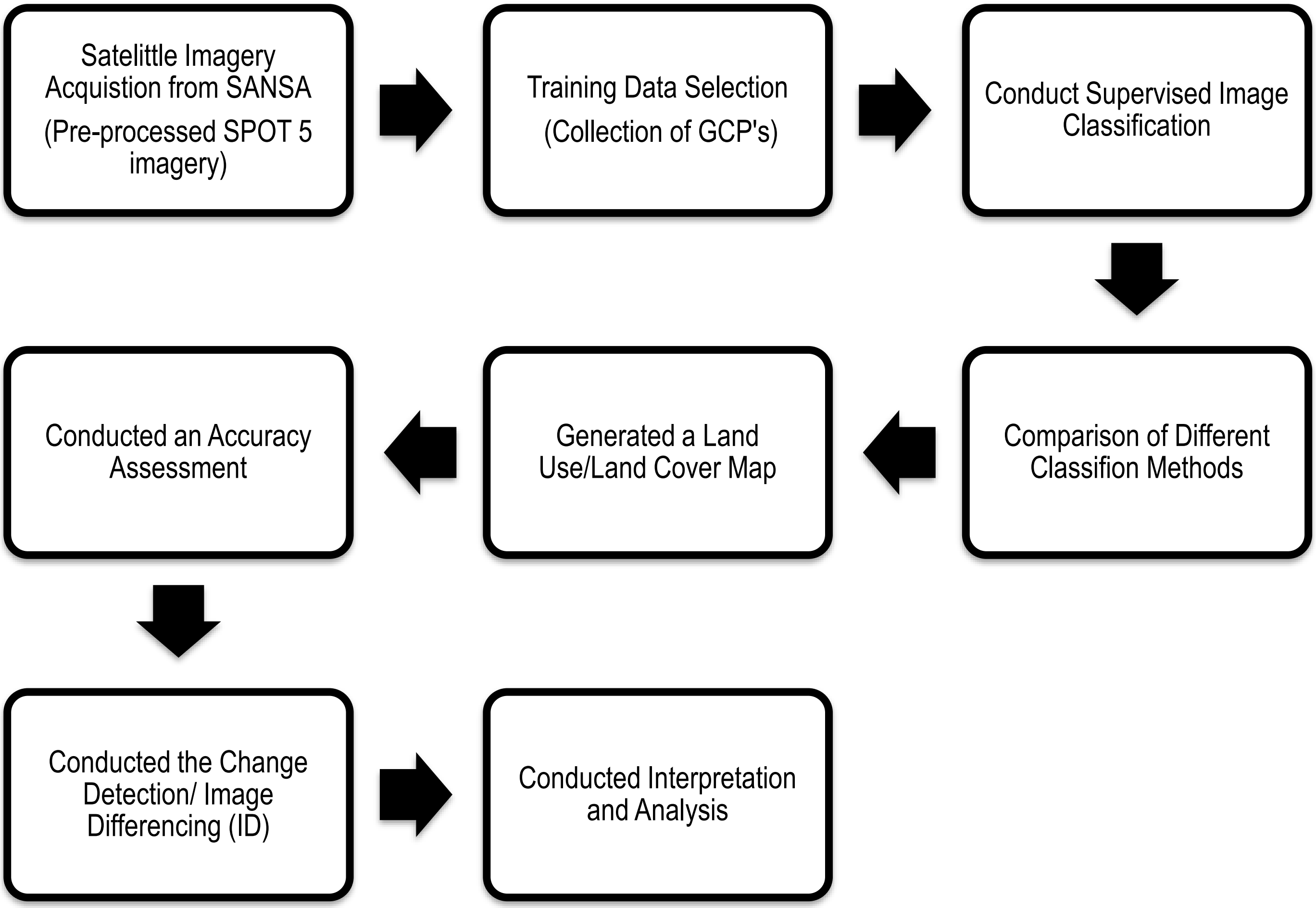

Figure 5B: *A summary of the methodological procedures utilised in this research endeavour*

5.5 Types of Satellite Imagery Pre-processing Methods

According to numerous authors, prior to utilising remotely sensed data it is crucial that the attained imagery undergo a procedure of pre-processing (Agapiou et al., 2011; Hussain et al., 2013; Kuenzer et al., 2015; Xian, 2015). This above mentioned process entails two specific courses of action; to first conduct geometric correction and secondly to perform radiometric correction on all acquired remotely sensed images.

Carrying out geometric correction on raw digital images allows for the correction of significant geometric distortions which occur due to a number of faults (Agapiou et al., 2011; Lillesand et al., 2014). These faults emanate from different sources and transpire as a result of "variations in altitude, attitude and velocity of the sensor platform to factors such as panoramic distortion, earth curvature, atmospheric refraction, relief displacement and nonlinearities in the sweep of the sensor's IFOV [*Instantaneous Field of View*]," (Lillesand et al., 2008: 486). Furthermore, the process of geometric correction is extremely necessary as it will allow for all the selected scenes to be of similar geographic datum (Agapiou et al., 2011; Sahu, 2007; Xian, 2015).

Similarly, conducting radiometric correction is important to the overall process of change detection analysis as it minimises the influence of sensor characteristics, solar angle, solar view angle and also atmospheric conditions (Chen et al., 2005; Lillesand et al., 2008; Sahu, 2007). Atmospheric correction of satellite imagery consists of the processing of the digital image to significantly decrease the overall influence of any errors and inconsistencies prevalent in the data, this is usually attributed to the effect of the atmospheric noise, which pertains to the brightness of the image values and effects the ability to accurately analyse the remotely sensed data (Chen et al., 2005; Kuenzer et al., 2015; Lu et al., 2002; Sahu, 2007; Xian, 2015).

However, there have been countless arguments surrounding the utilisation of both or either of the radiometric and geometric correction procedures. For instance, Agapiou et al. (2011) is of the opinion that radiometric correction can be excessively tedious, time-consuming and a challenging process when compared to that of geometric correction. Meanwhile, Hadjimitsis et al. (2010) state that radiometric corrections and the associated atmospheric corrections conducted on remotely sensed images is one of the most profound and significant pre-processing procedures.

It must be noted that all images attained from SANSA for this research were obtained geometrically and radiometrically corrected from the company's archives. Furthermore, the images were projected to the World Geodetic System (WGS) 1984 South Datum and thereafter clipped to the boundary of the study area by SANSA prior to downloading.

5.6 Classification Comparison

When conducting studies such as this, it is important to ensure that the correct image classification is carried out. Image classification is performed with the objective to, "automatically categorise all pixels in an image into land cover classes or themes," (Lillesand et al., 2008: 545). Image processing software allows for two types of classification processes; supervised and unsupervised classification (Lillesand et al., 2008; Richards and Richards, 1999; Sahu, 2007). In the following quote, Lillesand (2008) describes the clear distinction between these two classification processes:

> "The fundamental difference between these techniques is that supervised classification involves a training step followed by a classification step. In the unsupervised approach the

> image data are first classified by aggregating them into the natural spectral groupings, *or clusters*, present in the scene. Then the image analyst determines the land cover identity of these spectral groups by comparing the classified image data to ground reference data," (Lillesand et al., 2008: 547).

Evident from the above mentioned quote, supervised classification permits the analyst or researcher to categorise the pixels according to their own specific descriptions of the relevant land cover types in the acquired scene (Lillesand et al., 2014; Richards and Richards, 1999; Sahu, 2007). The analyst's prior knowledge of the study area is then utilised to successfully adapt the computer algorithms to the scene in question (Lillesand et al., 2014; Sahu, 2007). In contrast, unsupervised classification has the relevant LULC classes delineated after the classification process which makes the procedure unnecessarily tedious and time-consuming (Lillesand et al., 2014). It is for this reason and more that this study employs the methods of supervised classification.

Selecting a suitable classification technique to use for the purpose of LULC mapping is essential as it has a direct effect on the accuracy of the classification. Currently, there are a vast number of supervised classification methods being utilised by different researchers however, it must be noted that the selection of a particular classification technique will differ according to the nature of the study in question (Varshney and Arora, 2004).

In order to identify the best classifier to utilize in this study, the following three commonly used classifiers were assessed; the Parallelepiped Classifier, which is also commonly known as the box classifier, the Minimum Distance to Mean (MDM) classifier and the Maximum Likelihood Classifier (MLC). Using the latest image of the study area (2012), each of the above mentioned classifications were conducted in order to identify the most suitable and accurate classifier algorithm. Selecting the 2012 SPOT 5 image as the base image to test each classifier was ideal due to the fact that the corresponding data (Google Earth Imagery and aerial photographs) were easy to attain. While each of the previously mentioned algorithms has particular strengths and weaknesses in terms of its application, it is important to choose the classifier that generates the greatest accuracy and in order to conduct this comparison, the ERDAS Imagine 2013 program was utilised for this research endeavour.

5.6.1 Parallelepiped Classifier

The parallelepiped classifier, or the box classifier, is considered to be one of the easiest and uncomplicated classifiers algorithms in comparison to others known (Aronoff, 2005; Richards and Jia, 2006). Based on the simple Boolean 'and/or' function, the threshold of each class's signature is utilised in order to determine if the pixel in the question belongs to a specific class (Jensen, 2005; Teodoro et al., 2009).

Perumal and Bhaskaran (2010) have also identified that while making use of two bands, the parallelepiped classifier determines the training area of the pixels in each subsequent bands based on the minimum and maximum pixel value in the image. Therefore, pixels that are able to fall above the low threshold and below the high threshold of a particular class parallelepiped are assigned to that class (Lillesand et al., 2014; Schowengerdt, 2006; Teodoro et al., 2009). While one flaw of this method is that a single pixel may fall within the overlap area between two or more class parallelepiped, the second is that pixels can also not fall within any of that class parallelepiped, thus leaving that pixel unclassified (Lillesand et al., 2014; Teodoro et al., 2009)

5.6.2 Minimum Distance to Mean (MDM) Classifier

The MDM classifier is another commonly used algorithm due to the ease in its functionality and ability to be computationally efficient (Acharya and Ray, 2005; Lillesand et al., 2014). By first calculating the mean of each class and then the Euclidean distance of each pixel from the mean, the MDM thereafter assigns pixels to the class that has the lowest or minimum distance to the mean. In other words, the distance between the pixel in question and the mean must be at the absolute minimum (Patil et al., 2012; Perumal and Bhaskaran, 2010).

However, it must be noted that a pixel will be considered as unclassified should it be further than the user-defined distance from any particular class mean (Aronoff, 2005; Joseph, 2005). Aronoff (2005) goes further on to state that while the MDM is highly effective when classifying large images, the algorithm fails to account for a wider range of spectral values which can result in the incorrect classification of pixels.

5.6.3 Maximum Likelihood (ML) Classifier

Considered to be a far more computationally intensive algorithm, the ML classifier (also known as the Gaussian ML classifier) is conducted by calculating the likelihood that a given pixel belongs to a set of predefined classes, thereafter the algorithm continues by assigning each pixel to the specific class for which the probability is the highest (Jensen, 2005; Keuchel et al., 2003).

One of the key differences between the ML classifier and other algorithms is that it does not require any extended training processes (Pal and Mather, 2003). The algorithm states that all training data acquired for each class within each band tend to follow a normal (Gaussian) distance (Jensen, 2005; Keuchel et al., 2003; Pal and Mather, 2003). Due to the ML classifier's computationally intensive nature, the algorithm has a considerably slower processing time when compared to other classifiers, especially when processing larger images (Aronoff, 2005; Patil et al., 2012).

5.7 Post Classification Procedure

After conducting the required digital classification process, carrying out the accuracy assessment and change detection is the next crucial step in performing a LULC transformation study.

5.7.1 Accuracy Assessment

Used specifically to convey the degree to which a classification is regarded as correct, the assessment of remotely sensed data is of utmost importance (Foody, 2002; Foody, 2010; Varshney and Arora, 2004). There are various reasons behind undertaking an accuracy assessment, such as, "to provide an overall measure of the quality of a map, to form the basis of an evaluation of different classification algorithms or to attempt to help gain an understanding of errors," (Foody, 2002: 187).

According to literature, accuracy assessments were rarely thought of prior to the 1970's however, as digital technology evolved and digital classification processes became more complex there came a distinct need to assess the reliability of the overall classification being carried out (Congalton, 1991; Congalton and Green, 2008; Dicks and Lo, 1990; Jensen, 2005). In addition to the above, it has been noted that there are two types of accuracy which are currently identified; location based accuracy and classification based accuracy (Kocal et al., 2007; Strahler et al., 2006). Location based accuracy is said to be used in order to determine the amount of objects that mapped against a reference image, while on the other hand, classification based accuracy is focused on finding the overall pixels that have been classified into relevant classes – be it the wrong or correct classes (Kocal et al., 2007; Story and Congalton, 1986).

Furthermore, accuracy assessments have been found to be of both a quantitative and qualitative nature (Kocal et al., 2007; Russell and Plourde, 2001). Accuracy assessments with qualitative characteristics are based on visually comparing results obtained to that which is seen on the ground surface, while assessments of a quantitative nature are based on the comparisons of quantifiable parameters (Congalton and Green, 2008; Kocal et al., 2007).

One of the most frequently used methods of documenting the details of a conducted accuracy assessment of any classification in remotely sensed imagery is through the use of the error or confusion matrix (Foody, 2002; Foody, 2010). An error matrix or confusion matrix can be described as,

> "is a square array of numbers set out in rows and columns which express the number of sample units (i.e., pixels, clusters of pixels, or polygons) assigned to a particular category relative to the actual category as verified on the ground ... The columns usually represent the reference data while the rows indicate the classification generated from the remotely sensed data ... An error matrix is a very effective way to represent accuracy in that the accuracies of each category are plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification," (Congalton, 1991: 36)

In addition to the above, the error matrix acts as an indicator to highlight areas of incorrect or misclassification that has occurred between a generated map of the ground and the ground in reality. Thus the error matrix is able to report on the relationship between the true land cover classes to that of the classes which have been mapped (Congalton and Green, 2008; Patil et al., 2012). The error matrix also helps by generating a summary of statistics related to the classification accuracy assessment, including the Overall Accuracy (OA), the Producer's Accuracy (PA), the User's Accuracy (UA) and the Kappa (K) coefficient.

The Overall Accuracy (OA) indicates the total number of successfully identified samples in the classification relative to the total number of samples that occurs in the classified image, the Producers Accuracy (PA) relates to the probability of the reference pixel that has been accurately classified and, the Users Accuracy (UA) is based on the probability that a given pixel on the classified image in reality matches or represents the land cover class in the field (Congalton and Green, 2008; de Souza et al., 2013; Varshney and Arora, 2004). However, compared to all the other statistics generated by the error matrix, the K coefficient considers all elements of the error matrix while being the only measure of accuracy that considers and accounts for the agreement between the classified image and the test dataset arising due to chance (Varshney and Arora, 2004).

For this specific research, the accuracy assessment was conducted using the ERDAS Imagine 2013 software and the error matrix report with the subsequent accuracy measurements was produced. With the of the error matrix report, the classification that generated the highest K coefficient and OA were utilised to classify the images in question for this study.

5.7.2 Change Detection

In order to determine the extent of the occurred change within the area in question, a CD procedure was utilised. Provided with the ERDAS Imagine software, the Temporal Image Differencing (TID) or Image Differencing (ID) method was chosen as the most suitable technique for this specific study. Explained in further detail in Chapter two of this thesis, ID is the process whereby pixels from the first-date image are subtracted from those of the second-date image, thus generating a third image (Lillesand et al., 2014; Lu et al., 2004; Mas, 1999). While areas of change in the generated third image will attain significantly larger positive and negative values, areas that have experienced no change at all will have small or near zero values (Hussain et al., 2013; Jensen, 2005; Lillestrand, 1972).

Popularly known for the ease and simplicity in its procedure, the ID technique is said to be a highly cost effective method of CD which allows for easy interpretation and analysis (Dadras et al., 2014; Hussain et al., 2013; Lillestrand, 1972). One of the most significant drawbacks of this CD technique is that it is only able to detect areas of change or no-change and not a detailed summary of the change which is available with other CD techniques (Coppin and Bauer, 1996; Lu et al., 2004; Mas, 1999).

5.8 Summary

This chapter detailed the methodology and associated processes which were utilised in this study. Discussing elements such as the method of acquiring all the necessary data for this research, the process behind selecting which classification method would be best suited for this thesis, the importance of performing an accuracy assessment on the classified images and choosing the most suitable CD technique for data needed for this research.

Chapter Six: Results and Analysis

6.1 Introduction

This chapter will provide a detailed account of the results generated from all the processes described in the previous chapter. In the form of tables, graphs and tables this chapter will illustrate the results of each attempted classifier, the relevant land cover maps, and a comprehensive explanation of the change in each class between the two stipulated dates (2006 and 2012) and furthermore will also be documenting the results of the change detection analysis.

6.2 Finding a Suitable Classifier

As discussed in the previous chapter, three different classifier algorithms were tested in order to distinguish which would be the most accurate and suitable to conduct the land cover classification for this study. In addition, a sufficient base of supporting and reference data including GCP's, Google Earth Imagery and available aerial photographs were utilised with each classification.

6.2.1 Maps and Accuracy Assessment Results generated from each Classification

After applying each of the tested classifier algorithms, each one generated a land cover map, as seen in Figure 6A, Figure 6B and Figure 6C. Along with each land cover map that was generated for each algorithm, an accuracy assessment was also conducted (Table 6A). By reporting elements such as the OA, PA, UA and the kappa statistics, the accuracy assessment is able to provide the important details needed to evaluate each classification algorithm.

Table 6A: *The statistical results generated from the accuracy assessment of each tested classifier algorithm on the 2012 image of the study area*

Classifier	OA (%)	PA (%)	UA (%)	Kappa Index
Parallelepiped	56.67	56.19	66.93	0.47
MDM	63.33	57.61	61.11	0.52
ML	71.41	71.22	78.10	0.66

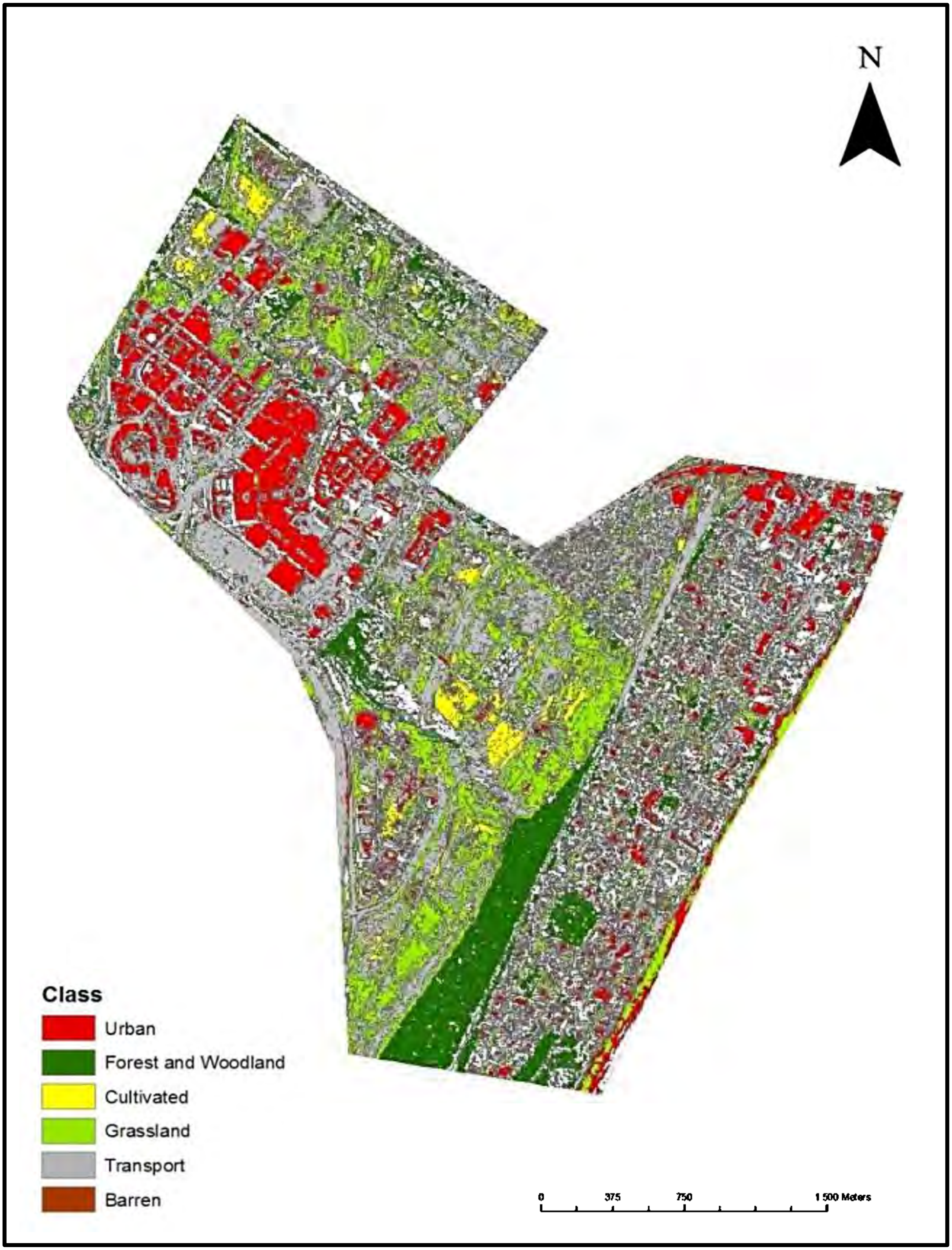

Figure 6A: *The study area in 2012 using the Parallelepiped classifier*

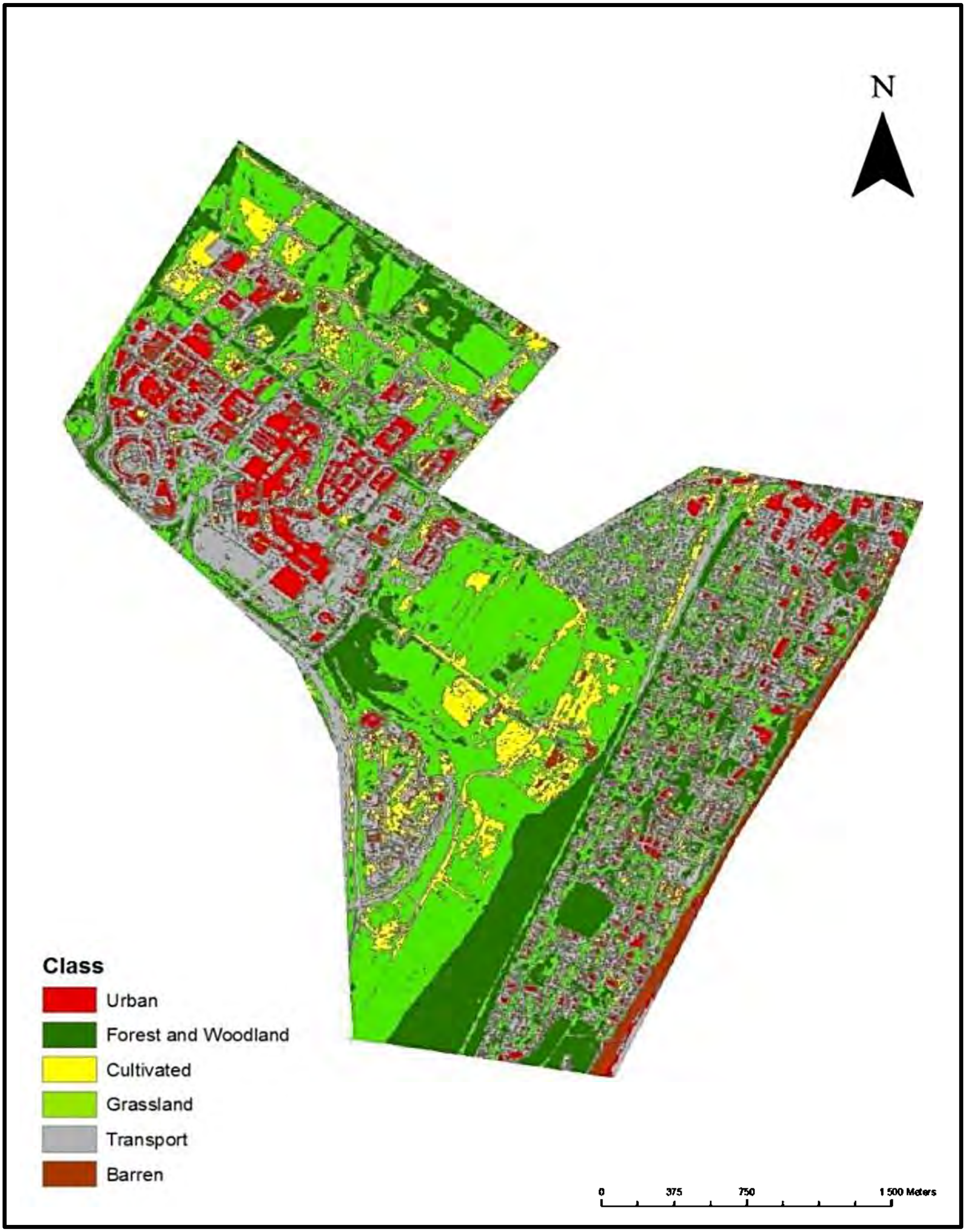

Figure 6B: *The study area in 2012 using the MDM classifier*

Figure 6C: *A map illustrating the study area in 2012 using the ML classifier*

6.2.2 Results attained from each Classification

With the lowest OA of 56.19% and a kappa statistic of 0.47%, the parallelepiped classifier is considered to be the least accurate algorithm performed. To further confirm this, the land cover map produced by the parallelepiped classifier (Figure 6A) depicts an exaggerated extent of the transport land cover class into areas where transport networks do not occur in reality. Due to the parametric rule of this classifier it has yielded a large amount of unclassified pixels, thus further reiterating the severe lack of accuracy from this algorithm as depicted in the evidence of Figure 6A and Table 6A.

The MDM classifier produced an OA of 63.33% and a subsequent kappa index of 0.52%. Despite the fact that this classifier generated a significantly improved result when compared to that of the parallelepiped classifier, its results are still evidently skewed. It is clearly evident from Figure 6B that the barren land cover class was underestimated by the MDM classifier and also depicts that certain sections of the study area were not appropriately classified by the MDM algorithm.

The ML classifier produced the highest OA of 71.41%and the highest kappa index of 0.66%, which has resulted in the algorithm being considered as the most accurate classifier when compared to that of the parallelepiped classifier and the MDM classifier. Accurately depicting the urban land cover class to be dominant, Figure 6C also shows that this classifier underestimated the extent of the transport land cover class. In order to rectify this, it can be recommended that more training site data can be acquired to improve the overall classification process and accuracy.

As a result, after considering all the generated maps (Figure 6A, 6B and 6C) and related statistics (Table 6A), the ML classifier was accepted as the preferred classifier for this research endeavour. The ML classifier was utilised to classify the 2006 and 2012 SPOT 5 images along with additional training sites for a more accurate final classification process.

6.3 Image Classification

Once the ML classifier was identified as the most suitable and accurate algorithm for this specific study area, it was then used to classify and produced land cover maps from the acquired SPOT 5 images of 2006 and 2012 (Figure 6D and Figure 6E respectively). Each with an area of 505.55 hectares (ha), the land cover maps of 2006 and 2012 illustrate a significant expansion of urban features and transport networks within the study area. In addition, there is a substantial decrease in the amount of cultivated lands and forest and woodland observed in the land cover map of 2012 when compared to the map of 2006. Similarly, the occurrence of barren land is notably higher in the land cover map of 2006 (Figure 6D) in comparison to the land cover map of 2012 (Figure 6E).

Upon further inspection of both land cover maps (Figure 6D and 6E), it is evident that in several places the classification of urban features was confused with the classification of areas that are either forested or that contain other types of vegetation. This confusion can be due to two reasons; the first being that this specific study area of Umhlanga Ridge contains many gated communities which have roof structures that are painted green (for example, the Somerset Park community) and has consequently resulted in the confusion between the urban and forest land cover classes.

Secondly, confusion may occur due to the heterogeneous or diverse nature of the area. Therefore, by allowing urban features to be mixed with the naturally occurring environment (grasslands, forest or woodlands), the mapping of urban spaces becomes particularly complicated with the added issue of mixed pixels. A frequently occurring problem in land change detection studies is found when residential areas and their surrounding urban features (road networks, trees and water sources) are clustered into a single pixel and class, rather than being classified as being individual classes (Epstein et al., 2002; Weng, 2011).

Being considered a ‘hard’ classifier, the ML algorithm assigns digital numbers or pixels according to the land cover class which they are mutually exclusive to (Weng, 2011). This per-pixel nature of the ML classification procedure, especially for this specific study whereby the ML classifier applied has resulted in the underestimation of the urban features occurring in the southern residential areas of this study area. This limitation – although small – has the potential to affect the accuracy and authenticity of the urban land cover class represented in the generated land cover maps (Figure 6D and Figure 6E).

***Figure 6D:** A land cover map illustrating the study area in 2006*

Figure 6E: *A land cover map illustrating the study area in 2012*

6.4 Accuracy Assessment

When producing a classified land cover map using remotely sensed data, it is important to note that the data is always subjected to some form of error. Therefore, it becomes the responsibility of the researcher to uncover and report all errors from the generated maps in order to increase the overall reliability of the classified data (Foody, 2010; Haregeweyn et al., 2012; Kocal et al., 2007; Strahler et al., 2006). To aid this above mentioned process of identifying error, accuracy assessments or an error matrix are carried out.

For the purpose of this study, an error matrix was produced (Table 6B and Table 6C) in order to evaluate the classification results of the two generated land cover maps (Figure 6D and Figure 6E). From the error matrix generated for the 2006 land cover map (Table 6B), the OA reported 83.87% while the error matrix for the 2012 land cover map (Table 6C) reported an OA of 85.29%. Additionally, it must be noted that the generated results of the OA's indicate that all the conducted classifications were at least 80% accurate. Furthermore, the 2006 kappa index was reported to be 0.80 whereas the 2012 kappa index was 0.82, consequently illustrating a slight increase between the two years in question.

Taking a more detailed look at the accuracies produced from each land cover class for the years of both 2006 (Figure 6D) and 2012 (Figure 6E) in conjunction with the PA and UA statistics, it is evident that the classifications were fairly good. With regards to the 2006 error matrix (Table 6B), the forest and woodland, urban and transport land cover classes all received an UA of 100%. However, a change emerged when the forest and woodland and cultivated land cover classes generated 100% in the PA, whilst the transport, urban and cultivated land cover classes yielded PA's of 75%, 60% and 83.33% respectively. In addition, it must be highlighted that while the barren land cover class produced a PA of 100%, it reported a decreased UA of 50%. Similarly, the grassland land cover class yielded an 80% PA, its UA stood at a considerably lower 66.67%.

On the other hand, the 2012 error matrix (Table 6C) did produce a similar 100% UA for the classes of forest and woodland and urban, however the barren land cover class also generated an UA of 100%. The lowest UA however was that of the transport land cover class which stood at a low 57.14% even though its PA was that of 80%. Looking at the PA results generated from the 2012 error matrix (Table 6C), the urban land cover classes produced 87.50%, the forest and woodland reported a lower yet still significant 85.71%, while the barren land cover class resulted in an 80% PA. Generating a 100% for its PA, the cultivated land cover class had a lower UA of 75%, while the grassland land cover class on the other hand had an accuracy of 83.30% for both the UA and the PA.

Despite the fact that most of these results illustrated a good overall outcome for these image classifications, it still fails to meet the acknowledged minimum standard accuracy level of 85% (Congalton and Green, 2008; Story and Congalton, 1986; Thomlinson et al., 1999). However, according to Foody (2002), many researchers fail to attain this required minimum level of accuracy. This can be attributed to the fact that not all study areas are commonly homogenous in nature and therefore possess differing trends.

Furthermore, Foody (2002; Foody, 2010) emphasize that the universal minimum standard required for thematic land cover maps is not universally acceptable, when practical actions are taken into account or are considered. However, it has been widely acknowledged that in order to improve the OA of a classification, employing the use of more ground truth data or reference data for the accuracy assessment, as the probability of the pixels belonging to land cover classes are increased.

Table 6B: *The error matrix for the classified image for 2006*

		Reference Data							
		U	G	C	T	B	F & W	Row Total	UA (%)
Classified Data	U	3	0	0	0	0	0	3	100
	G	1	4	4	1	0	0	6	66.67
	C	0	1	5	0	0	0	6	83.33
	T	0	0	0	6	0	0	6	100
	B	1	0	0	1	2	0	4	50
	F & W	0	0	0	0	0	6	6	100
Column Total		5	5	5	8	2	6	31	-
PA (%)		60	80	100	75	100	100	OA = 83.87	
Kappa Index = 0.80									

Table 6C: *The error matrix for the classified image for 2012*

	Reference Data							
		U	**G**	**C**	**T**	**B**	**F & W**	**Row Total**	**UA (%)**
Classified Data	**U**	7	0	0	0	0	0	7	100
	G	0	5	0	1	0	0	6	83.30
	C	1	0	3	0	0	0	4	75
	T	0	1	0	4	1	1	7	57.14
	B	0	0	0	0	4	0	4	100
	F & W	0	0	0	0	0	6	6	100
Column Total		8	6	3	5	5	7	34	-
PA (%)		87.50	83.30	100	80	80	85.71	OA = 85.29	
Kappa Index = 0.82									

6.5 Changes in the Land Cover Classes

6.5.1 Urban/Built Up Lands

Comprising of both commercial and residential areas and also consisting of both informal and formal settlement types, the urban land cover class in the Umhlanga Ridge is diverse. As depicted in Table 6D, the urban land cover class occupied an area of approximately 30.22 ha (5.98%) from the study area's total land extent of 505.55 ha in the year 2006. However, this amount grew extensively and by the year 2012 the urban land cover class extent covered up to 69.99 ha (13.85%) of the total land lover surface. With a drastic increase of 39.77 ha (7.87%) within a space of six years, the urban land cover class can be illustrated as being one of the most dominating and continuously expanding types of land cover in the area.

Considering South Africa's historical background and the added implications of the of the Apartheid regime the country is still in a developing phase, however it is experiencing vast and rapid urbanisation processes (Atkinson and Marais, 2006; Turok, 2012). Reiterated by numerous authors, it has been observed that within the time of twenty years of democracy, South Africa has made significant strides in advancing the country's economic standing through the means of developing the urban and industrial sectors (Musakwa and Van Niekerk, 2013; Nevhutanda, 2007; Odindi and Mhangara, 2011).

Umhlanga's transformation began in the early 1860's with one of the key participants in this transformation being that of the Tongaat Hulett Company. According to an interview conversation with Rory Wilkinson, the Planning Director of the Tongaat Hulett Development sector, the land use transformation of Umhlanga and its surrounding areas was initiated out of the dire need to create job opportunities for the large population which resided in the north of the KwaZulu – Natal province and travelled to the south of KwaZulu – Natal of employment on a daily basis.

Developments Director of the Tongaat Huletts Development sector, Ms Karen Petersen, reiterated this point in an interview and added that the conversion from agricultural land to an urban area was deemed to be considerably more profitable and feasible for the company than if it remained under active sugarcane cultivation. Subsequently, the Tongaat Hulett Company began progress for a major urban development node at the centre of Umhlanga (Umhlanga Ridge). By using more agricultural fields, the constantly expanding urban development area now includes features such as hotels, businesses, office parks, shopping complexes and extensive residential areas.

With Umhlanga considered to be one of the premier and upmarket holiday destinations for thousands of tourists from all parts of the world all year round, it is clearly evident that tourism is an influential factor to the expansion of urban developments. Due to its pristine views of the Indian Ocean, close proximity to attractions such as the Gateway Theatre of Shopping, the famous Umhlanga Lighthouse and vast nature based attractions offered in the area, there is a constant need to introduce more improved or modern urban features in order to accommodate the tourists and also the residents of the area.

With tourism as a driving force to uplift the South African economy, it also acts as a key strategy to generating jobs and skill developments to those previously disadvantages South Africans (Binns and Nel, 2002; Sharpley and Telfer, 2014). Binns and Nel (2002), state that areas of urban development must be aware of the associated negative impacts of tourism, such as the physical damage to the natural environment, depletion of resources and the increased pollution levels. Therefore, while urban areas are the central point of economic growth; they are also areas that consist of great innovation and are responsible for encouraging ecologically sustainable development (Cohen, 2006).

When urbanisation occurs at a rapid rate, it has the potential to lead to poor land use practices which can compromise the capability of future generations from meeting their needs (Musakwa and Van Niekerk, 2013). The National Framework for Sustainable Development (2008) is a detailed policy in which principles of sustainable development are deeply rooted in all facets of developmental planning, in addition to environmental management as well as in conservation related legislation (Cilliers et al., 2014). While sustainable development has become a key objective of successful urban planning and development, it is important to note that these practices are not always easy to implement and to also attain the full support of all communities involved (Musakwa and Van Niekerk, 2013). Nevertheless, members of the Tongaat Hulett Development have expressed during their interviews, the ways in which the company has successfully integrated sustainable development practices within Umhlanga and its surrounding areas.

In an interview with Mr Andile Mnguni, Development Executive at the Tongaat Hulett Development sector, he stipulated that the Hulett Development sector is an ISO 14001 certified company. Very broadly explained, ISO 14001 is a framework of set criteria that a company or organisation can follow in order to set up an effective Environmental Management System (EMS) (International Organization for Standardization, 2015). Furthermore, an ISO 14001 provides the company with a guarantee that all environmental impacts produced by the company is measured and thereafter allocated certain ways in which to mitigate the effects (International Organization for Standardization, 2015).

Apart from the above mentioned certification, Mr Wilkinson stated that the Tongaat Hulett Company, more specifically the Tongaat Hulett Developments sector, is constantly aware about the need to provide social, economic and environmental requirements in a balanced manner and also within the framework of ecological resilience. According to Ms Petersen, the Tongaat Hulett Company also ensures that sustainable development practices are implemented by rehabilitating and protecting forests and wetlands, removing all invading alien plant-life and by also planting trees along sidewalks and in open spaces. Mr Wilkinson added to this by stating that there will be an increased opportunity for public transport in the area of Umhlanga, in order to reduce the use of private motor vehicles. In addition, Mr Wilkinson and Mr David Jollands (Director of the Tongaat Hulett Development sector) have shared through their interviews that the Tongaat Hulett Development sector has currently identified an open space corridor of approximately 4000 ha in the north for rehabilitation and conservation of the natural environment.

Finally, studies have highlighted that the southern Africa region is currently experiencing immense urbanisation and will only continue to expand through time (Tortajada et al., 2013; Varis, 2006). To reiterate this, all four interviewees stipulated that expansion plans for the currently developed areas have already been put in place and will begin construction soon.

6.5.2 Transport Networks

With reference to the adapted land cover classification scheme (Thompson, 1996) illustrated in Chapter Five of this study (Table 5A), transport networks are referred to as a subclass of the urban land cover class. However, due to its immense importance and large extent within this study area, the transport land cover class has been considered as an individual class. Accounting for a total of 126.23 ha (24.97%) of the land in 2006 (Table 6D), the transport land cover class was calculated to be the most dominating land cover type of all the others considered in this study. In 2012 (Table 6D), generating a result of 201.41 ha (39.84%), the transport land cover class was once again depicted as the dominant land cover type with the drastic increase of 75.18 ha (15.37%) over six years, as clearly depicted in the land cover maps produced earlier (Figure 6D and Figure 6E).

It has long been an accepted notion that as the size of a city or urban area grows, the demand for transport and its associated infrastructure subsequently increases as well (Coffin, 2007; Fu et al., 2010; Nevhutanda, 2007). Similarly, it can be noted that the increasing statistical trends associated with transport in this specific study, is a direct result of the increasing growth of the area's population and urban features such as the commercial and residential areas along the northern and central regions of this study area.

Stipulated and reiterated in numerous studies, transport and its associated infrastructures have a direct relationship with the economic development of a country (Coffin, 2007; Fu et al., 2010). The National Transport Policy White Paper of South Africa (1996) explains transport as a crucial element that is necessary to uplift the social and economic development in the country. The rapid emergence of expanding transport networks – especially in Umhlanga – has played a key role in providing the link between the historically fragmented societies of South Africa (Nevhutanda, 2007).

As pointed out earlier by Mr Wilkinson, one of the reasons for converting Umhlanga into a hub of urban development was to help alleviate the strain of unemployed and unskilled members of society. In addition, it can be noted that by expanding transport networks the chance of obtaining a job becomes more realistic for people who stay far away from the places of opportunity (Fedderke and Bogetić, 2009; Kahn, 2000; Nechyba and Walsh, 2004). Furthermore, Fredderke and Bogetić (2009) assert that by increasing features such as road networks will allow for an immediate impact on the cost of transport, thus demonstrating the potential of transport in minimising the cost of services and products.

Umhlanga's rapid development has meant a subsequent rise in the extent of transport networks throughout the area. However, within the main node of urban development in Umhlanga, efforts have been made to reduce the use of private vehicle usage and rather utilise the public transport option. This would be a fundamental transition for all urban areas as it will allow for the relieved pressure of traffic congestion in these central urban areas. With roads and other transport infrastructure becoming a more prominent and common sight in urban landscapes, it is important to acknowledge that roads do have an adverse effect on the surrounding ecology (Trombulak and Frissell, 2000).

Due to its impervious characteristic, roads can affect the survival of organisms in the vicinity of the road and also results in the destruction of the natural environment (Trombulak and Frissell, 2000). Therefore the designing of roads and its maintenance needs to be carefully integrated into the environment with all ecological effects being taken into account and allowing for a sustainably developed network of roads and associated infrastructure (Trombulak and Frissell, 2000).

6.5.3 Grasslands

Being the second most dominant land cover of this study area, grasslands were reported to have covered at least 105.98 ha (20.96%) of the land in the year 2006 (Table 6D). In the year of 2012, the grassland land cover class showed a minor drop of 3.55 ha (0.7%) which resulted in a total land cover of 102.43 ha (20.26%) but still managed to maintain its position as the next most dominant land cove after the urban land cover class (Table 6D).

However, looking at the land cover maps generated for 2006 (Figure 6D) and 2012 (Figure 6E), it is evident that areas of the cultivated land cover class in 2006 had transitioned into the grassland land cover type by the year 2012. Therefore, it must be highlighted that the decrease indicated in the grassland land cover class in 2012 (Figure 6E) was a result of a land conversion rather than the assumption that the areas were diminished. Furthermore, the areas of the grassland land cover class in 2006 (Figure 6D) were later seen to be utilised in the expansion of urban landscapes by 2012 (Figure 6E).

At the moment, grasslands throughout South Africa are experiencing high levels of degradation and processes related to land conversion and transformations, which are both due to the overbearing practice of human activities (Egoh et al., 2011; Grobler et al., 2006). Grobler et al. (2006) has described that while grasslands host a large amount of flora and fauna species and overall high levels of biodiversity, studies have shown the extensive fragmentation of grasslands are due to the increased effects of urbanisation on the environment. Biggs et al. (2008) and Egoh et al. (2011) further reiterate that South Africa's loss of biodiversity has been a consequential result of increase human activities and LULC change; with more to come in the near future.

Although the intensive practice of human activities such as the overgrazing, mining and carrying out unsustainable agricultural farming methods have had a drastic effect on grassland ecosystems, the Tongaat Hulett Company have taken specific measures to maintain a balanced relationship with the surrounding ecology and grasslands. According to Mr Jollands, while the Tongaat Hulett development sector still adheres to the criteria set forth by the ISO14001 organisation, the company has an agreement with surrounding local settlements to allow rural communities to use a small portion of the grasslands on the outskirts of the area to improve their livelihoods by collecting grasses for traditional medical uses or to graze their cattle and other livestock.

6.5.4 Forest and Woodlands

Originally consisting of three subclasses (forest, woodland and wooded grasslands) in the land cover class suggested by Thompson (1996), this study has however combined all three of these subclasses into a single land cover class of 'Forest and Woodland'. Covering an extent of 108.67 ha (21.50%) for the year 2006 (Table 6D), the forest and woodland class is seen as a prevailing land cover class, as evident from the land cover maps generated for 2006 (Figure 6D). However, by the year 2012 the recorded spatial extent of the forest and woodland land cover class had decreased by approximately 53.21 ha (10.53%) resulting in a new extent of 55.46 ha (10.97%) (Table 6D). This change of a significantly reduced forest and woodland land cover class is clearly observed when comparing the 2006 (Figure 6D) and 2012 (Figure 6E) land cover maps to each other.

Being one of the most notably changed land cover classes, this transformation could be seen as a consequence of the largely increased urban land cover class. This can be proved by the illustrations in the 2012 land cover map (Figure 6E), which shows how forest and woodland areas have been cleared and converted into urban land cover, especially within the southern and northern parts of the study area.

With a large portion of biodiversity located within forests and woodlands, their preservation and conservation is quickly becoming more important with the growing demand for space to expand urban areas (Desclée et al., 2006; Olang and Kundu, 2011; Pearson et al., 2013). According to authors Biggs et al. (2008), the region of southern Africa is expected to experience extensive loss of biodiversity as a result of increasing urban development. Should urbanisation continue to expand into areas of forest, woodlands and even that of grasslands at its current exponential rate, the effects on the biodiversity and surrounding ecological areas will be widespread.

6.5.5 Cultivated Lands

With land that was previously utilised for the purpose of commercial sugarcane production, the Tongaat Hulett Company and their development sector have managed to maintain a substantial portion of this land use while expanding the urban landscape. The cultivated land cover class in this study refers to land that is still being used for the farming o sugarcane for commercial purposes. Although the cultivated land cover class reported a 74.91 ha (14.81%) extent in 2006 (Table 6D), there was a sharp decline of 55.90 ha (11.06%) by the year 2012 (Table 6D). With the extent of the cultivated land cover class standing at 19.01 ha (3.76%) in 2012, it is clear that this decline experienced in this land cover is due to the expansion of the urban landscape.

According to the two generated land cover maps (Figure 6D and Figure 6E), it is evident that majority of the cultivated land cover class has been converted into either grassland or urban land cover types. This conversion can be viewed as a process of preparation to transform this land into an urbanised area. Further proved by site visits conducted on the 26th and 27th of July 2015 and Google Earth imagery, most of this previously cultivated land has indeed been changed to urban features.

With most of its previous extent being occupied by the urban land cover class at present, the importance of sugarcane production is still adhered to by the Tongaat Hulett Company. For provinces such as KwaZulu – Natal and Mpumalanga, the production of sugarcane has been a long standing contributor to the South African economy and a source of income for those employed to farm the land (Maloa, 2011). Mr Jollands stated during his interview that the Tongaat Hulett Company and its development sector have taken the proper precautions to ensure that a specific amount of the sugarcane land will always remain unaffected and untouched by the expansion of the urban landscapes and its associated features.

6.5.6 Barren

With land types such as degraded lands, bare rock, soil and beach sands under the barren land cover class, the land cover type comprised approximately 59.54 ha (11.78%) of the total land cover of the study area in 2006 (Table 6D). However, by the year 2012 there was a minor decline of 2.29 ha (0.46%) in the barren land cover class, resulting in a 57.25 ha (11.32%) land cover extent (Table 6D).

Looking at the northern areas of both land cover maps (Figure 6D and Figure 6E), it is evident that most of the barren lands in this study area have been transformed and now consist of urban features and transport networks. On the other hand, some of the cultivated and grasslands depicted in the central region of the 2006 land cover map (Table 6D) also changed into barren lands. This could have been due to the extensive practice of human activities which have in turn resulted in widespread erosion and degradation of the soils (Egoh et al., 2011; Grobler et al., 2006; Smith et al., 2010).

While land degradation is seen as a global ecological issue which depletes the availability of organic soils, it also depreciates the available soil's productivity level for farming (Dlamini et al., 2014; Egoh et al., 2011; Smith et al., 2010). Being one of the leading reasons behind that competition for land, the increased occurrence of barren lands has restricted that amount of arable land that is available for commercial and subsistence farming and food production (Grobler et al., 2006; Smith et al., 2010).

Table 6D: *A summary of the land coverage and the percentage of the derived land cover classes for 2006 and 2012*

	2006		2012		Change (2012 - 2006)	
Class	**Area (ha)**	**Percent (%)**	**Area (ha)**	**Percent (%)**	**Area (ha)**	**Percent (%)**
Urban	30.22	5.98	69.99	13.85	39.77	7.87
Transport	126.23	24.47	201.41	39.84	75.18	15.37
Grassland	105.98	20.96	102.43	20.26	-3.55	-0.7
Forest and Woodland	108.67	21.5	55.46	10.97	-53.21	-10.53
Cultivated Land	74.91	14.81	19.01	3.76	-55.9	-11.05
Barren Land	59.54	11.78	57.25	11.32	-2.29	-0.46
Total	505.55	100	505.55	100		

6.6 Change Detection Patterns

The aim of implementing a CD is to aid in the understanding of the extent of change that has occurred in the study area in question between two positions of time, be it a long or short period (Gibson et al., 2013; Harris, 2003; Lillesand et al., 2014; Lillesand et al., 2008; Liu et al., 2005). Utilising an ID method, CD analysis was conducted on the classified images of 2006 and 2012. The applied CD process generated a map (Figure 6F) illustrating the changes that have occurred between the years of 2006 and 2012.

According to the map (Figure 6F), the sections indicated in red show areas that have experienced a decrease in the cover while areas in the light green depict areas that have experienced change during the time period of 2006 to 2012. On the other hand, regions that are dark green in colour show areas that have experienced no major transformations during the specified time period (Figure 6F).

In addition to the above, a detailed per-pixel result of the applied CD process (Table 6E) was provided. According to Table 6E, the CD process yielded an 8.80% (155725 pixels) decreased change of the pixels within the study area while 30.20% (536537 pixels) of pixels showed a significantly increased change between the years of 2006 and 2012. Furthermore, 61.0% (1084677 pixels) of the pixels depicted in this study area showed no change or transformation of any kind (Table 6E). Meanwhile, no pixels experienced partial changes or even an uncertainty during the CD process.

Table 6E: *The CD results (per pixel) for the LULC change between 2006 and 2012*

Change Type	Pixels	Percentage
Unchanged	1084677	61.0%
Decreased	155725	8.80%
Increased	536537	30.20%
Uncertain/ Some increase or Some decrease	0	0
Total Pixels	1776939	

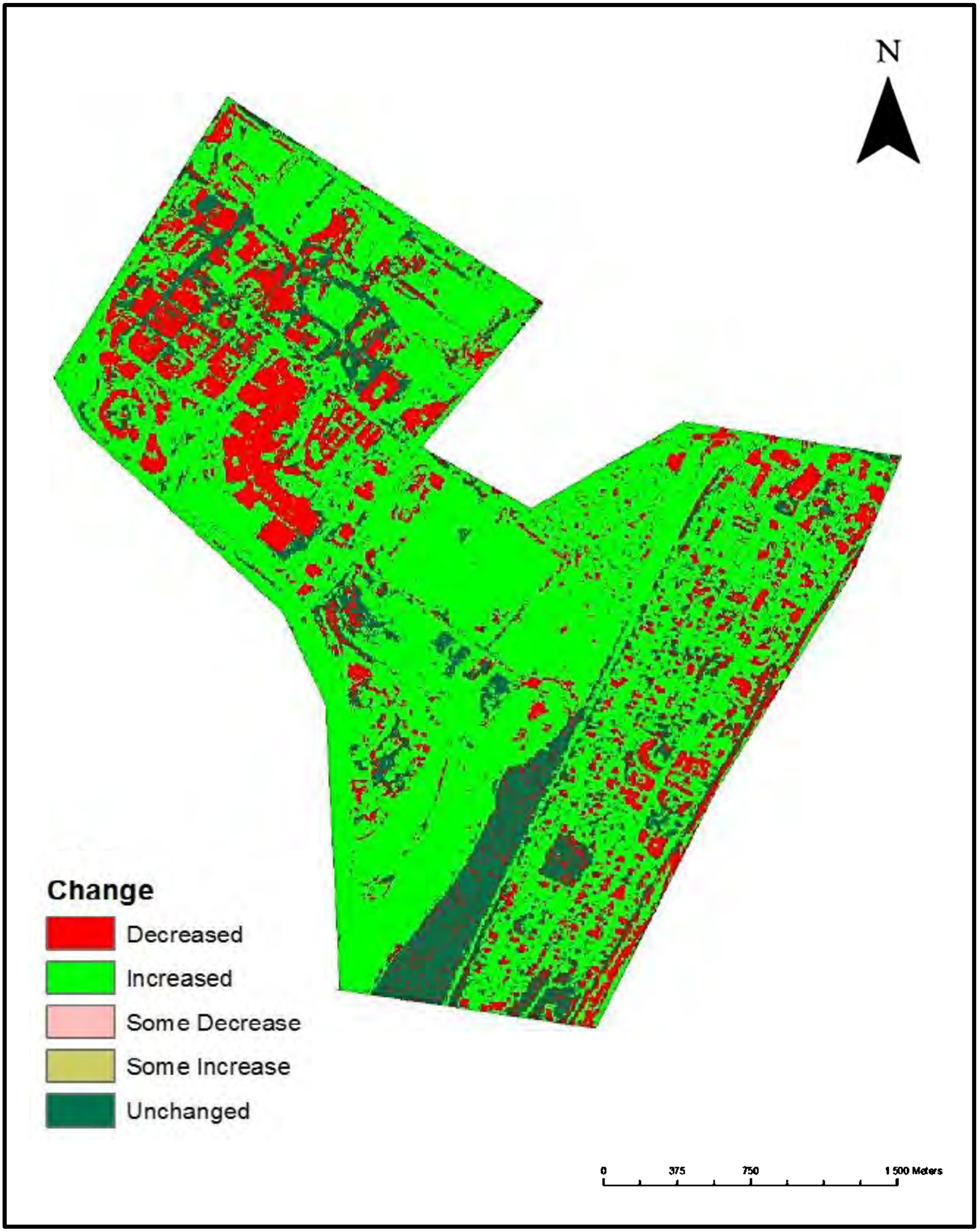

Figure 6F: *A land cover map illustrating the change of land covers in the study area between the years 2006 and 2012*

6.7 Socio-economic Implications

Part of what is meant to make this specific study different from others is that this study is also able to include the socio – economic implications that the changes experienced in Umhlanga Ridge have had on the Umhlanga community and its environment.

One of the most prominent ways in which the socio – economic implications of the LULC changes in Umhlanga Ridge is the increased number of employment opportunities. In the transformation of Umhlanga's land use and the creation of the URTC, all of the interviewees echoed the point that increasing opportunities of employment was a key objective. In addition to the increased employment opportunities in Umhlanga, it must be considered that people from all over South Africa are considering these job opportunities and at the same time, looking for places to stay in close proximity to their place of work. This then persuades workers to find a residence as close as possible to Umhlanga.

The immense LULC transformation of Umhlanga and its node of development (the URTC) have played a key role in attracting local and international investors. According to Mr Jollands and Mr Wilkinson, the aesthetically pleasing position and easy accessibility of Umhlanga has greatly influenced Durban as an ideal investment destination. Furthermore, Mr Wilkinson adds that international investors have also taken the opportunity to invest in Umhlanga's residential estates, which has resulted in a significant boost in Umhlanga's property value since the early 2000's.

Another important socio – economic implication highlighted by Ms Petersen during her interview was the fact that with the improvement of efficiency and the infrastructure in Umhlanga, there has been a positive contribution to the municipal rates revenues. This then proves that the KwaZulu – Natal provincial economy and South African national economy attains a significantly increased overall income from this rates change.

Ms Petersen stipulates that apart from the above mentioned factors of socio – economic implications, Umhlanga and the suburban area of the URTC also focuses on promoting social interactions as people are able to fulfil more of their needs in their local area with a variety of activities. She further notes that the URTC prides itself on the idea of reducing travelling distances and the concept of a 'Linked Trip', whereby one trip is used to undertake many activities, in turn making it more convenient for people and businesses to save time and money.

In conjunction to the above mentioned point, Ms Petersen sheds light on the Integrated Rapid Public Transport Network (IRPTN), which is a set of transport networks that will connect Isipingo, the Durban Port to Dube Trade Port and King Shaka International Airport through Umhlanga Ridge. The IRPTN project aims at looking ways to ease roadway congestion, air pollution and to also improve and encourage the use of public transport and in turn reduce the dependency on the use of private motor vehicles.

The inclusion of public opinions is a matter held with high regard at both the Tongaat Hulett Company and its development sector. During an interview, Ms Petersen thoroughly described the process of how the public are able to voice their opinions. According to what Ms Petersen said, the public and current residents are notified of any planned development during the Environmental Impact Assessment (EIA) process. Furthermore, it was added that notices are placed at the site, in newspapers and letters are sent to neighbouring residents to the proposed site. Thereafter the public are given thirty days to comment on the pending development and those comments are passed on to the project team allocated to the development in order to mitigate the issue as best they can.

Mr Wilkinson reiterated this above mentioned point and added that while most of the transformation ideas were generally accepted by majority of the public, the community of Prestondale were not open to the ideas of change and remained against it. However, thoroughly discussions with the Prestondale community members, the reasoning, benefits and overall value of the planned transformations were approved and accepted.

6.8 Future Changes for Umhlanga and Umhlanga Ridge

In addition to the above analysis, this study also aimed to highlight the future plans and changes of Umhlanga and Umhlanga Ridge. During the interviews, each of the participants were questioned about the future developments planned for this area and all were able to reaffirm the notion that Umhlanga's LULC will definitely continue to change and transform in the years to come. According to each interviewee, the URTC, Izinga, the Cornubia Park and Ridgeside are all existing developments within Umhlanga; however, with regards to the future developments of this area, all the interviewees echoed the fact that each of these current developments will be expanded.

While work on these expansions will commence in a timely manner, Ms Petersen has assured that each of the development projects will cater residential, commercial and business park land uses and be able to meet the needs of the public who utilise the area. While the URTC is still developing its residential area, Mr Wilkinson has stipulated that after the completion of the residential area, the URTC will be highly accomplished in terms of its developments and aim of creating a region of mixed land uses. Although the

Izinga precincts first phase of construction has already been completed, the second and final phase of its development will ensure a significant expansion of the currently implemented mixed land use design.

Similarly, while the development of the Cornubia Park has just begun, future development phases have been created, approved and will start construction soon after the first phase has been completed. According to the details of the Ridgeside development posted on the Tongaat Hulett Development sectors website, this specific precinct contains four development phases which provides a link between Umhlanga Ridge and the Umhlanga Rocks Village (Tongaat Hulett Development, 2014). Reiterated by Ms Petersen, it was stated that other sub-precincts will emerge within the Ridgeside Park in order to effectively uphold to its mixed land use criteria and reduced the use of private motor vehicles.

6.9 Summary

Provided in this chapter were the results (in the form of maps, tables and figures) for this particular study, along with a detailed analysis of the generated results. Utilising the results produced from each tested algorithm, the ML classifier was found to be the most suitable and accurate classifier for this study. The ML classifier was therefore used to classify the 2006 and 2012 remotely sensed images acquired from SANSA. The mapped results and the associated accuracy assessment results were then reported with the 2006 image (Figure 6D) yielding an OA of 83.87% (Table 6D) and the 2012 image (Figure 6E) producing an OA of 85.29% (Table 6D).

One of the most obvious transitions from the produced land cover maps (Figure 6D and Figure 6E), the land cover extent statistics (Table 6D), the CD processes map (Figure 6F) and the CD statistical results (Table 6E), was that the urban and transport land cover classes experienced the most significant LULC expansion. Furthermore, the grassland, cultivated, barren and forest and woodland land cover class depicted decreases in their special extents.

Lastly, with regards to the socio – economic implications experienced in Umhlanga, aspects such as bringing increased revenue to the South African economy, attracting international investors, providing a significant amount of job opportunities, Umhlanga and its nodes of urban development have actively promoted a sense of place and community while still being able to encourage economic investment.

Chapter Seven: Conclusions, Limitations and Recommendations

7.1 Introduction

This chapter focuses on reporting the general conclusions identified from this research endeavour. This chapter will also highlight the limitations that were experienced while conducting this research and suggest suitable recommendations that can be utilised in order to further or extend the study.

7.2 General Conclusions

In order to evaluate the LULC change that has taken place in the suburban area of Umhlanga Ridge (eThekwini Municipality), SPOT 5 images were attained, classified and analysed. LULC information is gradually becoming a necessity when attempting to observe and monitor the trends and patterns of different types of cover in a specific area (Lambin et al., 2003; Meyer and Turner, 1994). Especially with LULC changes occurring at such a rapid and unprecedented rate, remote sensing has the ability to provide extensive detail to LULC information and aid in the overall transformation of one land cover type to another (Geist and Lambin, 2002; Meyer and Turner, 1994; Meyfroidt et al., 2013). From previously conducted studies in this specific field, remote sensing has the unique capability to monitor LULC changes over multiple temporal scales (Blaschke, 2010; Lillesand et al., 2014; Lillesand et al., 2008).

From the evidence generated from this research within the time period of 2006 to 2012, it is clear that the area in question has changed substantially. According to the results yielded from this stud, the urban land cover class increased by 7.87% between the years of 2006 and 2012. While these rates of urban expansion have both long and short term impacts on the environment, its expansion has managed to infringe on other land cover classes, as seen from the land cover maps generated in Chapter six (Figure 6D and Figure 6E).

Another land cover class which experienced a significant expansion was that of the transport network class. Reporting an increase of approximately 15.37%, it can be stipulated that as urban landscapes and features continue to expand, the demand for types of transport networks will also increase in order to accommodate the users and residents of the area (Coffin, 2007; Liu et al., 2005; Nevhutanda, 2007). With a clear and direct relationship between the classes of urban and transport, it becomes important to adhere to the principles of SD in order to mitigate the extent of the damages affecting the environment and all associated resources (Manandhar et al., 2009). One of the most profound challenges of the modern world is the growing need to ensure that sustainable methods are utilised when developing a community or country; socially and economically.

For many years and through many generations, the dominant agricultural activity in cultivated lands has been the production of sugarcane for commercial uses. Further influenced by the favourable weather conditions in the city of Durban and in the suburban development of Umhlanga Ridge, the area became known as one of the leading cultivators of the crop within KwaZulu – Natal (Tongaat Hulett Development, 2011; Tongaat Hulett Sugar, 2014). However, due to the expansion of the urban and grassland land cover classes, the once prominent land cover class of cultivated land suffered a significant decrease of approximately 11.05% in its spatial extent.

With the immense responsibility to house and maintain the overall biodiversity of the study area, the forest and woodland and grassland land cover classes both experienced a substantial decrease in their extents within the time period of six years. From the results produced in the previous chapter, the forest and woodland land cover class yielded a 10.53% decrease in its spatial extent while the grassland land cover class reported an 11.05% reduction in its land cover extent. By the year 2012, it was evident that the encroachment of the urban landscape on both of these land cover classes has led to a highly stressed biodiversity and overall ecological organisms.

Although, the barren land cover class underwent a minor decrease of approximately 0.46% by the year 2012, it has been stipulated that as the expansion of the urban landscape continues at an unprecedented rate, land degradation will subsequently increase, thus resulting in bare soil surfaces which could lead extensive soil erosion and eventually the inability to use that land (Egoh et al., 2011; Grobler et al., 2006; Smith et al., 2010). However, while the size of the barren land cover class is to remain high for a number of years to come, rapid urban development has the potential to affect this class even more.

In addition to the above, the classification and analysis of land cover maps for the years 2006 and 2012 also highlighted the socio – economic implications experienced due to the rapid LULC change. Apart from extensive research, interviews were conducted with four members of the Tongaat Hulett Development sector, in order to further discuss Umhlanga's LULC transformation and the associated socio – economic implications.

Overall, the interviews showed that the main driving force behind Umhlanga's LULC transformation was a vast number of employment opportunities, especially to previously disadvantaged people. In addition, the creation of Umhlanga as a tourism attraction has led to the increase in international business and property investors visiting the growing suburban area. Similarly, the Tongaat Hulett Development sector highlights that being an ISO 14001 participant, the company strives to adhere to SD principles when transforming and improving the area. By the planting of more trees, protecting and maintaining open spaces of naturally occurring environments and by also introducing the IRPTN project among other examples, the Tongaat Hulett Company and Development sector make it a necessity that all developments is conducted in a sustainable manner.

7.3 Limitations

7.3.1 Classifier algorithm limitations

The ML classifier was identified as the most accurate algorithm to classify the remotely sensed data. Even though this selected classifier was able to successfully define the six land cover classes within the study area, upon conducting an analysis it was discovered that the classification did show minor disparities as it underestimated the urban land cover class in the 2012 image. This underestimation – although small – has the potential to skew the statistics generated from the classification. As noted in the previous chapter, one of the ways in which to correct this issue would be to use a more efficient and intricate algorithm that is specifically utilised in the local scale urban mapping.

According to Otukei and Blaschke (2010) and Paola and Schowengerdt (1995), the use of advanced non – parametric classification algorithms are highly effective when detecting land cover patterns within complex environments. Further reiterated by Weng (2011), non – parametric classifiers such as the Artificial Neural Networks (ANN), the Decision Tree Classifier (DTC) and the Support Vector Machines (SVM) can be utilised to improve research such as this, to overcome some of the noted limitations and drawbacks.

7.3.2 Lack of historical remotely sensed data

For the purpose of this research, remotely sensed data from high resolution sources were needed in order to accurately classify and map the multifaceted landscape of the Umhlanga Ridge area. As mentioned earlier, this research endeavour would have preferred to attain data from earlier years, however that data was either of an extremely low resolution or not available. Landsat 5 TM imagery was available from sources such as SANSA and also the USGS archives but due to the low spatial resolution of these images, the integrity, accuracy and overall results of the study would have been compromised. It was soon realised that higher resolution multispectral imagery was needed to classify the amount of details within this study area.

7.3.3 Limitations of the interview process

In order to supplement this study, interviews with members of the Tongaat Hulett Development sector were conducted using a Snowball sampling method. One of the most profound limitations experienced during this process was the fact that although more than ten members were approached to be interviewed, only four participants were interested in partaking in the study.

After having each interviewee agree and sign a consent form, problems regarding the availability for a face-to-face interview became evident. As a result, the interviews were able to be conducted through the means of a telephone call or email. Mr Mnguni and Mr Jollands participated in a telephonic interview, while Ms Petersen and Mr Wilkinson emailed in their answers.

Another limitation which was experienced with the telephone interviews was that the interviewees tended to be distracted by their environments and other activities (McCoyd and Kerson, 2006; Novick, 2008; Opdenakker, 2006). Similar to that of the telephone interviews, the email interviews can be considered a more modern and efficient form of attaining information from a source; however, there were flaws experienced in this process as well.

Although emailing a list of questions to the interviewee allowed the participants to compile reasonable and logical answers to the questions, the process of emailing the questions allowed the participant to forget about the questions, thus needing a follow up email from the interviewer. This can be misconstrued and found to be bothersome to the interviewee, who thereafter becomes reluctant to participate in the study (McCoyd and Kerson, 2006).

In addition to the above, a significant limitation experienced during the interview process was being able to accurately determine the future changes of Umhlanga Ridge. Although the interviewees were able to provide a detailed and thorough outline of the upcoming developmental changes for Umhlanga and Umhlanga Ridge, it must be questioned whether the interviewee’s description can be considered scientifically accurate and valid.

7.3.4 Change detection limitations

A significantly restricting element of this research endeavour was with regards to the CD process. Utilising the ERDAS Imagine software, the only available technique for CD was the ID method. Although this method is considered to be the easiest to work with, this technique only has the ability to find binary changes (i.e. Whether there has been change or no change) occurring within the two time periods. Furthermore, this limitation prevented a detailed CD matrix from being produced, which would have been able to detect the exact nature and extent of the change.

7.4 Recommendations

Based on the above factors that have limited this research, this section provides some recommendations that can be implemented in order to improve this thesis.

7.4.1 Improve the spatial resolution

This study utilised SPOT 5 satellite imagery with a spatial resolution of twenty metres. However, the results of this study can be greatly improved by using higher spatial resolution remote sensing imagery. Attaining data from the TerraSAR X satellite, which has a spatial resolution of up to one metre, will allow for greater map detail in the landscape of the area.

7.4.2 Models to determine/ predict future LULC transformations

As mention earlier, although the interviewee's verbal confirmation of developmental changes in Umhlanga and Umhlanga Ridge is valid, it cannot provide the scientific accuracy and precision of the changes. However, as highlighted in an article by Veldkamp and Lambin (2001), the utilisation of prediction modelling in LULC transformation studies has the potential to enhance our understanding of the driving forces that are responsible for LULC change so that preventative measures can be taken and to provide alternative pathways of knowledge, accuracy and validity to future transformations. One of the most commonly suggested models utilised when predicting future patterns of LULC changes is that of the CA-Markov Model (Nouri et al., 2014).

7.4.3 Longer time periods

As mentioned before, this study was initially meant to analyse imagery from as far back as the year 1995 till the year 2014, however, access to this data was unfortunately not possible due to the lack of suitable archived data from sources such as SANSA and the USGS Earth Explorer. For this reason, an appropriate recommendation would be to search the archives of other sources, such as the National Aeronautics and Space Administration (NASA) Socioeconomic Data and Applications Centre (SEDAC).

7.4.4 Other CD techniques

Due to the severe lack of access to other types of CD techniques, the ID method was utilised. Therefore, it is recommended that other more efficient CD techniques such as the CVA technique, can be employed in order to generate a more detailed analysis of the areas documented change.

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Appendix

Appendix 1: Below is a copy of the consent form which was sent to and signed by each of the interviewees, prior to conducting the interview.

UNIVERSITY OF KWAZULU-NATAL
COLLEGE OF AGRICULTURE, ENGINEERING AND SCIENCE
SCHOOL OF AGRICULTURAL EARTH & ENVIRONMENTAL SCIENCE

Consent to Participate in Masters Research Project

To whom it may concern

I, Nadira Kercival, am currently registered to complete a Masters degree at the University of KwaZulu-Natal (School of Agriculture, Earth and environmental science). The topic for this research assignment is, "A land change detection analysis of Umhlanga Ridge and the associated socio-economic implications of the noted changes".

The objectives of the research are:

- To identify the dominant land use and land cover changes that have occurred though time (1995, 2000, 2005, 2010 and 2014) in Umhlanga Ridge.
- To evaluate the extent of the changes that has taken place in Umhlanga Ridge.
- To determine the future changes of Umhlanga Ridge.
- To examine the socio - economic implications of these changes in Umhlanga Ridge.

Your assistance as a key informant is kindly requested in the answering of a questionnaire which will assist in gathering the relevant data required to conduct this research project.
Answering of this questionnaire will take approximately 15 - 20 minutes of your time.

Please note that your participation in this study is undertaken with the understanding that:

1. All information provided will be treated with the strictest confidence.
2. Your participation is voluntary and you have the right to choose NOT to participate in the survey at any point.
3. All information that you provide will be used for research purposes only.
4. Please feel free to raise questions should you require more information on these questions.
5. The data obtained from this exercise will be stored with the research supervisor and or researcher in a secure location at the University of KwaZulu-Natal for a period of five (5) years, after which it will be shredded.
6. Should you have any further queries regarding this survey, or if you would like more information regarding the research topic, please contact myself, Nadira Kercival, on nadirakercival@gmail.com or my research supervisor, Dr Michael Gebreslasie, on Gebreslasie@ukzn.ac.za .

Please feel free to contribute any other vital information you deem significant to this research assignment. Your contribution to this research endeavour is extremely valued.

Thank you for your time and consideration.

Sincerely
Nadira Kercival

Declaration

I…………………………………………………………………………………… (Full name of key informant) hereby confirm that I understand the contents of this document and the nature of the research project and I consent to participating as a key informant in the research project. Furthermore, I understand that I am at liberty to withdraw from the project at any time, should I so desire.

Signature of Key Informant ……………………………………………

Date

Appendix 2: The following document is the transcript of the interview conducted with Mr Mnguni.

Questionnaire

1. **Please state your full name and position at the Tongaat Hulett Company.**
   Andile Mnguni
   Development Executive
2. **How long have you been involved with the growth of the development in Umhlanga?**
   Since 2011 in Umhlanga Ridge Town Centre
3. **Comment on the initial idea behind starting the land use transformation of the greater Umhlanga area (from being an area of agricultural land to a hub of urban development)?**
   Transformation and value creation for stakeholders
4. **How was the introduction of the Umhlanga Ridge New Town Centre included in this transformation?**
   Strategic position
5. **Why was a mixed land use design utilised in the transformation of Umhlanga Ridge?**
   Lifestyle and environmental considerations. Live, work, play, study and be at leisure.
6. **How has implementing a mixed land use design influenced the residential and commercial patronage of the area?**
   Positive influence and property values grew
7. **What socio-economic implications have occurred due to the on-going land use transformation in Umhlanga Ridge?**
   Employment opportunities
   Huge rates base for municipality
   Traffic increased.
8. **Would you say that the overall socio-economic status of Umhlanga Ridge and its current residents have been positively influenced by the land use transformations and developments in the area? If so, state how?**
   Yes, see earlier comment
9. **Are the public and the current residents allowed to be actively involved in the transformation and development of Umhlanga Ridge? If so, how are they able participate?**
   Yes, through public meetings and stakeholder engagement discusions
10. **Please state some of the concerns that were experienced during the land change process? (ie. was this transformation welcomed by the public?) If so, how has the Tongaat Hulett Development sector been able to solve these mentioned issues?**
    Crime concern, Development of security companies was used to address this
    Traffic concerns, roads upgrades were implemented
    Noise concerns, EMP [Environmental Management Plans] was put in plan
11. **In an age of climate change awareness and environmental conservation, how has the Tongaat Hulett development's been able to maintain a level of environmental sustainability with its surrounding natural environment?**
    We are an ISO14001 company and support environmental sustainability

12. What are some of the development projects that are currently taking place in Umhlanga Ridge?
    Ridgeside
    Izinga
13. What are some of the future developments or expected transformations that will be taking place in Umhlanga Ridge?
    Future phases of the above
14. In your opinion, is there anything regarding the process of transformation and development that could have been improved upon or conducted differently?
    No

Thank you for contributing to this research endeavour!

Appendix 3: The following document is the transcript of the interview conducted with Ms Petersen

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Questionnaire

1. **Please state your full name and position at the Tongaat Hulett Company.**
   Karen Petersen – Developments Director at Tongaat Hulett Developments.
2. **How long have you been involved with the growth of the development in Umhlanga?**
   For the past 8 years (Since 2007)
3. **Comment on the initial idea behind starting the land use transformation of the greater Umhlanga area (from being an area of agricultural land to a hub of urban development)?**
   Firstly, urban development and the increase in the population of people migrating to the city led to the expansion of the city towards the north where most of the land was owned by Tongaat Hulett. Secondly, the land values achieved through land conversion was deemed to be more profitable than if under active sugarcane cultivation. Therefore on the right landholdings, at the right time, and for the highest and best use, converting land from agriculture into urban development was feasible for the company.
4. **How was the introduction of the Umhlanga Ridge New Town Centre included in this transformation?**
   The increase in demand for more residential development in Umhlanga and the need for people to work and shop close to their residences led to the introduction of the Umhlanga Ridge New Town Centre.
5. **Why was a mixed land use design utilised in the transformation of Umhlanga Ridge?**
   The idea of integrating different land uses was a way of mitigating the high travelling cost and traffic congestion that resulted from people working in the north and residing in neighbouring communities. The traffic is now distributed rather than it being congested coming into Umhlanga in the morning and moving towards the city in the evening.
6. **How has implementing a mixed land use design influenced the residential and commercial patronage of the area?**
   The mixed use design has provided investors with an opportunity to expand their businesses and/or invest in an area where people work and reside. It has enhanced the economic vitality of commercial spaces and the perceived security of the area. It also has provided and encouraged more housing opportunities and choice.
7. **What socio-economic implications have occurred due to the on-going land use transformation in Umhlanga Ridge?**
   It has increased employment opportunities in Durban. It promotes efficient land uses and infrastructure thus contributing positively to the municipal rates revenues. The area promotes social interactions as people are able to fulfil more of their needs in their local area with a variety of activities. The introduction of the Integrated Rapid Public Transport Network (IRPTN) that will connect Isipingo, the Durban Port to Dube Trade Port and King Shaka International Airport through Umhlanga Ridge will improve public transportation reducing auto dependency, roadway congestion and air pollution.

8. **Would you say that the overall socio-economic status of Umhlanga Ridge and its current residents have been positively influenced by the land use transformations and developments in the area? If so, state how?**
   Yes it has. It has reduced travelling distances and has enabled linked trip where one trip is used to undertake many activities making it convenient for people and businesses, saving money and time. It enhances the area's unique identity and development potential thus promoting a sense of place and community, encouraging economic investment.
9. **Are the public and the current residents allowed to be actively involved in the transformation and development of Umhlanga Ridge? If so, how are they able participate?**
   Yes they are. The public and current residents are notified of any planned development during the Environmental Impact Assessment and the PDA processes. Notices are placed onsite and on newspapers and letters are sent to neighbouring residents to the proposed site. The public is then given 30 days to comment on the development. Those comments are then given to the project team to mitigate as best as they can any public concerns.
10. **Please state some of the concerns that were experienced during the land change process? (ie. was this transformation welcomed by the public?) If so, how has the Tongaat Hulett Development sector been able to solve these mentioned issues?**
    People in general are sceptical of change and tend to question the impact that potential development would have on current investment. We find ways of mitigating their concerns and also assure them of how the planned development complements and enhances the current developments.
11. **In an age of climate change awareness and environmental conservation, how has the Tongaat Hulett development's been able to maintain a level of environmental sustainability with its surrounding natural environment?**
    As a company, we take it upon ourselves to make sure that the environment is conserved. Forests and wetland areas are rehabilitated and protected with alien plans removed by the company. Some of our developments have wild animals e.g Mount Edgecombe Estate. We also adhered to environmental laws by protecting wetlands and buffer zones and replanting where necessary. We plant trees along sidewalks and open spaces as a way of mitigation.
12. **What are some of the development projects that are currently taking place in Umhlanga Ridge?**
    We have Izinga, Umhlanga Ridge Town Centre, Umhlanga Ridge Town Centre Western Expansion (Cornubia New Town), and Ridgeside. These development projects cater for residential, commercial and business park land uses
13. **What are some of the future developments or expected transformations that will be taking place in Umhlanga Ridge?**
    Izinga (future phases), the balance of Cornubia and other precincts within Ridgeside.

14. In your opinion, is there anything regarding the process of transformation and development that could have been improved upon or conducted differently?
The inclusion of more schools in the area as the population increases and other social facilities.

Thank you for contributing to this research endeavour!

Appendix 4: The following document is the transcript of the interview conducted with Mr Jollands.

Questionnaire

1. **Please state your full name and position at the Tongaat Hulett Company.**
   David Jollands – Director of the Tongaat Hulett Development's sector
2. **How long have you been involved with the growth of the development in Umhlanga?**
   From about 2008
3. **Comment on the initial idea behind starting the land use transformation of the greater Umhlanga area (from being an area of agricultural land to a hub of urban development)?**
   Although the company owned majority of the land, putting that land to use and keeping aside a smaller yet still profitable portion of sugarcane property, meant an influx in profits for the Tongaat Huletts Company. Also, the need to create more opportunities of employment was very important.
4. **How was the introduction of the Umhlanga Ridge New Town Centre included in this transformation?**
   The Umhlanga Ridge New Town Centre was a point of development that also served as a node of integration between the urban and the surrounding environment. The centre was also meant to accommodate the residents and provide attractions to holiday – makers.
5. **Why was a mixed land use design utilised in the transformation of Umhlanga Ridge?**
   The need to introduce an area that incorporated the principles of sustainable development was important. This design allowed for the combination of the surrounding environment and the urban development of Umhlanga to occur sustainably. It also allowed for the reduction in the use of private transportation within the area.
6. **How has implementing a mixed land use design influenced the residential and commercial patronage of the area?**
   All kinds of people come to Umhlanga. People come here for personal (residents), business and leisure (holiday – makers) reasons. There has definitely been a complete change and this is especially due to the fact that Umhlanga is an ideal location for all kinds of development, while still being aesthetically pleasing on the eye.
7. **What socio-economic implications have occurred due to the on-going land use transformation in Umhlanga Ridge?**
   Increased job opportunities and overall economic improvements for the area.
8. **Would you say that the overall socio-economic status of Umhlanga Ridge and its current residents have been positively influenced by the land use transformations and developments in the area? If so, state how?**
   Yes, the convenience and close proximity to stores, businesses and residential areas is one of the most highlighted points that come across from the members of the public. People are very open to the idea of living a sustainable lifestyle when provided with the means to do so.

9. **Are the public and the current residents allowed to be actively involved in the transformation and development of Umhlanga Ridge? If so, how are they able participate?**
   Yes, there are scheduled public meetings when issues with regards to the surrounding developments in the area. There are also strategic processes put in place to ensure that all problems and concerns are voiced and dealt with in the best way possible.

10. **Please state some of the concerns that were experienced during the land change process? (ie. was this transformation welcomed by the public?) If so, how has the Tongaat Hulett Development sector been able to solve these mentioned issues?**
    Change will always have some sort of challenges, especially when the area that people live in are going to be changed and or compromised in some way. However, the Tongaat Hulett Company tries to make sure that all developments will be beneficial to the public and that any concerns that they have will be taken into consideration.

11. **In an age of climate change awareness and environmental conservation, how has the Tongaat Hulett development's been able to maintain a level of environmental sustainability with its surrounding natural environment?**
    We adhere to the ISO14001 organisation criteria but we also have relaxed accords with the surrounding low cost areas to utilise the land on the outskirts for their own means while making sure to keep their practices sustainable.

12. **What are some of the development projects that are currently taking place in Umhlanga Ridge?**
    An expansion of the Umhlanga Ridge Town Centre is currently taking place

13. **What are some of the future developments or expected transformations that will be taking place in Umhlanga Ridge?**
    the development of the Cornubia Park will be one of the first initiatives to begin next year, while other already created areas will be expanded or, as we call it, in its future phases.

14. **In your opinion, is there anything regarding the process of transformation and development that could have been improved upon or conducted differently?**
    Certainly the inclusion of more schools in the area and maybe an alternative manner of implementing more efficient public transportation systems.

Thank you for contributing to this research endeavour!

Appendix 5: The following document is the transcript of the interview conducted with Mr Wilkinson.

Questionnaire

1. **Please state your full name and position at the Tongaat Hulett Company.**
   Rory Edward Wilkinson – Planning Director

2. **How long have you been involved with the growth of the development in Umhlanga?**
   Since I joined Tongaat Hulett Developments in 1998 – ie 17 years

3. **Comment on the initial idea behind starting the land use transformation of the greater Umhlanga area (from being an area of agricultural land to a hub of urban development)?**
   Initial idea came out of the Tongaat Hulett Planning Forum in the late 1980s where the need to look at addressing the spatial forms of the apartheid city was recognized. The sugar cane land between the coast and the inland R102 corridor was essentially a 'buffer strip' which, due to the single landownership, was able to be planned in a holistic and integrated manner and in a manner which could have the biggest impact on the region. The dire need was to create new economic and employment opportunities in the north due to the fact that the majority of the city population resided to the north but the jobs were all in the south – large and costly and inefficient travelling patterns….as well as spatially integrating the disparate and isolated settlements in the north

4. **How was the introduction of the Umhlanga Ridge New Town Centre included in this transformation?**
   The URTC was therefore seen as a fundamental intervention aimed at creating a new economic and employment node in the north and which would be the first component of the spatial integration between the coastal and inland corridors.

5. **Why was a mixed land use design utilised in the transformation of Umhlanga Ridge?**
   The URTC was conceptualized as a mixed use node based on the principles of the New Urbanism (mixed use, urban, high intensity but at a human scale, well defined spatial layout, highly accessible) – the need to create a new compact city form (new at the time) was recognized given the unsustainability of the suburban sprawl and the need to provide a mixed use environment was also based on the need to become more sustainable and more efficient – ie people could live, work and play in the same area – mixing jobs, economic opportunities and residential takes maximum advantage of the infrastructure and creates the appropriate critical mass for economic opportunities and public transport.

6. **How has implementing a mixed land use design influenced the residential and commercial patronage of the area?**
   The URTC was a new and novel concept and we were not sure how the market would respond but the development's location, ease of access as well as the layout and design elements together with the management mechanisms set up resulted in a very positive market response – from both a commercial and residential perspective. There is no doubt that the typology of apartments and smaller units was something that was required in the market together with being close to the emerging and increasing number of employment opportunities in the broader node.

7. **What socio-economic implications have occurred due to the on-going land use transformation in Umhlanga Ridge?**
   There have been many socio economic implications not the least of which has been the provision of thousands of new employment opportunities (including relocations of course), significant quantum of

new rates for the city, many millions of annual new taxes to the fiscus, new economic opportunities but critically providing a new node in close proximity to the surrounding region.

8. **Would you say that the overall socio-economic status of Umhlanga Ridge and its current residents have been positively influenced by the land use transformations and developments in the area? If so, state how?**
Absolutely yes – look at the property values of the area which have risen substantially since the early 2000s. The injection of major new investment created a new economic node that enhanced Durban as an investment destination.

9. **Are the public and the current residents allowed to be actively involved in the transformation and development of Umhlanga Ridge? If so, how are they able participate?**
There is a management association that is the voice of the existing owners but that also provides a vehicle for the public and community to become more involved. Generally however the public/community would only get involved where new development proposals are proposed.

10. **Please state some of the concerns that were experienced during the land change process? (ie. was this transformation welcomed by the public?) If so, how has the Tongaat Hulett Development sector been able to solve these mentioned issues?**
Generally the transformation has been seen as positive with the exception being the Prestondale community who were afraid of the change to their settled and established status quo – but through engagement with them we were able to demonstrate the value add and overall benefit to the region and that infrastructural services would be provided and maintained.

11. **In an age of climate change awareness and environmental conservation, how has the Tongaat Hulett development's been able to maintain a level of environmental sustainability with its surrounding natural environment?**
We are very conscious of the need to plan appropriately from a sustainability perspective which we see as the need to provide for social, economic and environmental requirements in a balanced manner but within a framework of ecological resilience. In this regard we have identified an extensive open space corridor in the north of some 4000 hectares that will be rehabilitated, conserved and managed. Part of this is also the need to increase densities and to create the opportunity for public transportation to limit the role of the motor vehicle.

12. **What are some of the development projects that are currently taking place in Umhlanga Ridge?**
Ridgeside, Izinga, Cornubia, URTC residential precinct

13. **What are some of the future developments or expected transformations that will be taking place in Umhlanga Ridge?**
Once the above have been complete the Umhlanga Ridge will be pretty much developed.

14. **In your opinion, is there anything regarding the process of transformation and development that could have been improved upon or conducted differently?**
Land use transformation is always a difficult and complex process that upsets the status quo and hence there are always challenges. Things can always be done differently and better but in such a complex and ever changing environment I believe that what is emerging is something that we can be proud of. The main missing piece is now a decent and reliable, safe and secure public transport system.

Thank you for contributing to this research endeavour!