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# *The Application and Effectiveness of Remote Sensing and Geographical Information Systems for Mapping and Monitoring Land Use and Land Cover Changes for Development Planning in UMnini Trust Traditional Council, eThekwini Municipality*

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***The Application and Effectiveness of Remote Sensing and Geographical Information Systems for Mapping and Monitoring Land Use and Land Cover Changes for Development Planning in UMnini Trust Traditional Council, eThekwini Municipality***

A short dissertation submitted in partial fulfilment of the requirements for a Master's Degree in Town and Regional Planning (MTRP) from the School of Built Environment and Development Studies, University of KwaZulu Natal

## ABSTRACT

In the second half of the 21st century, developing countries experienced rapid population growth, which tended to settle in peri-urban areas of the cities because of limited spaces in the urban core areas and high urban land values. This movement into the outskirts of the cities has promoted peri-urban densification or urban sprawl/growth where the population become desperate for land and resides in close proximity to railway and road corridors, and environmentally sensitive areas etc. This rapid peri-urban densification decreased the availability of agricultural potential land and created a huge demand for social services delivery from municipalities.

Therefore, municipalities need current and accurate information about trends of growth and development in a specific geographic area to determine the amount of social services need to be provided, which is significant for their development plans. Moreover, for accurate and up-to-date information and trends of growth analysis, South African municipalities rely on the techniques and tools such as aerial photographs and sample surveys, which are often inadequate to provide real time and accurate information on a regular basis, as these techniques collect this kind of information on a yearly basis while the population grows on a daily basis in developing worlds.

The aim of this study was to assess the application and effectiveness of remote sensing (RS) and geographical information systems (GIS) for mapping and monitoring land use and land cover changes (LULCC) trends for development planning in uMnini Trust traditional council between 2001 and 2016. This time period has been chosen to align the study with the 15 years after eThekwini Metropolitan municipality was created in 2000, it was important to monitor and map the extent of growth in peri-urban areas of the metropolitan, which are the result of urban sprawl where people are situated in close proximity to urban core areas in search for economic opportunities.

This study was guided by objectives, which are as follows; to determine the current LULCC planning and assessment processes used by municipality in uMnini Trust traditional council, to critically analyse the extent to which remote sensing and GIS have been used for sustainable land use planning and management; to identify different land use and land cover types found in uMnini Trust traditional council between 2001 and 2016, and analyse/categorise the changes that has occurred during the study period, in order to be able to analyse the rate and magnitude at which the peri-urban densification has been occurring in the study area which has a direct influence over the required infrastructure and social

services. Lastly, to analyse challenges and constraints of using remote sensing and GIS for mapping and monitoring land use and land cover changes in uMnini Trust traditional council.

This study adopted mixed (qualitative and quantitative) research methods. This combination of methods was employed in this study in order to provide a better understanding of research problems than either approach. Cognitive fit theory, sustainable development theory, and unified theory of acceptance and use of technology model were the theoretical bases for this study. Rapid peri-urban densification has contributed to land use changes, and also often led to rapid consumption of green or environmentally sensitive areas. Unregulated growth and development in urban areas has also resulted in the saturation of urban core areas, which increasing demand for land for development at the outskirts of the urban areas.

Cognitive fit theory states that the use of geospatial technologies such as remote sensing and GIS, when the user possess relevant skills and expertise this yield good results that could help to come up with possible solution to assist in decision making process. Sustainable development theory advocates that there should be a development to satisfy the needs for the present generation, however, it must balance triple bottom line which include the social, economic, and environmental protection in ensuring that the needs of the future generations will be met. The unified theory of acceptance and technology model emerged because there was a need for the establishment of advanced technological innovations and application that have positive impacts on human and work life. This encouraged the organizations and governments to adopt the use of information technology in solving complex spatial related problems such as incompatible land uses.

The results of this study revealed that there has been a gradual decline of agricultural potential areas in uMnini Trust traditional council within the study period. Rapid peri-urban densification has contributed and continues to contribute to rapid LULCC in the study area. It has been noted that this growth has implications on the provision of infrastructure and service delivery, as these people are increasing on a weekly or monthly basis which make it difficult for the municiplaity to have real time and accurate information about rate, trend, and magnitude of LULCC for their development plans. Integration of remote sensing and GIS in this study has demonstrated that this approach could be effective in providing LULCC in short period of time, which has been the shortcoming of the traditional planning tools.

## DECLARATION

### COLLEGE OF HUMANITIES

### DECLARATION - PLAGIARISM

I, Mpumelelo Mthembeni Ngwabe (213 533 615), declare that;

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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5. This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the reference sections.

Signed ……

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## LIST OF ACRONMYS

AHRR- Advanced Very High Resolution and Radiometer

CA- Cellular Automata Markov

CFT – Cognitive Fit Theory

DEM- Digital Elevation Model

DFA – Development Facilitation Act (No. 67 of 1995)

D'MOSS- Durban Metropolitan Open Spaces System

EMR- Electromagnetic Radiation

ERDAS- Earth Resources Data Analysis System

GIS- Geographical Information System

GIS- T – Geographical Information System - Transportation

GPS- Geographical Positioning System

ICM- National Environmental Management Act: Integrated Coastal Management Act

ID- Innovation Diffusion Theory

IDP- Integrated Development Plan

IFOV- Instantaneous Field of View

ISODATA- Iterative Self- Organizing Data Analysis

ITB – Ingonyama Trust Board

KZN AEA- KwaZulu Natal Agriculture and Environmental Affairs

KZN Cogta- KwaZulu Natal Cooperative Governance and Traditional Affairs

KZN- PDA- KwaZulu Natal Planning and Development Act (No.6 of 2008)

LA21- Local Agenda 21

LADP- Local Area Development Plan

Landsat TM- Landsat Thematic Mapper

Landsat ETM- Landsat Enhanced Thematic Mapper

LCM- Land Change Modeler

LULC- Land Use and Land Cover

LULCC- Land Use and Land Cover Change

LUMS- Land Use Management System

MARIS- Mississippi Automated Resource Information System

MPLU- Model of PC Utilization

MRLC- Multiresolution Land Characteristics

MS- Multispectral Scanner

MSA- Local Government: Municipal Systems Act (No. 32 of 2000)

NDP- National Development Plan vision 2030

NEMA- National Environmental Management Act (No.107 of 1998)

NLCD- National Land Cover Data

NRSA- National Remote Sensing Agency

PLUM- Planning and Land Use Management by- law

RS – Remote Sensing

RMSE- Root Mean Square Error

SANSA- South African National Space Agency

SCT- Social Cognitive Theory

SDF- Spatial Development Framework

SPOT- Satellite Probatorre d' Observation la Terre

SPLUMA- Spatial Planning and Land Use Management Act (No. 16 of 2013)

SSDP- South Spatial Development Plan

STATSA- Statistics South Africa

TAM- Technology of Acceptance Model

TPB- Theory of Planned Behavior

TRA- Theory of Reason Action

VHR- Very High-Resolution images

UTAUT- Unified Theory of Acceptance and Use of Technology Model

WCED- World Commission on Environment and Development

# CHAPTER ONE: INTRODUCTION AND BACKGROUND

## 1.0 INTRODUCTION

This research assesses the application and effectiveness of remote sensing and GIS for mapping and monitoring land use and land cover changes (LULCC) for development planning, mainly in areas administered by traditional councils such as uMnini Trust traditional council. These areas have different spatial allocation and management systems to the one used by municipalities as they belong to Ingonyama Trust Board in the province of KwaZulu Natal. It is important to map and monitor trends of growth and development to determine the extent to which built-up areas rapidly consume green or environmentally sensitive areas over time because of peri-urban densification which affect sustainable urban development goals. Traditional techniques and methods used by municipalities and other institutions such as aerial photographs and sample surveys, which are collected on a yearly basis are often inadequate in the face of rapid peri-urban densification that occurs on a regular basis. According to Cay *et al (*2004), the integration of satellite images (remote sensing) and GIS provide current and accurate information on urban sprawl and trends of growth, as these remotely sensed images are updated weekly or monthly and; could be supplementary planning tools. Updated and accurate information is required by municipalities for their development plans, and for ensuring sustainable equitable and efficient provision of public facilities and services to an increasing population.

## 1.1 BACKGROUND

The world population is constantly growing and is projected to reach approximately 9.8 billion in 2050, and 11.2 billion in 2100 (United Nations Department of Economic and Social Affairs, 2017). About 60% of this population is expected to be urbanized, which will create a huge demand for land in urban areas, forcing some to move into the periphery of cities to settle on cheaper farmland (United Nations Department of Economic and Social Affairs, 2017). In developing countries, rapid land use and land cover change trends mostly in the peri-urban areas are the result of multiple factors such as the increasing population and their diverse socio-economic activities. According to Ngcofe and Thompson (2015), information about Land Use and Land Cover Changes (LULCC) is required for scientific, economic, and government applications at different levels (both globally and locally). Yousefi *et al* (2015) maintains that LULCC information is required for a wide range of spatial planning activities, ranging from urban planning at the local level to regional development. Ries (2008), and Yousefi *et al* (2015) argue that LULCC trends should be detected and

monitored using geospatial technologies such as remote sensing and GIS within municipalities and other institutions throughout the world for planning, monitoring and development of towns and cities.

Remote sensing (RS) ca be defined as the art and science of gathering information about an object, area, or phenomenon from distance through the analysis of the data obtained by the device (Lillesand *et al*, 2000). RS consists of different techniques used for obtaining images and other forms of electromagnetic records about the earth surface without any physical contact, and the treatment and processing of the remotely sensed imagery data (Lillesand *et al*, 2000; Patra, 2014). According to Singh (1989) and Chen (2008), there are two types of remote sensing instruments namely: active and passive sensors. Active sensor refers to the process whereby the sensor generates its own energy (electromagnetic radiation) to detect the target under observation on the Earth's surface, while, passive sensor refers to the process whereby the sensor uses solar radiation (sunlight) that is reflected or emitted from the observed object. Moreover, Paradzayi *et al* (2008) argue that remote sensing mainly depends on the airborne and space borne platforms such as aerial photographs, satellite images and other data that are useful for the observation of the Earth surface. In addition, remote sensing activities are ranging from the operation of satellite systems, image data acquisition, storage, subsequent data processing, interpretation and so on (Chuvieco and Huette, 2010).

Geographical information system (GIS) can be defined as a powerful computer-based analytical technique with an organized collection of computer hardware, software, geographic data, personnel and procedures used to capture, store, manage, analyze, manipulate, retrieves and generate spatial and attribute data (Melesse *et al*, 2007; Chou, 1996). According to Ripple (1989), GIS refers to the mapping and spatial analysis for both spatial and attribute data to support the decision-making process of an organization. In the same line of thought, Wright *et al* (2014) and Richards and Jia (2006) maintain that GIS represent all types of geographical data which are used in cartography, remote sensing, surveying, management utilities, photogrammetry, geography, and urban planning (Wright *et al*, 2014; Richards and Jia, 2006).

Furthermore, Husman and de By (2009) adds that GIS is not just a computer-based analytical technique used to create maps, even though it can create maps with different scale, projections and colors. However, this analytical technique allows the user to determine spatial relationships of the map's feature, as it can store data which provides the user with the ability to create the outputs to use for specific purposes (Arnoff, 1989; Husman and de By, 2009; Wright *et al*, 2014). These unique capabilities of this analytical technique make GIS surpasses other technologies used in the urban and regional planning field such as ArchCAD and AutoCAD, therefore, based on these abovementioned capabilities, this analytical technique has been utilized

in different applications for planning purposes ranging from inter alia zoning, land use, transportation, development planning, land suitability analysis, and site selection (Budic, 1994).

From planning and development perspective, the information acquired from remote sensing and GIS on land use/ land cover changes is significant for selection, planning, and implementation of land use schemes to meet increasing needs and welfare of the society (Rawat and Kumar, 2015). These innovative and effective techniques are complementary to more traditional methods of monitoring and analysis. They are improvements to existing planning methods and require less time and provide improved accuracy together with their unique analytical capabilities that have reliable information for planning and management of towns and cities. Land use and land cover change mapping and monitoring using trends of growth and development over time can aid decision makers to assess spatial land use and land cover changes, and plan for the efficient and equitable distribution of public facilities and services to accommodate the needs for rapid increasing population which is required in the integrated development planning process within a specific geographical area over time.

### 1.2 PROBLEM STATEMENT

The issue of rapid population growth has implications for land use, and environmental management and planning in peri-urban areas. The use of outdated techniques and traditional methods for land use and land cover change (LULCC) assessments becoming inadequate in the face of innovative and more efficient methods of land use planning and management at the local government (Appiah *et al*, 2015). These traditional methods of data collection are also time consuming, less reliable at times, and expensive to the local municipalities with restricted assets such as financial and human capital (Krishnamurthy and Adiga, 2013). For example, certain traditional councils like uMnini Trust traditional council in eThekwini municipality continue to rely on the application of these conventional strategies for land use planning and management, raising the question on the adequacy and efficiency of their use for land use planning and management. Subsequently, the problem for proper peri-urban densification and trends of growth analysis has been attributed to the absence of spatially detailed information (Hashem and Balakrishnan, 2014). The use of traditional techniques such as sample surveys does not provide detailed and accurate information about peri-urban densification and trends of growth in a specific geographical area.

Furthermore, the contestation of power between municipal and traditional authorities in peri-urban areas of KwaZulu Natal has also left these areas (traditional councils) to operate outside the municipal land use scheme as these areas fall under the Ingonyama Trust Board (KZN Cogta, 2014). In the face of this different

traditional and municipal land tenure system, the introduction of the Spatial Planning and Land Use Management Act (No.16 of 2013) and KwaZulu Natal Planning and Development Act (No.6 of 2008) promotes the uniform or wall-to-wall planning scheme either of rural or urban areas that requires current and accurate information about land use and land cover trends in a specific geographic area over time. The tension between these authorities has contributed to land allocations in rural and traditional council areas, which are sometimes in conflict with the municipal development plans, creating problems in terms of ensuring equitable and sufficient provision of infrastructure, and social services to the increasing population.

Subsequently, the integration of remote sensing and GIS techniques has been regarded as the most significant tools for mapping and monitoring LULCC, for development planning because of their ability to provide steady, accurate, and real-time information about an area regardless of land ownership and thus aiding sustainable land use planning and management in peri-urban areas (Balakrishnan and Alomary, 2013). Rawat and Kumar (2014) adds that integrating remote sensing and GIS for mapping and monitoring land use and land cover changes in peri-urban areas is a better approach for local government and urban planners to plan for sustainable urban development.

### 1.3 AIM

The main aim of this study is to assess the application and efficacy of remote sensing and geographical information systems (GIS) for mapping and monitoring land use and land cover changes (LULCC) trends of uMnini Trust traditional council between 2001 and 2016 for development planning.

### 1.4 OBJECTIVES

Accomplishment of the stated aim of this study is guided by the following objectives:

(i) To determine the current LULCC planning and assessment processes used by municipality in uMnini Trust traditional council

(ii) To critically analyse the extent to which remote sensing and GIS have been used for sustainable land use planning and management

(iii) To identify different land use and land cover types found in uMnini Trust traditional council between 2001 and 2016 and analyse/categorise the changes that has occurred during the study period

(iv) To analyse challenges and constraints of using remote sensing and GIS for mapping and monitoring land use and land cover changes in uMnini Trust traditional council

## 1.5 RESEARCH QUESTIONS

### 1.5.1 MAIN RESEARCH QUESTIONS

To what extent have remote sensing and geographical information systems been applied for mapping and monitoring land use and land cover changes for development planning in uMnini Trust traditional council between 2001 and 2016?

### 1.5.2 SUB-QUESTIONS

The sub - questions guiding this research are as following:

1. What are the current LULCC planning and assessment processes used by municipality in uMnini Trust traditional council?
2. To what extent have computer-based tools such as remote sensing and GIS been used for sustainable land use planning and management?
3. What different land use and land cover types are found in uMnini Trust traditional council between 2001 and 2016? How can these different land use and land cover types and changes within the jurisdiction of uMnini Trust traditional council between 2001 and 2016 be categorized/analysed and mapped?
4. What are the challenges and constraints facing the use of remote sensing and GIS for mapping and monitoring land use and land cover changes in uMnini Trust traditional council?

## 1.6 HYPOTHESIS

When the transition and processes have been well administered, where the municipalities or other institutions have sufficient capacity to implement geospatial techniques such as remote sensing and GIS, these technologies could be an efficient and innovative planning tools which can be used for mapping and monitoring LULCC for development planning as supplementary to traditional planning methods.

## 1.7 JUSTIFICATION FOR THE STUDY

The study of this nature is quite important more especially in developing countries who are still venturing into science and technology as a vehicle to make day-to-day work easily. This study introduces something unique in the South African context to look at the benefits and shortcomings of incorporating satellite images into existing traditional planning methods. The current planning tools such as aerial photographs and sample surveys which are collected on a yearly basis at the peri-urban areas of the city more especially in developing countries, at times these tools become inadequate and time consuming in the face of innovative and effectiveness techniques such as remote sensing (satellite images) and GIS. The rationale of this study is

that the inclusion of these techniques into the existing planning methods could fast track the collection of accurate and current information regarding growth and development patterns of a particular geographic area. Currently, there is no municipality in South Africa which uses satellite images (remote sensing) for land use planning and management. The stance of this study is that the incorporation of such technique together with GIS could assist in the preparation of informative municipal spatial and development plans, also, in ensuring equitable and sufficient provision of social services to an increasing population more especially in peri-urban areas, which are not fully incorporated on the plans of the municipalities.

UMnini Trust traditional council was selected because of being among the first traditional councils, where Local Area Development Plan and Draft rural scheme were introduced to guide and regulate future development as a result of rapid peri-urban densification, which has been witnessed before the adoption of these strategic spatial plans. Traditional councils which are situated at the periphery of the city in KwaZulu are affected by peri-urban densification as they have different land allocation and management to the one used by the municipality. This different governance has created the incidents where land allocations and development are in contrary to the development plans of the municipality. Therefore, this study advocates for the use of geospatial technologies such as satellite images and GIS that provide the information about densification without any physical contact to the targeted object/feature under observation. This could help the municipality to gather this information regardless of the land ownership. This could also assist the municipality to acquire the information about land use/land cover on a regular basis and also for the preparation of the wall-to-wall planning scheme as per SPLUMA.

"Remote sensing and GIS have been endorsed for providing current and accurate information on a daily, weekly, and monthly basis for a synoptic view and multi-temporal land uses/land cover data that are often required" (Dewan and Yamaguchi, 2009). From an urban and town planning perspective, real time and accurate information for peri-urban development and trends of growth analysis is required as the inappropriate developments as a result of rapid peri-urban densification frequently occurring in adjacent to the rivers and other drainage systems, also in close proximity to corridors such as transport routes and railways which is the case in the study area. However, current traditional planning methods used for peri-urban densification and trends of growth analysis are time consuming, less reliable at times, do not provide spatial detailed information and inadequate in the face of innovative and more efficient methods of land use planning and management at the local government (Rawat and Kumar, 2015; Butt *et al*, 2015).

Therefore, the integration of remote sensing (RS) and geographical information systems (GIS) techniques have been regarded as the new planning approaches required for mapping and monitoring land use and land cover changes for development planning (Zhang *et al*, 2014). These techniques are useful in providing current and accurate information about the land use and land cover changes in peri-urban areas mostly in areas under traditional councils, compared to the current traditional planning methods used in land use planning and management such as aerial photographs and sample surveys (Gu *et al*, 2016). Furthermore, this study is useful for long term development framework of the local municipality as change detection could assist in conceptualizing and formulating municipal development plans such as Spatial Development Framework to determine development challenges and provide strategies for use and development of land.

Moreover, the effectiveness of these techniques can also be explained by the fact that they are not in dispute with the traditional planning methods, however, are additions to existing traditional planning methods and require less time, and improved accuracy together with the unique analytical capabilities that could enhance land use planning and management. The abovementioned factors make this study useful as it will fill the gaps and limitations that are still in existence in terms of mapping and monitoring land use and land cover changes for development planning especially in areas administered by traditional councils.

## 1.8 DISSERTATION STRUCTURE

**CHAPTER ONE** provides with an introduction and background to the study by focusing on the importance of LULCC analysis for land use planning and development, the problem statement and the aim of the study. The problem statement offers a clear outline of the research problem that was investigated. The aim and objectives and the research questions that guided the study are also outlined. It further presents the research questions, hypothesis, and a detailed justification and relevance of conducting the study of this nature.

**CHAPTER TWO** presents a literature reviews related to the application and effectiveness of Remote Sensing and GIS for mapping and monitoring LULCC for development planning, it further discusses South African legislative and policy framework related to the study.

**CHAPTER THREE** presents the conceptual and theoretical framework which underpins the assessment of the application and effectiveness of remote sensing and GIS for mapping and monitoring LULCC for development planning. Key concepts (remote sensing, GIS, development planning, land use and land cover etc.), and the cognitive fit theory, sustainable development theory as well as unified theory of acceptance

and use of technology which are theoretical base were linked to the issue under study and explain past and currents trends (2001-2016) of developments in uMnini Trust traditional council.

**CHAPTER FOUR** presents and discusses the research methods employed in this study. Both qualitative and quantitative research methods were employed. The primary data was collected by means of on-site observation and the series of key stakeholder interviews. These provided the basis for the data analysis presented in chapter seven.

**CHAPTER FIVE** discusses both international and South Africa precedent case studies, for a developed country it discusses three counties within the State of Mississippi, United States of America. While for a developing country, it presents the case of Tirupati peri-urban in India, and Port Elizabeth in Eastern Cape, South Africa as classical precedent case studies.

**CHAPTER SIX** presents the focus/case study area, its location, demographics, and other relevant background information.

**CHAPTER SEVEN** presents and discusses the study's findings based on the analysis of the data gathered for this study and on secondary data from eThekwini municipality which is relevant to the area under study.
**CHAPTER EIGHT** presents a summary of the major findings in relation to the aims and objectives of the study and suggested recommendations

## CHAPTER TWO: LITERATURE REVIEW

### 2.0 INTRODUCTION

This chapter intends to provide with the literature established by various authors, practitioners, and scientists related to the assessment of the application and effectiveness of remote sensing (RS) and geographical information systems (GIS), for mapping and monitoring land use and land cover changes trends, for development planning over a certain period of time. In this chapter, there will be a thorough discussion about the capabilities of integrating remote sensing and GIS in various applications under planning discipline which include land use planning and management, urban planning, urban development planning, and land use and transportation planning to mention but the few. It further discusses the processes of classifying/categorizing land use and land cover trends, using remotely sensed imagery from remote sensing and GIS to determine land use/ land cover classes or themes, LULCC techniques and analysis, and modelling of LULCC using remote sensing and GIS. Notwithstanding, this chapter provides with South African policy/ legislative framework that underpin the study.

*2.1 Integrating Remote Sensing (RS) and Geographical Information Systems (GIS) for Land Use Planning and Management*

The integration of remote sensing and GIS in various urban and regional planning applications ranging from land use planning and management, environmental management, and monitoring development in peri-urban, towns or cities has received considerable attention in the literature (Gao, 2002). The integration of these systems has been regarded as a major achievement in history as they were two independent systems operating in their respective applications. However, currently these systems have been integrated into one system for desirable results in town and regional planning applications (Sundaram *et al*, 2015). In the same line of thought, Wilkinson (2007) adds that this integration is a new planning strategy aiming to promote sustainable urban development planning.

Therefore, current major developments are taking place through integrating remote sensing data with GIS. The first part of this integration of these two systems begin with remote sensing as a powerful technique used to gather multi-date imagery data which is a primary source of geographic data from satellites. Subsequently, GIS is used as analytical technique for spatial analysis and data overlay of different types which is essential for geography, planning and environmental applications (Zhang *et al*, 2014; Archibald, 1987). This integration

of tools and techniques is a promising perspective especially for various applications of these techniques ranging from development and regional planning (Zhang *et al*, 2014; Thakur *et al*, 2015).

This integration incorporates raster data from remote sensing and vector data from geographical information system that are integrated for environmental planning, spatial planning applications and other software requirements (Hinto, 1996). According to Ehler *et al* (1991), integration of remote sensing and geographical information systems is necessary and has a full potential in land use planning and management. According to Bahrain (2003), a Town Planner can integrate remote sensing and GIS for better management of urban and sub-urban areas for particular location and spatial extent:

- Identifying and analyzing the spatial distribution of different land use and land cover types in a specific geographical area;
- Transportation networks to improve the connectivity of the urban and sub-urban areas and other related infrastructure;
- Different census-related statistics and socio-economic interrelated indicators; and
- The ability to map and monitor necessary related variations in these features over a certain period of time

Urban agglomeration and application of remote sensing and geographical information systems (GIS) has been employed at diverse stages of planning, implementation, and monitoring of the urban projects such as land use planning, land suitability analysis, and so forth to yield desirable results (Al-Haddad, 2015). These tools are not only integrated because of being powerful in their applications, but also are cost-effective techniques for mapping and monitoring spatial distribution, land use and land cover changes over time in a specific geographical area such as uMnini Trust traditional council (Chuvieco and Huette, 2010). Franklin (2001) adds that there has been an integration of tools in areas of remote sensing, GIS, and spatial models. GIS has become a central analytical tool that manage geographic data by integrating all sources of spatial data ranging from remote sensing, census data, cartography, Global Positioning Systems (GPS) and so on (Franklin, 2001).

In addition, ortho-image from remote sensing has been used as a GIS base layer in the development of thematic maps for land use and land cover and other geospatial datasets by extraction of cartographic elements such as buildings and roads from the specific imagery (Merchant and Narumalani, 2009). The integration of these techniques and tools have been endorsed for yielding good results based on their capabilities in areas of urban planning, development planning to mention but the few that will be further

discussed in the following sections. This kind of integration is essential in ensuring effective mapping and monitoring of land use and land cover trends, using these efficient techniques and tools, rather than the traditional planning methods, which are regarded as being less reliable and time consuming at times (Appiah *et al*, 2015). It has been noted that municipalities and other institutions require frequent information for population growth to determine the rate and magnitude of changes (LULCC), and the number of people who are expected to be serviced by the municipality which is quite significant for their development plans. In the context of this study, the integration of these techniques and tools as a supplementary planning method could assist the municipalities and other institutions, to acquire information about development and use of land within the municipal jurisdiction on a regular basis, to determine the extent and patterns to which the area is growing which is significant on their development plans.

*2.2 Linking Remote Sensing and Geographical Information System in Urban Planning and Urban Development Planning*

In the second half of the 21st century, developing countries are still experiencing rapid industrialization and urbanization, which are the results of modernization processes that influences rapid land use and land cover dynamics (Tiwary, 2016). In the midst of this intensive land use and land cover changes, urban planning is the process which has been employed by the municipalities and other institutions to generate development plans in order to regulate and control incompatible land uses which affects sustainability, and spatial resilience as some of these land uses are distributed within environmentally sensitive areas in towns or cities as a result of intensive peri-urban or urban growth (Xiao and Zhan, 2009). This process consists of various sectors ranging from land use, housing, transport, environment and land development at different stages that are significant for improving quality of life of increasing urban population (O-Yeh, 1991). The objective of urban planning is to promote sustainable urban development and influence policy options to create better future for all (Appiah *et al*, 2015).

The use of geospatial technologies such as geographical information system (GIS) in urban planning provides required platform for data analysis using maps, spatial and attribute data to determine spatial patterns and relationships (Saynajoki *et al*, 2014; Tiwary, 2001). This is important for change analysis in an area using spatial distribution and patterns to map and monitor the extent to which changes are occurring in a specific geographical area over time (Chavare, 2015; Xiao and Zhan, 2009). Moreover, Jhawar *et al* (2005) maintains that in urban planning remote sensing is used as a platform for thematic maps preparation using remotely sensed data for visual interpretation. This is significant when integrating these thematic maps using

GIS mainly for urban sprawl analysis and urban land use and land cover change trends analysis over time for land use planning and management (Tiwary, 2001; Jhawar *et al*, 2005).

The significance of these systems in planning and development derived from the failure of traditional planning methods such as sample surveys, and aerial photographs as they are labor intensive, too expensive, and produce outdated and less accuracy data (Wang, 2008). Hence, these systems are recommended for providing current and accurate information used for updating and monitoring land development, urban sprawl and trends of growth over time (Chen *et al*, 2001). In the same line of thought, Chavare (2015) adds that remote sensing and GIS in urban planning used for strategically designing and transportation for smart growth plans. However, the setback in urban planning is that remote sensing is not widely used in this field despite its strengths to provide very high-resolution (VHR) images, and other meaningful data as urban planning requires large volume of data both at the time of planning, and at the time of implementation of the plan, therefore, there is a significant need for incorporating remote sensing in urban planning (Chavare, 2015).

Besides, geographical information system (GIS) is a mostly common used analytical tool by urban or spatial planners, for example, for spatial modelling from GIS can provide a platform through the use of predictive growth modelling tools such as iCity to address issues related to urban planning such as spatial and land use homogeneity of urban areas (Chavare, 2015; Jhawar *et al*, 2012). Therefore, in case of this study, the integration of remote sensing and GIS provide with a platform for data analysis to query spatial patterns and relationships on the data collected (Chavare, 2015). Remote sensing provides with multi-date imagery which are used as a base layer for GIS in the preparation of land use maps which are included on the municipal development plans to understand the spatial trends of peri-urban growth and rate/magnitude of changes (LULCC) over time in a specific geographic area (Merchant and Narumalani, 2009).

According to Paul (2007), rapid urban population growth has been regarded as the main cause of urban sprawl or decentralization that has a direct contribution to incompatibility of land uses, unorderly development which affects safety and image of the area in the peri-urban areas. Peri-urban growth in developing worlds that includes Latin America, Asia, and Africa, has resulted to the highest demand for urban land for residential purposes, and the need for new public infrastructure and services (Zarenda, 2013). Moreover, in the same line of thought, Paul (2007) asserted that peri-urban densification has influenced a decline on agricultural potential areas and biodiversity loss in these peri-urban areas of town and cities. Local governments and municipalities have demanding responsibilities to facilitate and regulate the development and use of land and

draft municipal development plans to ensure that there are development controls in place to discourage any future developments which are in conflict with their future development and spatial plans.

Xiao and Zhan (2014) assert that the processes for development planning involves the use of remote sensing, which is useful as a data source for monitoring of urban expansion and land use/land cover trends in a particular geographical area over a certain period of time. This technique provides a platform for spatial and temporal analysis of urban sprawl and land use change which are important analyses for development planning processes. The use of remote sensing for analyzing, planning, and manage urban growth challenges has emerge as the new planning strategy for development planning (Czajkowski and Lawrence, 2013). In the same line of thought, Tiwary (2016) contend that modern techniques and tools such as remote sensing and GIS are used by various institutions such as municipalities in order to predict and analyze urban development, detect and monitor change. Moreover, there are various applications of geographical information system (GIS) in development planning ranging from displaying data and designing to facilitate planning and development controls at the strategic level (Raghunath, 2016).

According to Yaakup (2003), as a result of rapid population growth that contribute to rapid urban sprawl in peri-urban regions, the local authority has to adopt policies and plans to ensure that development controls are in place to limit unregulated developments, which are not in line with the Integrated Development Plan (IDP) and Spatial Development Framework (SDF) of that particular municipality (Raghunath, 2006; Yaakup, 2003).These plans and policies for development planning must complement with the towns or city's development plans and national development policies, which is part of integrated development planning processes (Tiwary, 2016). Xia and Zhan (2014) argue that development planning process involves the monitoring of land use and land cover changes and other many applications.

Therefore, it has been demonstrated that the integration of remote sensing and GIS, produce positive results in development planning. As discussed by Paul (2007), the issue of rapid-peri densification in uMnini Trust traditional council has required the serious intervention from the municipality, to monitor and facilitate "unregulated" developments that has implicated environmentally sensitive areas such as floodplain, and D'MOSS regions. Notwithstanding, integrating remote sensing and GIS enhance the capacity to address, regulate, and coordinate, development and use of land to achieve sustainable development goals as they provide with up-to-date spatial and attribute data. It is utmost important to elaborate on the integrated development planning in South Africa, as LULCC information acquired from integrating remote sensing and GIS, contributes to integrated development planning processes of the affected municipality. This kind of

information help the municipality to determine priority areas in terms of providing infrastructure and services in their future plans, as these geospatial technologies display patterns and trends of densities in a given area at a shorter period of time.

*2.3 Integration of Remote Sensing and Geographical Information Systems in Land Use Suitability Analysis*

According to Raghunath (2016), there is a need for new development of land uses to accommodate rapid influx of population mostly in peri-urban regions that contribute to the shortage and demand for public facilities and social services such as houses, water, roads, electricity and so forth. This include the accommodating needs of future generations on the plans considering rapid densification occurring in peri-urban areas. Chandio *et al* (2010) and Collins *et al* (2001), maintain that GIS has capabilities to perform spatial analysis in order to identify areas using multi-criteria analysis for proposal of new developments such as schools, housing, shopping centers, solid waste disposal, industry, community halls, and agricultural land through providing platform for land use suitability analysis.

In the same line of thought, Malczewski (2004) contend that land use suitability analysis considers identifying environmental constraints to that particular new development and provide a platform for environmental modelling to determine land use type that is suitable for a particular geographical location (Chandio *et al*, 2010; Malczewski, 2004). In case of this study, it has been noted that developments are taking place within environmentally sensitive areas as there are no strict regulations, and facilitation of land uses as these areas (traditional areas) are not fully administered by the municipalities as they fall under Ingonyama Trust in KwaZulu Natal. This uncertainty for environmental protection as result of "inappropriate" new developments, as they are in contrary to the municipal development plans in the study area has threatened sustainable urban development goals.

Notwithstanding, Chen (2014) adds that land use suitability analysis is the central element in urban and sub-urban planning and decision-making processes. In the same line of thought, Duc (2006) defines land use suitability as the ability of a particular type of land to accommodate a particular use. De Almeida (2005) maintains that land suitability assessment is among planning tools for the design of land use distribution and patterns to prevent environmental conflict through separating incompatible land uses. This analysis incorporates the processes of multi-criteria analysis for evaluation and grouping land of a specific location based on the suitability for a defined use. According to Joerin *et al* (2001), land use suitability is similar to choosing an appropriate location for a specific land use. GIS has been considered as the most important analytical technique for overlaying different maps to define similar zones, and apply classification techniques

to assess and analyze, for instance, the agricultural land suitability level of each zone (Trung *et al*, 2006; Joerin *et al*, 2001).

Innovative and efficient techniques and tools such as remote sensing and GIS are commonly used for evaluating land use suitability analysis. Remote sensing has full potential for providing accurate and current information on land use and land cover changes for urban planning, land use management and for appropriate allocation of services and infrastructure within peri-urban or urban areas (Mundia and Aniya, 2005). In land use suitability analysis, these techniques and tools are most important for improving land use planning and assist local government in policy making and predictive urban modelling (Abdullahi and Pradhan, 2017).

This analysis using remote sensing and GIS help municipalities and other institutions with policies strategies for mapping and monitoring urban change to enable to predict and forecast the changes occurred and spatial location of built up areas in the area to accommodate rapid population growth (Mundia and Aniya, 2005). Yalew *et al* (2016) argue that remote sensing and GIS in land use suitability analysis deals with the detection, mapping and analysis of urban sprawl trends, and provide with "suitable" location for new development. Houet *et al* (2010) and Bhatta (2009) maintain that land use suitability analysis come up with strategies to identify inherent and potential land for intended development. This section simple illustrates the significance of integrating remote sensing and GIS, to ensure that there are efficient techniques to determine suitable land for new infrastructure and services development, to accommodates the needs of the population in peri-urban areas such as uMnini Trust traditional council which contributes to rapid land use and land cover dynamics when not regulated.

*2.4 Land Use and Land Cover Change Techniques and Analysis*

Change detection has been regarded as one of the central applications of remotely sensed data (Lu *et al*, 2010). In recent years, very high-resolution (VHR) images from remotely sensed data for change detection has become the significant tools for image processing, and commonly used in geographical information systems to update and generate land use maps, environmental monitoring, and for a wide range of planning and development purposes (Lu *et al*, 2010; El-Haltab, 2016). Singh (1989) Hegazy and Kaloop (2015) defines change detection as the process of determining the differences from the various image datasets using multitemporal imagery data. In the case of this study, Landsat Thematic Mapper for 2001 imagery and Landsat Enhanced Thematic Mapper for 2016 imagery were used to determine the rate of LULC changes within this specified timeframe.

Notwithstanding, Wang *et al* (2009) and Olaleye *et al* (2009) maintain that change detection technique mainly used to obtain the information about the land use and land cover changes on the target area from very high-resolution (VHR) images and up-to-date map database. Therefore, land use change detection analysis is most important for spatial and urban planning; as it helps to identify various dynamics occurring in different theme or classes of land use/land cover over time. For example, to analyze the reasons for the increased built-up areas in an area, while there is a gradual decrease of potential agricultural land areas when comparing multidate imagery for sustainable urban development over time using multidate imagery data (Hegazy and Kaloop, 2015; Briassoulis, 2014; Butt *et al*, 2015).

Change detection studies for the image examination, the practitioners have used diverse techniques and tools ranging from but not limited to Radar and Advanced Very High-Resolution Radiometer (AHRR), LandSat Thematic Mapper (TM), LandSat Enhanced Thematic Mapper (ETM), Multispectral Scanner (MS), Satellite Probatorre d' Observation de la Terre (SPOT) data, aerial photography and so forth (Mouat *et al*, 1993; Al-doski *et al*, 2013). Moreover, Rewet and Kumar (2015) adds that change detection analysis incorporates but not limited to these techniques ranging from image differencing, classification, image rationing, image regression, principal components analysis, multidate composite image, change vector analysis, post classification comparison, cross tabulation and so on (Mouat *et al*, 2008; Rewet and Kumar, 2015; Ries, 2008).

*2.5 Remote Sensing and Geographical Information System (GIS) in Land Use and Transportation Planning*

Developing countries are facing rapid population growth in their towns and cities, this is a major challenge in developing world that result to enormous growth at the outskirts of the towns or cities which contribute to urban sprawl and influence the increased car ownership that indirectly pose serious threat on land use and transportation planning (Gulhan and Ceylon, 2016). Rapid population increase has an influence on the increasing demand for transportation facilities in urban or sub-urban areas (Wei *et al*, 2009). To mitigate these challenges, various institutions like municipalities have successfully used aerial photographs, satellite images and GIS as the most powerful techniques and tools for mapping and monitoring urban facilities for development planning that include urban roads networks (El-Shair, 2003). In urban transportation planning, satellite images play a significant role in mapping and monitoring road conditions and are quite important to monitor road networks as it plays a crucial role in the wellbeing of the local communities. To map and monitor road conditions, this technique uses hyperspectral images or high-resolution imagery from satellites to be able to observe road conditions (Lyons and Harman, 2002).

The municipalities and other institutions use this information for repair and maintenance of their road networks. According to O'Hara (2002), remote sensing is important for planning and better decision support tools for transportation networks within municipalities and other institutions, and in pavement construction this system can be used because of its very high-resolution imagery (O'Hara, 2002; Fouracre *et al*, 2006). Alterkawi (2001) maintains that remote sensing is significant for current and future transport infrastructure development and construction as it is able to provide greater quantity data to ensure quality monitoring and evaluation. This data is collected more frequently which makes remote sensing surpasses other systems in urban transportation planning.

Geographical information system (GIS) also plays a crucial role in urban transportation planning, the speed to which population grows at the periphery of towns and cities in developing countries and huge demand for land uses such as for agriculture, commercial, residential, and industrial development have impacts on the transportation facilities such as roads, railway, sideways, and other facilities that link activities (Strafford Regional Planning Commission, 1997). GIS as analytical technique has capabilities to perform buffer analysis to ensure that these land uses do not occur nearby the road networks but there is enough space between road networks and any proposed land use as it is the case in uMnini Trust traditional council where the housing/settlement developments have implicated coastal dunes and situated within road networks such as N2 and R102 buffer zones (Fouracre *et al*, 2006). This analytical tool also has the capability to perform modelling to determine new location for development of road networks (Alterrkawi, 2001). Integration of remote sensing and GIS, in this section could improve land use planning and encourage new transportation facilities in the municipality that is safer and more efficient for the users (Loidl *et al*, 2016). Moreover, there are benefits of integrating these tools and techniques in land use and transportation planning like nodal development/zoning, livable walkable communities, and access management to promote sustainable development (Loidl *et al*, 2016).

Furthermore, transportation planners, scientists, practitioners have introduced Geographical Information Systems -Transportation (GIS-T) as a valuable tool to address the transportation problems associated with rapid population growth mostly in developing countries like urban traffic congestion (Loidl *et al*, 2016). Therefore, GIS-T as cost-effective method for data integration assist for decision-making and planning purposes (Agyemang, 2013). This tool is used by various institutions such as the municipalities for diverse applications ranging from infrastructure planning and management, transportation safety analysis, travel demand analysis, public transit planning and operations, traffic monitoring and control (Hummel, 2001). In

terms of its applicability, GIS-T has been successfully used in the Kimbu Adenta corridor in Accra, capital city of Ghana. Where GIS-T was employed to visualize the trend of traffic congestion and create individual segment of the road network on the map to formulate control measures in place to free flow of traffic on the corridors (Agyemang, 2013).

*2.6 Modelling Land Use and Land Cover Changes using Remote Sensing and Geographical Information Systems*

According to Al-Bakri (2013), modelling and assessment of land use and land cover changes is vital important part of land use planning and assist in the formulation of sustainable land use policies for local government. In the same line of thought, Hadi *et al* (2002) adds that the modelling of land use and land cover could be regarded as a scientific field that is recently receiving much attention as the population rapidly increasing in developing countries, so modelling land use and land cover changes (LULCC) involves identifying the effects of the diverse socio-economic activities of the population on the environment. LULCC models are the techniques used by various institutions such as the municipalities for advance analysis of the causes and consequences of LULCC to understand the systems functionality and to assist in land use planning and policy formulation (Hadi *et al*, 2002; Al-Bakri, 2013; Megahed *et al*, 2015).

Furthermore, there are diverse algorithms and methods employed when performing modelling of land use and land cover change by practitioners (Hadi *et al*, 2002). For example, Cellular Automata (CA) Markov is commonly used for forecasting land use and land cover changes. Zhou (2004) and Hadi *et al* (2002) maintain that this modelling algorithm is the most powerful technique for modelling and prediction of land use and land cover change as it deals with spatial integration and stimulates multi-LULC types. Fortunately, both remote sensing and GIS are able to perform modelling of land use and land cover changes using land change modeler that is found both in ArcGIS extension and TerrSet software.

Land Change Modeler (LCM) is an integrated software used to analyze and predict land use and land cover change and for validating results (Megahed *et al*, 2015). Rawat (2015) adds that LCM to analyze and quantify land use and land cover changes in specific area, evaluates LULCC using remotely sensed multidate images, and quantify changes in these different times, thereafter, display changes occurred in the area using various graphs and maps. In addition, Al-Bakri (2003) argue that integrating powerful tools and techniques such as remote sensing and GIS make it possible to do the modelling of LULCC where historical and current land use and land cover are mapped at reasonable costs. Butt (2015) and Al- Bakri (2003) maintain that GIS in modelling of land use and land cover change used to provide output maps and attribute data to analyze and

quantify changes occurred among or between a time series either of satellite images or aerial photography (Al-Bakri, 2003; Butt, 2015).

Land use change models are interdisciplinary in nature, whereby various fields used them for better understanding of the dynamics of land uses that emerged from decision making processes of human at different levels, from local to global level (Brown *et al*, 2003; Turner, 1995). According to Verburg *et al* (2004), land use change models support the analysis of the causes and consequences of land use changes, and support land use planning policy. Costanza and Ruth (1998) adds that models are significant tools in support for the prediction of future land uses under diverse scenario conditions and assist to implement informed decisions based on the prediction. Nevertheless, models are the basic fundamental tools of analysis for a planner specializing in transportation and land use planning (Brown *et al*, 2003; Iacono *et al*, 2000).

Chaudhuri and Clark (2013) assert that the success of these land use change models depend on the availability of very high resolution (VHR) images with better accuracy and precision from remote sensing, and increased computational power (Brown *et al*, 2003; Chaudhuri and Clark, 2013). Peri-urban or urban growth and land use change models are significant and have full potential techniques in urban spatial planning and management (Wray *et al*, 2013). In the same line of thought, Wray *et al* (2013) adds that urban land use modelling incorporates testing of spatial location theories, collaboration between diverse activities such as land uses, actors, and others in urban setting. Wegener (1995) maintains that models were used in Western countries as useful mechanisms of urban development and significant tools for forecast and control of the future of towns or cities. According to Agarwal *et al* (2000), land use change models used by practitioners and researchers to determine dynamics and key drivers of land use /land cover change, thereafter, inform related policies affecting such dynamics in local government. Therefore, the following section discusses South Africa policies and legislative framework that deemed relevant to this study.

## 2.7 SOUTH AFRICAN POLICY AND LEGISLATIVE FRAMEWORK

This section provides with legislative and policy framework that have direct and indirect implications to this study. Also, this section is quite relevant as the understanding of LULCC as a result of rapid peri-urban densification has impacts on sustainable urban development (both globally to local), as the population requires infrastructure and social services to sustain their livelihoods from the affected sphere of government. Therefore, the respective sphere of government has to incorporate the increasing population on their development plans and ensure that there is a sustainable implementation of development controls to facilitate and regulate “inappropriate” developments that implicate the status of natural environment. Notwithstanding,

this section of the study will discuss national and provincial legislative and policy framework that are deemed relevant to the nature of the study which are as follows:

*2.7.1 National Development Plan (NDP) vision 2030*

The National Planning Commission of South Africa implemented the National Development Plan with different goals to develop the Republic of South Africa vision 2030. Amongst these goals, this plan encourages the planning that includes everyone, whereby, community plays a significant role in planning and development of their communities. Community participation in planning which is a bottom up approach of development is crucial important as the community knows their area in and out. In addition, the goals of this plan include the construction of new infrastructure for the current and future generations. The development and upgrade of the infrastructure in South Africa aimed to accommodate the rapid population growth especially in urban and peri-urban areas where more than half of the total population in developing countries live.

*2.7.2 Development Facilitation Act (No.67 of 1995)*

It is enshrined in Chapter 1 of the Development Facilitation Act (1995) that in a specific geographical area there must be an application for land development. Chapter 1 of the very same Act also highlights that the application for land development must be to the actions of State and local government body. Moreover, contend that the applications of this nature serve as a guideline by reference to which any competent authority shall exercise any discretion or take any decision in terms of this Act or many laws dealing with land development, including any such law dealing with subdivision, use, and planning of or in respect of land.

Furthermore, this Act also provides with general principles for land development that underpin the policy, administrative practice and laws. Based on, policy, administrative practice and laws for rural and urban development should facilitate the development of formal and informal, existing and new settlements. These policy, administrative practice and laws should promote efficient and integrated land development, where, there is a promotion of the integration of the social, economic, institutional and physical aspects of land development, optimizing the use of existing resources including such resources relating to agriculture, land, minerals, bulk infrastructure, roads, transportation, and social facilities.

In addition, promotes a diverse combination of land uses, also the level of individual erven or subdivision of land. Nevertheless, this Act promotes the establishment of policy, administrative practice and laws that promote sustainable land development, where, its promote the establishment of viable communities, that promote sustained protection of the environment and, ensure the safe utilization of land by taking into

consideration factors such as geological formation and hazardous areas. However, Chapter 5 and 6 of this Act were deemed unconstitutional by the Constitutional Court in 2010 as they undermine the roles and functions of the different spheres of government. Thereafter, in 2013 there was an establishment of the National Spatial Planning and Land Use Management Act (No.16 of 2013).

*2.7.3 Constitution of the Republic of South Africa (No.108 of 1996)*

The Constitution of the Republic of South Africa (1996) is regarded as the highest authority of law in the Republic of South Africa. This Act set out the legal framework for the rights and responsibilities of the citizens of the Republic, and defines different spheres of the government (national, provincial and local) and corporative governance amongst them. In the context of this study, municipal planning enshrined on the section 152(1) and (2) of the Constitution defines the role of the municipality for sustainable planning and development. Schedule 4 Part B of the Constitution of the Republic of South Africa stipulate the roles and functions of the local government that incorporates municipal planning, building regulations, municipal public transport, trading regulations, and so forth.

*2.7.4 Spatial Planning and Land Use Management Act (SPLUMA) (No.16 of 2013)*

Spatial Planning and Land Use Management Act (SPLUMA) of 2013 Chapter 2 emphases the establishment of the Municipal Planning Tribunal for the municipal area to deal with the development applications in the land under the municipal jurisdiction includes areas under Ingonyama Trust like uMnini Traditional Council. Whereas, Chapter 3 of this Act provides a single, uniform framework for spatial planning and land use management regardless of the area is in rural or urban areas. This Act also provides for inclusive, developmental, equitable and efficient spatial planning at different spheres of government ranging from local to national level. The Act provides with the framework for policies, principles, norms and standards for spatial planning and land use management. Moreover, address spatial and regulatory imbalances of the past; promote uniformity and consistency in procedures and decision-making processes by authorities. Also, provides the platform for the facilitation and control of land use and development.

*2.7.5 Integrated Development Planning in South Africa*

According to Gueli *et al* (2007), integrated development planning refers to the process and strategic plan, to redress spatial inequalities, and disaggregation of the apartheid planning. To redress these diverse inequalities and ineffectiveness caused by the apartheid policies and planning. Post 1994, the government of South Africa for planning and development introduced an integrated approach to achieving more sustainable processes and outcomes for progress and development (Oranje *et al*, 2000). According to Robinson (2009), integrated development planning is a planning approach and Integrated Development Plan

(IDP) that is the end product of the process. This strategic plan belongs to planning and development tools designed to align with the Constitution of the Republic of South Africa (No. 108 of 1996), to ensure the development agenda that promotes inclusiveness, public participation, transparency, and accountability to local communities.

According to Todes (2004) and Local Government: Municipal Systems Act (No.32 of 2000), integrated development planning is an inclusive and legislative process that municipalities prepare as strategic plan. Geyer (2006) adds that integrated development planning is process in which different spheres of government and other relevant institutions integrated at local government to address development issues that affect local people. Harper (1994) maintains that integrated development planning also involves integration of social, economic and environmental aspects at the local government to achieve integrated and sustainable development. New integrated approach to development and planning responds to the needs of the local communities which is part of reconstruction approach to redress skewed spatial policies of the apartheid government (Gueli *et al*, 2007). In addition, Todes (2004) argue that integrated development approach at the municipal level provides with the platform for the municipalities that were previously neglected to directly engage in service delivery planning and to identify and prioritize strategic developmental interventions with both short and long-term impacts.

In the post-apartheid era, development planning has received much attention in the South African literature. Integrated development planning is not new in the literature as it is adopted by various countries throughout the world with an intention to address development needs and changes of the municipalities (Sowman and Brown, 2006). In the countries outside South Africa, this integrated development plan is defined as a "*development plan*" that is essential to indicates areas that require change, how they should change and what they could be like in future. Development planning conduit through which types of development that should take place and the location of the proposed development programs and projects are highlighted (Todes, 2004). Therefore, integrated development plan (IDP) refers to the most important tool used by the local government in undertaking its developmental responsibilities in South Africa that is reviewed annually and revised after every five years (Local Government: Municipal Systems Act, 2000).

According to Corporative Governance and Traditional Affairs (2012), in the context of South Africa Integrated Development Plan (IDP) is a mandatory document required from all municipalities that contains short, medium, and long-term objectives and strategies, this document guide and informs municipalities' activities. Theron (2005) adds that integrated development plan superseded all other plans introduced to guide

development at the local government. According to Section 25 of the Chapter 5 of the Local Government: Municipal Systems Act (No.32 of 2000), IDP should reflect the following:

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

*2.7.6 National Environmental Management Act (NEMA) (No.107 of 1998)*

National Environmental Management Act (1998) emphasis that for efficient environmental management, the concerns of the people and their needs must be at the forefront, and serve the physical, psychological, developmental, cultural and social interest equitable. However, development in specific geographic area must be social, environmental and economically sustainable. Chapter 1 emphasis that sustainable development requires the consideration of all relevant factors including the following:

i) In any development processes, the disturbance of ecosystems and loss of biological diversity when it is needed must be minimized and avoided.
ii) Negative impacts of development on the environment and on human environmental rights must be anticipated and prevented when necessary. Therefore, the development must minimize environmental impacts and maximize environmental benefits of the development.

*2.7.7 NEMA: Integrated Coastal Management Act (No.14 of 2008)*

Considering that eThekwini Metropolitan where uMnini Traditional Council is situated within is a Metropolitan located on the coastal land which makes it significant to adopt the Integrated Coastal Management Act (2008). This Act encourages the protection and preservation of the coastal ecosystem, and the protection of the natural functioning of the different coastal processes. As part of the adoption of this Act at the municipal level, the municipalities spatially located on the coastal land must draft the coastal management plan to demonstrate how they will ensure the protection of the coastal environment to promote sustainable development. This plan must be in line with the Integrated Development Plan (IDP) of that specific municipality. Therefore, housing/settlement development occurring within coastal dunes, floodplains in the study area undermines the coastal environmental management.

## 2.8 PROVINCIAL LAWS

*2.8.1 KwaZulu Natal Planning and Development Act (No.6 of 2008)*

The province of KwaZulu Natal promulgated the provincial level law for spatial planning and land use management, which is KwaZulu Natal Planning and Development Act (2008) with Chapter 4 that highlights the aspect of development of land situated outside the scheme. UMnini Trust traditional council that fall under eThekwini Metropolitan do not have land use scheme for land use and development purposes. This area falls under Ingonyama Trust Board that governs land use planning and management in traditional councils of KwaZulu Natal. Therefore, this Act in Chapter 4 provides with the procedures that should be followed by the respective municipality for the development of land in areas outside the scheme such as the rural and traditional council areas. Nevertheless, this Act provides a single set of procedures for planning and development throughout KwaZulu Natal (wall-to-wall planning scheme) regardless of being rural or urban area.

*2.8.2 KwaZulu Natal Traditional Leadership and Governance Bill, 2013*

KwaZulu Natal Traditional Leadership and Governance Bill (2013) emphases the changes of the structure of traditional authorities to traditional councils. This Bill also defines the area of jurisdiction and the role of the traditional councils. Chapter 2 of this Bill provides the requirements of the recognition of *isiZwe*, which includes:

Firstly, a community may be recognized by the Premier as *IsiZwe* if it

a) Is subject to a system of traditional leadership observed in that community's customs
b) Observes a system of customary law

c) Recognizes itself as a distinct *IsiZwe* with a proven history of existence, from a particular point in time up to the present, destines and separation from other *IsiZwe*
d) Occupies a specific geographical area, and
e) Has a number of *IsiGodi* under Induna

Moreover, Chapter 5 of this Act highlights the roles, powers, functions of the traditional leaders. Whereas, Sub-section 34 provides the cooperative governance between municipalities and traditional councils for planning and development and other aspects.

## 2.9 CONCLUSION

This chapter managed to provide with the clarity, evaluation, discussion and summary of a wide range of literature from various scholars, scientists, and practitioners related to the assessment of the application and effectiveness of remote sensing (RS) and geographical information systems (GIS) for mapping and monitoring land use and land cover changes for development planning. To contextualize this study, this chapter also provided the relevant South African policy and legislative framework. The following chapter provides with the conceptual and theoretical framework related to the study.

## CHAPTER THREE: CONCEPTUAL AND THEORETICAL FRAMEWORK

### 3.0 INTRODUCTION

This chapter presents and discusses key concepts that underpin the study conducted, it further discusses the theoretical framework related to the study. This chapter commence by the conceptual framework, which identifies and assesses those key concepts that were relevant in contextualizing the study. Subsequently, theoretical framework examines and reviews theories that deemed relevant to the assessment of application and effectiveness of remote sensing and GIS, for mapping and monitoring land use and land cover change for development planning.

### 3.1 CONCEPTUAL FRAMEWORK

*3.1.1 Remote Sensing (RS)*

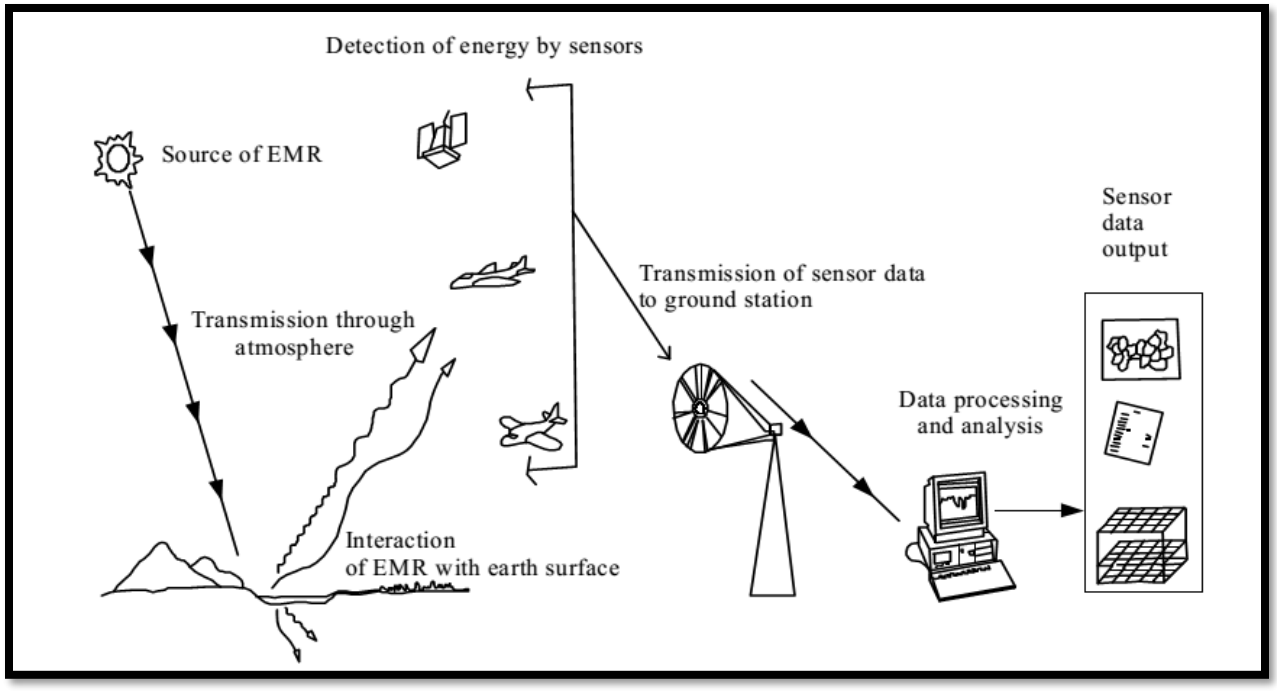
Remote sensing (RS) also called earth observation, refers to the technique used to acquire information about objects or areas at the Earth's surface, without being in direct contact with the object or geographical area (Lillesand *et al*, 2014). This art and science of obtaining information in case of this study about land use/land cover change and monitor peri-urban expansion and trends of growth from distance with the help of software in the specific area over a certain period of time. It is not limited by the different land tenure system between municipal and traditional authorities, as the sensors (active or passive), and other software detect required information on the target of the Earth's surface regardless of being rural or urban. According to Patra (2007) and White (1997), remote sensing imagery are obtained with a sensor other than (or in addition to) a conventional camera through which a scene is recorded. This incorporates electronic scanning, using radiation outside the normal visual range of film and camera, that include thermal, infra-red, radar, microwave, ultraviolet, as well as multispectral, special techniques which are supplied to process and interpret sensing imagery for the purpose of producing land use/ land cover maps, thematic maps in the field of geography and planning etc (Gu *et al*, 2016).

According to Lawrence and Jewett (2013), remote sensing technique in development planning act as a data source for monitoring of urban expansion and land use/ land cover trends in a particular geographic area over a certain period of time. Moreover, Campell (1996) mentioned that there are various stages for remote sensing needs to be followed in order to be able to acquire information on the Earth's surface which are as follows:

- A source of electromagnetic radiation or EMR (sun)
- Transmission of energy from the source to the surface of the Earth, through atmosphere
- Interaction of EMR with Earth's surface
- Transmission of energy from surface to remote sensor mounted on a platform, through atmosphere
- Detection of energy by the sensor
- Transmission of sensor data to ground station
- Processing and analysis of the sensor data, and
- Final data output for various types of application e.g for planning

Figure 3.1 below shows how remote sensing system gives a synoptic view of the surface of the earth using various stages.

*Figure 3.1: Stages of Remote Sensing System*




*(Data Source: Patra, 2007)*

*3.1.2 Geographical Information System (GIS)*

GIS refers to a computer based analytical technique used to capture, store, manipulate, analyze, manage, analysis of spatial related data components (Richards and Jia, 2006). According to Chang (2010) and Li *et al* (2005), this analytical technique can be manipulated in order to analyze data visually and interpret the

trends, patterns, and relationships that might not be visible in a written or tabular form. GIS has been used by the municipalities to produce various maps using remote sensing imagery as a base layer in development of thematic maps and geospatial datasets (Merchant and Narumalani, 2009). In the municipalities, these maps are used for conceptualization and formulation of the spatial development framework (SDF), integrated development plans, zoning, land use management plans, local area development plans, with the intention to facilitate and guide development within its area of jurisdiction including rural and traditional council areas. In this study, these maps and tables are used to determine the trends of growth and development, and for the identification of any growth and development that are inconsistent (including those occurring on environmentally sensitive areas, near road and railway corridors etc) with the municipal development plans, so that the municipality will be proactive in the implementation of development controls. According to Chang (2010) GIS provides with a platform to query spatial and attribute data, and has interrelated five components which are as follows;

- Software- refers to the functions and tools needed to capture, analyze, store, management, and display as output spatial and attribute data. For example, the use of ArcGIS software.
- Hardware- this component is made up of the tangible equipment such as computer (monitor, mouse, keyboard, and tower), geographical positioning system (GPS) receiver which is used to collect coordinates for a particular land use (s), printers, and scanners.
- Human- the personnel who operate GIS system
- Data- it is the information to be represented
- Procedure- this refers to the methods that need to be established and followed to achieve its objective

*3.1.3 Land Use and Land Cover (LULC)*

The concepts of land use and land cover are consistently used interchangeable in the literature (Dimyati *et al,* 1996). In terms of definitions, land use refers to the extent to which land has been utilized by humans for habitat and their diverse socio-economic activities on the earth's surface (Rawat and Kumar, 2014). According to Briassocilis (2003), this concept incorporates the human-induced activities that directly relate to land, making use of its resources or having an impact on them. Subsequently, land cover refers to the biophysical state of earth's surface and immediate subsurface (Rawat and Kumar, 2014). It also includes the type of vegetation that covers the land surface, other aspects of the physical environment, such as soil, biodiversity, surfaces, and groundwater, as well as to human structures, such as buildings or pavements (Briassocilis, 2003; Rawat and Kumar, 2015). The intention of this study is to monitor and map LULCC trends

for development planning, to determine the extent to which urban expansion has decreased green or agricultural potential areas over a specified period of time in uMnini Trust traditional council using remote sensing and GIS between 2001 and 2016. Therefore, this study determines the rate and magnitude of LULC changes as a result of diverse socio-economic activities and increasing population which implicates land use and natural status of land cover.

*3.1.4 Land Use Management System (LUMS)*

According to Seto *et al* (2014) Land use management system refers to the system that is officially declared useful in determining and regulating the development and use of land in a particular geographical area like uMnini Trust traditional council. In the same line of thought, Charlton (2008) adds that in the South African context, this system (LUMS) has been regulation orientated, the idea is to control the impacts and consequences of human-induced activities that are regarded as negative to development, although it encourages desirable development. According to South African Affordable Housing (2012), land use management system (LUMS) was implemented mainly in the interest of promoting sustainable development and to improve the quality of life for the public interest.

In the case of uMnini Trust traditional council, indigenous knowledge systems have been the approach used for land allocation and management. Moreover, to facilitate and regulate development and use of land in the traditional councils as they belong to Ingonyama Trust which has different system to the one used by the municipality. The SPLUMA and PDA promote wall-to-wall planning scheme which means there must be a collaboration between these systems (traditional and municipal) for land use management in these areas, to ensure that inappropriate and unregulated developments which lead to the encroachment of environmentally sensitive areas by built form as a result of urban expansion are regulated and facilitated to promote sustainable urban development.

*3.1.5 Development Planning*

According to the Local Government Development Planning Guidelines (2014), development planning refers to the planning and use of land to ensure functionality and sustainable urban development. The rational for development planning is to ensure that available resources are utilized efficiently to meet the needs of the present generation while considering that the needs of future generations will be met. In case of this study/research project, information gathered about the rate and magnitude of peri-urban densification used as a footprint that helps the municipality to determine “unregulated” and “inappropriate” developments which are in conflict with their development plans using geospatial technologies such as remote sensing and GIS

to ensure the introduction of development controls in terms of the development and use of land. As it is the case in uMnini Trust traditional council, rapid peri-urban densification has resulted to major developments that are occurring within coastal dunes, and near corridors to mention but the few. Therefore, development planning encourages the municipality to take remedial actions through drafting an action plan for sustainable urban development while ensuring the preservation of the natural environment. The study also considers a long-term development planning through the prediction and forecasting the development and use of land and LULCC in the near future to stimulates action plan to be proactive on the causes and consequences of diverse socio-economic activities that contribute to these changes.

*3.1.6 Spatial Planning*

According to Joscelyne (2015), spatial planning can be viewed as the key aspect of land use planning that should be identified as an important tool in striving towards sustainable development. In the same line of thought, Todes (2010) assert that spatial planning has been developed in response to economic, societal, and environmental issues as a mechanism to manage and guide the way in which the land is being used. Among the reasons led to the spatial planning occurred, was due to the growing recognition of issues such as spatial fragmentation, growing unregulated development, and rising environmental issues in a number of countries (Allmendinger and Haughton, 2009). EThekwini municipality has introduced uMnini Local Area Development Plan, environmental management plan, and Draft rural scheme as spatial plans aiming to facilitate and guide future development in the study area.

These spatial plans together with the municipal South Spatial Development Plan, SDF, and IDP have identified uMnini Trust as a major tourism node (eThekwini Municipality SDF, 2014-15). However, as a result of rapid peri-urban densification along the coastal strips of the study area, there was a need for the municipality to come up with spatial plans to regulate and monitor growth as it rapidly encroaches Coastal Management Zone that threatened the potential of the area as a major tourism destination. Therefore, spatial planning demonstrates a significant shift in planning focus towards a more pro-active and forward-looking approach (Todes, 2008). This approach is an important tool that goes beyond just ordinary (traditional) land use planning to bring together and integrate policies to the development and use of land with other policies and programs which influence the nature of places and how they function (Joscelyne, 2015).

*3.1.7 Traditional Council Areas*

In the context of Kwa-Zulu Natal province, traditional councils such as uMnini Traditional Council refers to the specific land ownership on behalf of the Ingonyama Trust Board within the jurisdiction of eThekwini

Metropolitan. The traditional councils were established in the early 2000s, based on Chapter 2 of the Traditional Leadership and Governance Act (No. 41 of 2003). The functions of the traditional councils include inter alia, supporting municipalities in the identification of community needs, participating in development programmes of municipalities and of the provincial and national spheres of government, promoting indigenous knowledge systems for sustainable development and disaster management, promoting the ideals of cooperative governance, integrated development planning, sustainable development and service delivery.

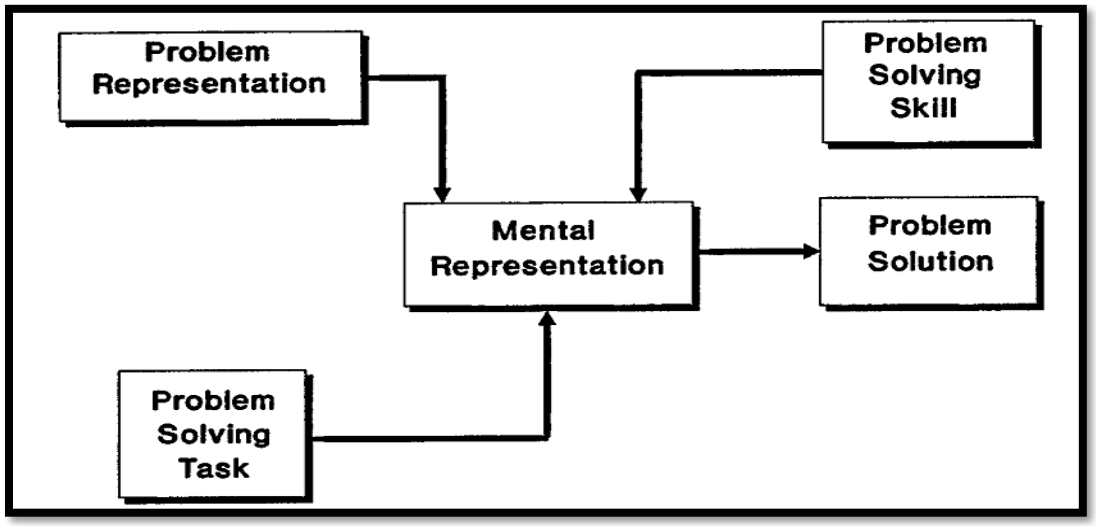
## 3.2 THEORATICAL FRAMEWORK

### *3.2.1 Cognitive Fit Theory*

#### *3.2.1.1 Historical Overview of the Cognitive Fit Theory*

Cognitive Fit Theory was coined by Iris Vessel and Galleta in 1991. It is regarded as the cost benefit and decision-making or problem-solving theory (Teets *et al*, 2010). This theory is significant to local government in search for the alternative methods to move away from traditional methods for land use planning and management, which have limitations in terms of accuracy. Figure 3.2. below illustrate the decision-making processes in Cognitive Fit Theory.

*Figure 3.2: Diagram showing Decision-Making Model for Cognitive Fit Theory*




*(Data Source: Vessey and Galleta, 1991)*

#### *3.2.1.2 Principles of Cognitive Fit Theory*

Based on Figure 3.2, the task for problem solving and the problem representation of the particular task impact the effectiveness of the problem-solving process. The problem representation (which is the information used

to represent the problem being resolved) forces policy makers or decision makers to pursue a specific mental representation (how data for a particular problem is represented) of the problem enabling to come up with an effective problem solution (John and Kundisch, 2015). In the same line of thought, Teets *et al* (2010) maintains that the way(s) in which the software user presents the problem and tasks performed for problem solving have an influence on the accuracy of the outcomes for problem-solving process. When there is an inconsistency in the problem-solving process, speed, and accuracy of data representation will be affected (Teets *et al*, 2010; Vessey, 1991; John and Kundisch, 2015).

According to Vessey and Galleta (1991), cognitive fit theory explains the fit of specific technology as depicted in Figure 3.2. GIS and other geospatial technologies such as remote sensing and aerial photographs because of their capabilities to perform a specific task are essential for decision-making or problem-solving performance. Falschlunger *et al* (2015) assert that there are different tasks involved in decision-making processes to come up with the solution to the problem like symbolic and spatial tasks. In terms of symbolic task for problem solving, this task evaluates the discrete data, exact data values in order to utilize them for best analytical processes. This task basically involves the use of techniques and tools such as remote sensing and geographical information systems which use discrete data for different types of analysis (Chan *et al*, 2012).

Subsequently, spatial tasks refer to scenarios where decision makers or policy makers analyzes the entire problem identified using techniques like remote sensing and GIS for data display and output to evaluates spatial relationships and to do comparisons in the data using maps and graphs (Falschlunger *et al*, 2015; Vessey and Galleta, 1991). In the case of this study, land use or spatial planners can manipulate data using satellite images and GIS to better understand the relationships between rapid peri-urban densification and its impacts on land use and land cover changes that influence unorderly and unregulated developments which are inconsistent with the municipal development plans in a specific area over a certain period of time. Also, enable decision makers come up with the strategies on how this problem should be addressed.

Therefore, cognitive fit theory mainly deals with effectiveness and efficiency of information analysis using decision-making support tools such as remote sensing and GIS to resolve complex spatially-related problem. According to Kuang (2012) and Unwin (2013), for task complexity, after the symbolic and spatial tasks, there must be a recognition of spatial patterns and relations of the data represented between 2-3 information cues. Better understanding of the trends or patterns of analyzed data enable decision makers to estimate the trends for future projection. In this case, in-depth understanding of land use and land cover changes can help policy

makers to make sound land use policies for the future land use planning and management purposes (Kuang, 2012; Unwin, 2013; Chan *et al*, 2012).

Kuang (2012) and Teets *et al* (2010) also mention tasks for problem solving. These tasks include exploratory, confirmatory, and production tasks. Exploratory task involves those tasks where the user evaluates the visualization from the software (either RS or GIS) to identify an underlying structure for trends in data being presented or to uncover possible hypothesis test. These trends determine the spatial distribution of the housing or settlement development and provision of public facilities and services over a certain period of time to service increasing population in a particular geographic area, moreover, mapping and monitoring the extent to which peri-urban growth has encroached green or environmentally sensitive areas.

Confirmatory task deals with the confirmation or refutation of hypothesis. For example, hypothesis of this study is that remote sensing and GIS are effective and efficient tools for mapping, and monitoring land use and land cover changes for development planning. After the analysis of the trends and their visualizations (using maps and graphs), decision makers can solve complex problem using these techniques and tools to influence decision making processes and come up with the solution to the problem which means the hypothesis of the study is confirmed or accepted. In addition, production task can be supported using visualization task-based report (Kuang, 2012; Vessey, 1991; Teets *et al*, 2010).

*3.2.1.3 Lessons from the Cognitive Fit Theory*

Local government and municipal officials employ innovative and efficient techniques and tools such as aerial photograph, remote sensing and GIS to resolve complex spatial problems within municipalities. Therefore, cognitive fit theory promotes the representation of the problem, where the users of the software and hardware are able to come up with the relevant solutions for land use planning and management in the municipality. In relation to this theory, remote sensing provides multidate imagery to identify the nature of the problem, subsequently, GIS as an analytical technique used to assess spatial patterns and displays this data for visualization and interpretation using maps and graphs, to determine the extent of land use and land cover changes over a certain period of time. The spatial trends in the data can help decision makers to come up with a sustainable solution to the LULCC problem, and to predict future land use and land cover trends in the specific area under study over time. Furthermore, decision makers' analyses and integrates the findings from both remote sensing and GIS to come up with a sustainable solution to the complex spatial problems. However, in order to produce reliable solution to spatial related problem, the user must possess necessary skills to operate these systems to solve a spatial problem.

*3.2.1.4 Critiques of the Cognitive Fit Theory*

Cognitive Fit Theory (CFT) has been criticized for exclusively concentrating on the problem solution, omitting the origin of the problem (John and Kundish, 2015). The existing information about the problem is the nature of the problem to be solved, therefore, new information is needed (working representation) to solve a particular problem (John and Kundish, 2015; Mumford and Gustafson, 2007). Basically, this new school of thought argue that human as a form of mental representation must generate new ideas for problem solving and not only rely on available information which might be inadequate to solve the problem. In the context of this study, the criticism of this theory is that it focuses on solving rapid peri-urban densification which influence land use and land cover changes, and its contribution to a grossly decline on agricultural potential areas and increased encroachment of environmentally sensitive areas caused by urban expansion. However, seeking problem solution using GIS and other geospatial technologies while omitting the root cause of the problem do not completely assist in problem solving. For example, the decision maker has to determine the root cause(s) of rapid peri-urban densification such as poverty and high land values in urban areas to mention but the few which push some to the peripheries to mention but the few, and therefore, come up with the strategy to regulate and facilitate future development in the study area, such as the introduction of the local area development plan, settlement planning, and rural scheme to achieve sustainable urban development goals.

*3.2.2 Sustainable Development Theory*

*3.2.2.1 Historical Overview of Sustainable Development Theory*

In the 1972 Stockholm Conference on the Human Environment, delegates at this conference acknowledged that there is a conflict between environment and development throughout the world (Kates *et al*, 2005). Development programs and projects occurred in an unstainable manner that resulted in degrading the natural environment and contributing to biodiversity or habitat loss (Kates *et al*, 2005). Thereafter, in 1987 there was the World Commission on Environment and Development (WCED) also known as "Brundtland Commission". This commission came out with the definition of sustainable development as the "ability to make development sustainable to ensure that it meets the needs of the present generations without comprising the ability of future generations to meet their own need" also referred to as the integrational equity (World Commission on the Environment and Development, 1987).

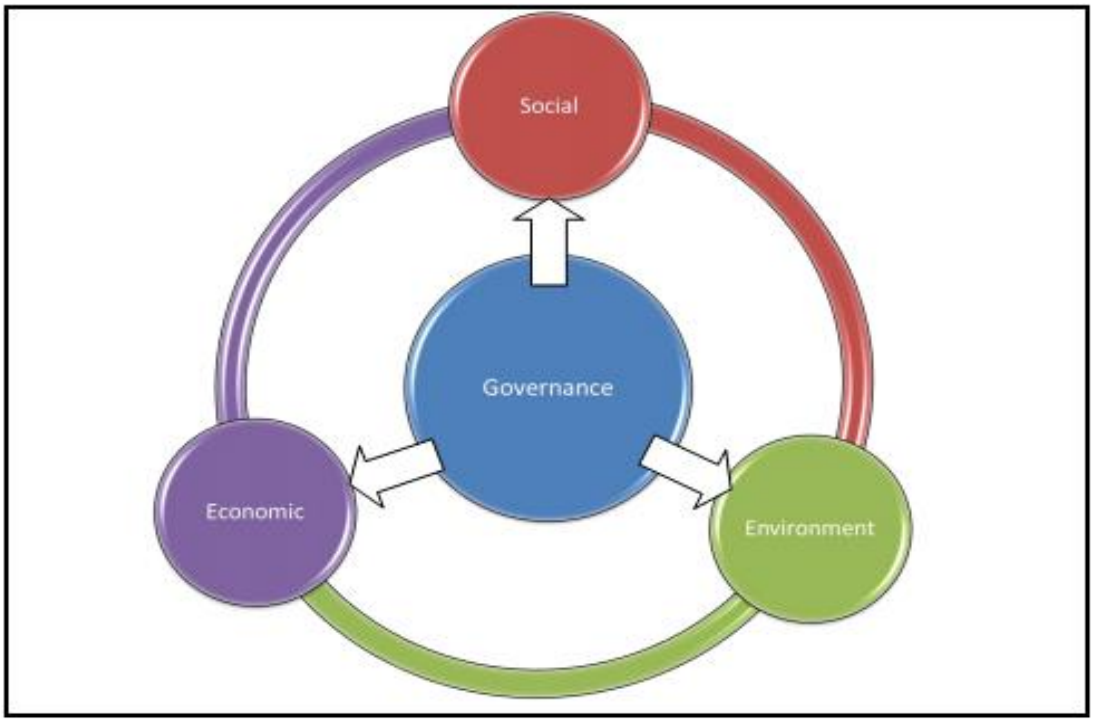
*3.2.2.2 Principles of Sustainable Development Theory*

According to Soubbotima (2004), sustainable development is the most significant approach towards integrated development and poverty alleviation throughout the world. Therefore, this approach has been

adopted by many countries of the world because of its significance in development planning and environmental management. Drexhage and Murphy (2010) point out that different countries have implemented programs and policies in order to improve the living conditions of the poor in their countries with an integration of the three pillars of sustainable development which incorporates; social, economic, and the environment. Developing and less developing countries are at the forefront of sustainable development while developed countries make it the least of their priorities. In South African, sustainable development has been adopted in order to redress the spatial, social, and economic inequalities of the apartheid government and to better the future for South African citizens (Dixon and Pretorius, 2001). Moreover, sustainable development in South Africa aims to improve the provision of social services like health, education, infrastructure, welfare, and to improve the economy of South Africa and ensure that development occur whilst the environment is well protected (Dixon and Pretorius, 2001).

Cristiana *et al* (2014) contend that sustainable development can also be viewed as both the principle that has to be taken into consideration and a development outcome of a planning process. Damtoft *et al* (2008) argue that sustainable development represents the new theory of development. It shifts the traditional approach of development actions at international level that promoted top down approach of development with limited participation of local people towards a broad-based participation by all interested and affected parties. According to Deliadebina (2012), in addition to the three original pillars of sustainable development, there is an additional pillar, which is governance that ensures that development take place in an honest, transparent and non-corrupt manner. Figure 3.3 below show pillars of sustainable development.

*Figure 3.3: The Diagram for Four Pillars of Sustainable Development Theory*




*(Data Source: Mngadi, 2013)*

*3.2.2.2.1 Governance*

As depicted in Figure 3.3, governance remains at the center of these three pillars of sustainability/ sustainable development to provide guidance in terms of their functioning. These pillars of sustainability are there to make sure that development projects and programs integrate social, economic and environmental spheres for the development to be sustainable. In terms of the nature of this study, governance meant to ensure that housing or settlement development occurring within coastal management zone (between coastal strips and N2 of uMnini Trust traditional council) are facilitated and controlled as this diminishes urban sustainability and threatened coastal dunes. Therefore, this unregulated development in the study area should be regulate by considering social, economic, and environmental protection for future developments to achieve sustainable development goals.

*3.2.2.2.2 Economic Sustainability*

According to Harris (2003), an economically sustainable system is mandatory to ensure that goods and services are produced on a continuing basis to improve the fight against poverty. In addition, economic sustainability maintains manageable levels of government and external debt, and avoids extreme sectoral imbalances that damage the environment, agricultural or industrial production. In case of this study,

economic sustainability means preservation or conservation of the environment, through facilitating and regulating rapid peri-urban developments, that consume agricultural potential areas which result to a decline on agricultural production and affect food security.

*3.2.2.2.3 Environmental Sustainability*

This pillar of sustainability promotes an environmentally sustainable system that maintains a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classified as economic resources (Harris, 2003). In ensuring environmental sustainability in the study area, the municipality has to implement development controls and those well documented spatial plans to regulate and facilitate future development along the coastal areas of uMnini Trust traditional council. Even though the municipality encourages densification along transportation routes, however, this should not affect urban sustainability as it is a case within the coastal management zone of the study area (uMnini LADP, 2006).

*3.2.2.2.4 Social Sustainability*

The mandatory obligations of this pillar of sustainability is to achieve fairness in distribution of resources and opportunity. There should be adequate provision of social service delivery including health, and education, gender equity, and political accountability and participation (Harris, 2003). Deliadetsima (2012) argue that there is a strong relationship between sustainable development and spatial planning. Land use and development of buildings and infrastructure development usually result to various implications that affect sustainable development. According to Naess (2001), to achieve social sustainability the development of land uses, patterns of built up areas and infrastructure and services in a particular geographic area should be sustainable, therefore, it must ensure that inhabitants of the area attain their basic needs in a way that can be sustained in the future, and consistent with universe sustainable development objectives.

This interrelationship is combined under the umbrella term of sustainable urban development or the “extreme” sustainable city (Hove, 2004). This demonstrates that sustainable development and spatial planning are integrated because of dramatic climate change and increasing socio-economic problems in cities and regions throughout the world (Bossel, 1999; Deliadetsima, 2012). According to uMnini LADP (2006), social sustainability in uMnini Trust would inter alia entail appropriate basic needs provision, development of relevant social facilities, establishment of social structures to accommodate the needs of the population all of which, has to be sustainable in terms of affordability.

*3.2.2.3 Lessons from Sustainable Development Theory in Development Planning*

Environmental externalities such as rapid population growth in peri-urban, towns and cities especially in developing countries have introduced a serious concern on the future of our wellbeing and even our existence in the long run (Mahbub e*t al*, 2011). These externalities such as rapid urban growth has contributed to land use and land cover changes over time in particular geographical area as it is the case in uMnini Trust, therefore, for development planning processes the authorities have to regulate and facilitate these unsustainable actions responsibly, and effectively through the promotion of eco-friendly practices to achieve urban sustainability. According to Sachs (2015), sustainability and sustainable development has become the familiar concept and theory in the literature for urban planning, development, and management, and also for urban policy makers and professional practices.

This is because of the fact that sustainability and sustainable development promote social and economic development without compromising environmental development for future generations. Development and spatial planners encourage the sustainable cities formation via the leverage of urban planning and design to ensure that any development projects minimize environmental impacts, but maximize environmental benefits (Cecere e*t al*, 2014). In the face of climate change which threatens sustainability and sustainable development, towns and cities undergone development planning has to also consider resilient cities in order to adapt easily to shocks or stresses caused by environmental externalities (Cecere e*t al*, 2014; Sachs, 2015; Singh *et al*, 2012).

*3.2.2.4 Critiques of Sustainable Development Theory*

Different scholars have criticized this theory contesting that this notion of sustainable development as a universal solution to all the global environmental problems is ineffective and has failed (Critiana *et al*, 2014). According to Hove (2004), sustainable development is a fantasy theory and in terms of practice as in west countries, there is an excessive consumption that is environmentally unstainable. Fernado (2003) contend that sustainable development promotes development projects and programs that consider environmental development. However, western countries which are the largest emitters put sustainable development as the least of their priorities. Escobar (1995) assert that sustainable development is a fallacy, as it tends to put economic development over environment. Therefore, sustainable development is equivalent to growth (capital market expansion) not the environment. This is derived from the fact that maximization of capitalist market expansion and being environmentally sustainable and equitable consumption cannot be achieved simultaneously, there will always be the one that supersedes another (Ferando, 2003; Hove, 2004). In terms

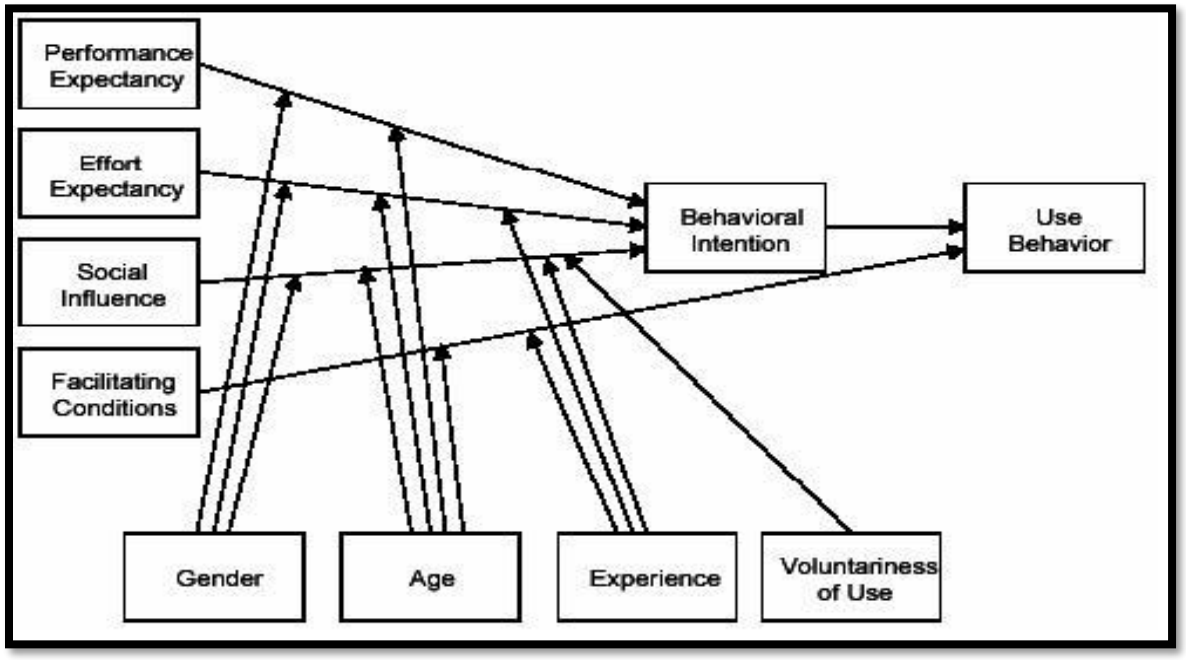
of the implications for this study, prevalence of unregulated or unplanned rapid densification along the coastal areas of uMnini Trust traditional council, has caused serious environmental degradation and compromise sustainable urban development as there are housing or settlement (social development) occurring within Coastal Management Zone that supersedes environmental protection as discussed by Ferando (2003) and Hove (2004). When these pillars of sustainability are not balanced, sustainable development goals are compromised which is not good for future generation. In this study, social development has eventually superseded environmental management, as the people are degrading agricultural potential areas in search for cheaper farm land in peri-urban areas.

### *3.2.3 Unified Theory of Acceptance and Use of Technology Model (UTAUT)*

#### *3.2.3.1 Historical Overview of the UTAUT*

In the past few decades, the design, development, and acceptance of technology have gained more attention in developing countries through the UTAUT. Unified Theory of Acceptance and Use of Technology Model (UTAUT) was developed by Vankatesh *et al* (2003) as a comprehensive synthesis model of individual acceptance that is compiled because of the influence of revision and integration of the eight dominant theories or models (Tan, 2013). These models or theories are as follows: theory of reasoned action (TRA), theory of planned behavior (TPB), technology of acceptance model (TAM), social cognitive theory (SCT), innovation diffusion theory (ID), model of PC utilization (MPCU), the combination of technology acceptance model and the theory of planned behavior. UTAUT emerged because there was a need for the establishment of advanced technological innovations and application that have positive impacts on human and work life. This encouraged the organizations and governments to adopt the use of information technology (Taiwo and Downe, 2013). Card *et al* (2013) argue that UTAUT also was influenced by the increased interaction between human and computer to perform a specific task. Vankatesh *et al* (2003) and Taiwo and Downe (2013) maintain that this interaction tends to be affected by various factors that influences humans to use computer and its applications. Figure 3.4 below presents the diagrammatic view of the Unified Theory of Acceptance and Use of Technology Model.

*Figure 3.4: The Unified Theory of Acceptance and Use of Technology Model (UTAUT)*




*(Data Source: Vankatesh et al, 2003)*

In reference to this study, remote sensing and GIS are computer-based systems used for many operations and applications through their wide implementation in many disciplines (Chang, 2010). The integration of these innovative and efficient systems assists the municipalities, and other institutions to understand how LULCC change affects and interacts with global earth systems, therefore, information is needed on what changes occur, where and when they occur, moreover the rates at which they occur, and the social and physical forces that drive those changes (Lambin, 1997). In case of this study, changes in land cover and in the way, people use the land have recognized over the last 15 years is important for environmental management and development planning (Turner, 2002). The emergence of the high-tech like GIS and remote sensing systems has assisted in a consistent monitoring and modelling of land use/land cover patterns. According to Kachhwala (1989), the application of remotely sensed data made possible to study the changes in land cover in less time, with a better accuracy in association with GIS that provides suitable platform for data analysis, update, and retrieval (Chilar, 2000; Kachhwala, 1989). However, despites the positive outcomes of these systems it is maintained in Alwahaishi and Snasel (2013) that in developing countries, it is the lack of top management support and capital resources that stand as barriers in information technology adoption and advancement.

*3.2.3.2 Principles of Unified Theory of Acceptance and Use of Technology (UTAUT) Model*

According to van Schaik (2009) in relation to Figure 3.4 above, there are four core constructs of the UTAUT which include; performance expectancy, effort expectancy, social influence, and facilitation conditions. Vankatesh e*t al (*2003) and van Schaik (2009) contend that performance expectancy refers to the mentality of the user of the system either remote sensing or GIS believing that the use of the system can help in performing the task. Effort expectancy also depends on the user behavior that the system that he/she is using will be easy to use based on the skills the practitioner possesses. Social influence includes external forces such as other humans who influences the user of the system. The final contrast, facilitating conditions are based on the user behavior that the organizational and technical infrastructure are there to assist in the use of the system.

The abovementioned factors are influenced by experience, age, gender, and voluntariness of use from the practitioner for effective acceptance of the technology in the organization or government (Vankatesh e*t al, 2003*; van Schaik, 2009; Williams *et al*, 2015; Ahmad *et al*, 2014). The prevalence and use of GIS and other related geospatial technologies by the municipalities like eThekwini Metropolitan and other institutions for their day-to-day operations make it easier for decision-making process. However, as illustrated by Vankatesh et al (2003), the effectiveness and accuracy of these technologies entirely depends on the vast experience and age of the user. In terms of this study, acceptance of geospatial technologies such as GIS and remote sensing for mapping and monitoring land use and land cover change for development planning could help the authorities for supplementary planning methods and to resolve complex spatial related problems.

*3.2.3.3 Lessons from the Unified Theory of Acceptance and Use of Technology Model (UTAUT)*

Different organizations and government departments require advanced technology and innovation to perform their day-to-day duties and to acquire current and up-to-date information that helps in decision making process. The acceptance and use of the advanced technologies like remote sensing and GIS, requires the practitioner with relevant skills and expertise, and vast experience to use the technology in order to yield high accuracy results. To obtain best results within municipalities and other institutions for planning and other software purposes, as depicted on Figure 3.4 this is entirely depends on the user behavior and belief that the system (in this context GIS and remote sensing) will assist in completing tasks. The acceptance of remote sensing and GIS and their use for development planning requires the organization and local government to have technical infrastructure in order to enable the effective use of the system. The application of these

systems contributes to human wellbeing because their ease of use, ability to achieve the task, and their positive impact on the workplace performance.

### 3.3 CONCLUSION

This chapter discussed key concepts and theories underpinning this study, their applications and their relevance to remote sensing and geographical information systems for mapping and monitoring land use and land cover changes for development planning. The use of concepts such as remote sensing, GIS, land use and land cover, spatial and development planning etc compliments with the theories presented on this chapter, and they have immense implication on this study. As the use of remote sensing and GIS requires make day-to-day easier and needs someone with relevant skills and expertise to operate the systems in order to yield expected outcomes. Therefore, better understanding of these techniques and tools guarantees positive decision-making process in a fight against development of peri-urban densification which diminishes the right of future generation to meet their needs on a conducive environment. Chapter two that follows reviews relevant literature that relates to this study, it further discusses the related South African policy/ legislative framework.

## CHAPTER FOUR: RESEARCH METHODOLOGY

### 4.0 INTRODUCTION

This chapter provides with the methods and techniques used in this study to gather information about the assessment of the application and effectiveness of remote sensing and geographical information systems for mapping and monitoring land use and land cover changes for development planning. Methodology provides the basis for meeting the overall objectives of the study, as it has been outlined in an introductory section. The main objective of this study was to assess the application and efficacy of remote sensing and geographical information systems (GIS), for mapping and monitoring LULCC trends of uMnini Trust traditional council between 2001 and 2016 for development planning.

### 4.1 RESEARCH DESIGN

According to Vosloo (2014) research design refers to "*a strategic framework for action that serves as a bridge between research questions and execution, or implementation the research strategy"*. In the same line of thought, Parahoo (1997: 142) adds that research design refers to "*a descriptive strategy on how, where, and when data will be collected and analyzed*". This study employed the case study research design to provide a descriptive or explanatory analysis of the rapid peri-urban densification and its impacts on LULC and in ensuring sustainable provision of infrastructure, and services more especially in areas administered by traditional councils. This study provides with an in-depth assessment of the application and effectiveness of using innovative and efficient techniques and tools such as satellite images (remote sensing) and GIS as supplementary planning methods for peri-urban densification and trends of growth analysis.

Analytical study of this nature was significant from the eThekwini municipality to incorporate this increasing peri-densification on their development plans. Moreover, incorporating accurate and current information which provided on a weekly or monthly basis while the traditional planning methods used by municipalities such as aerial photographs and sample surveys for population density and trends analysis provide this kind of information on a yearly basis despite the fact that the population grows on weekly or monthly basis in peri-urban areas. Therefore, the adoption of the innovative and efficient techniques as supplementary planning methods for land use planning and management, was an approach to acquire LULCC on a frequent basis in ensuring sustainable equitable and efficient provision of public services and amenities like water, housing, and sanitation.

## 4.2 METHODS OF DATA COLLECTION

According to Buthe and Jacobs (2015) and Kathari (2004), the concept of research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. In it we study the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them.

This study adopted a mixed methods of data collection, mixed methods focus on collecting and mixing both qualitative and quantitative data in a single study. This combination of methods was employed in this study in order to provide a better understanding of research problems than either approach. Qualitative research method defines as a type of research method that investigates and seeks answers to a question, collects findings, produces findings that were not determined in advance and produces findings that are applicable beyond the immediate boundaries of the study (Flick, 2009). The benefits of qualitative research are that, it provides complex textual descriptions of how people experience a given issue, it makes use of open-ended questions and gives participants the opportunity to respond in their own words, rather than forcing them to choose from fixed responses. Also, qualitative research is "*a form of systematic empirical inquiry into meaning"* (Shank, 2002:5), while Lincoln (2000:3) states that qualitative method is "an *interpretive and naturalistic approach*". Meriam (2009) and Terrel (2012) argue that qualitative research approach has enabled the researcher to source and elicit adequate information during personal interviews, observations and so forth.

Subsequently, Cresswell (2013) states that quantitative research method is "an approach for testing objectives theories by examining the relationship among variables. These variables can be measured, typically on instruments, so that numbered data can be analyzed using statistical procedures". These methods are useful for data collection in addressing a specific research. Quantitative research method typically deals with numbers and anything that is measurable in a systematic way of investigation of phenomena and their relationships begins with data collection based on a hypothesis or theory and it is followed with application of descriptive or inferential statistics. Surveys and observations are some examples that are widely used with statistical association. So, the mixed methods yield good results as opposed to adopting either method.

## 4.3 SAMPLING AND SAMPLING METHODS

According to Webster (1985) cited in Mugo (2002), defines sampling *"as the act, process, or technique of selecting a suitable sample, or represent finite part of s statistical population whose properties are studied to*

*gain information about the whole selected population".* For Kumar (2011), the main intention of sampling in the mixed research methods (qualitative and quantitative) is to acquire an in-depth understanding of the factors being studied.

*4.3.1 Purposive Sampling*

According to Etikan *et al* (2015), purposive sampling is a non-random technique that does not need underlying theories or a set number of participants. The researcher sets out the people who can and are willing to provide the information by virtue of knowledge and experience. The acquisition of primary data was from thirteen (13) key research respondents to this study. This study used *random or chain sampling technique,* which is a non-probability sample that is created by using members of the group of interest to identify other member of the group like asking a subject at the end of the interview for suggestions about who else to interview for better understanding of the matter under observation (Perrsman, 2014). In this technique, the respondents were selected based on their knowledge and experience they had about the application and effectiveness of remote sensing and geographical information for mapping and monitoring land use and land cover changes for development planning.

In addition, the research respondents incorporate a senior manager from Corporate GIS Unit responsible for photogrammetry and senior GIS specialist; senior spatial planner and GIS Technician from KwaZulu Natal Corporative Governance and Traditional Affairs (KZN- Cogta), Senior Manager: Land Use Management, Senior Development Planner, Senior Spatial Planner, GIS and Remote Sensing expert, Coordinator: Land Use Management (South Region), IDP Manager, and Senior Technical Planner from eThekwini Municipality Department of Development Planning, Environment and Management unit, Chief(*Inkosi*) of uMnini traditional council. Last but yet importantly, a senior town planner from the planning consultancy that was appointed to prepare uMnini Local Area Development Plan and Draft Rural Scheme aimed to guide and facilitate future developments in the study area.

## 4.4 INSTRUMENTS FOR DATA COLLECTION

In this study, interview schedule was used to gather information from key informants who are experienced in their respective fields, this instrument was part of qualitative methods. This study also incorporated the review of documents such as eThekwini Municipality Integrated Development Plan (IDP) 2017-2021 and Spatial Development Framework (SDF) 2017-18, uMnini Local Area Development Plan and Draft Rural Scheme to determine future municipal development plans within the study area which will eventually implicates land use/ land cover changes. The purpose of reviewing these documents was to assess the

plans for the provision of infrastructure and services, as the increasing population is not only implicating land use and land cover but also the municipal development plans. However, the population that increases on a weekly or monthly basis also requires their infrastructure and social services from the responsible municipality which should be incorporated on their municipal package of plans (such as IDP and SDF). Also, there were on-site observations and one-on-one in-depth interviews with key stakeholder respondents that had knowledge and experience about the topic to address the objectives and questions of this study. This study also employed tools and techniques such as remote sensing and GIS for quantitative data of the study to map and monitor the extent to which land use and land cover changes as a result of rapid peri-urban densification. ArcGIS under quantitative data analysis was chosen over other analytical tools such as QGIS was based on its capabilities for capturing, storing, manipulating, management, and output satellite images for land use/land cover change analysis. For satellite images, Landsat was the one provided this information for free which incorporates the collection of Landsat imagery data for 2001, 2006, and 2016 from National Environmental Affairs and perform a broader analysis for visual observation and interpretation of LULCC using aforementioned techniques for mapping and monitoring for development planning in uMnini Trust traditional council during the study period.

*4.4.1 Primary Data*

Primary data refers to those which are collected for the first time and are always given in the form of raw materials and originals in character. The importance of primary data collection for research is that this data is not been manipulated (Mottier (2005). In the context of this study, primary data was gathered through the use of interviews and on-site observations.

*a) Interviews*

Interview as a qualitative data collection method refers to a conversation whose purpose is to gather description of the (life world) of the interviewees with respect to interpretation of the meanings of the described phenomena (Kvale, 1996 cited in Alshenqeeti, 2014). Therefore, interview is an extendable conversation between partners that aims at having an "in-depth information" about a certain topic or subject, and through which a phenomenon could be interpreted in terms of the meaning's interviewees bring to it (Schostak, 2006:54). A series of interviews using semi-structured questions were conducted with thirteen (13) key stakeholders' informants such as Integrated Development Planning (IDP) manager from eThekwini municipality.

The other key informants were the senior spatial planner and GISc Technician from KZN Corporative Governance and Traditional Affairs (Cogta) who were interviewed on whether the municipalities have the capacity to employ these innovative and effective techniques and tools for land use planning and management. During these interviews, attempt was made to find out how these tools and techniques influence the day-to-day operations of the municipalities. The other interviewees (key informants) incorporate senior development planner, senior spatial planner, Remote Sensing and GIS expert, senior manager land use management, LUMS coordinator (South Region), and senior technical planner from the department of Development Planning, Environment and Management Unit from eThekwini Municipality. In addition, this study also conducted interviews with the senior town planner from the planning consultancy that prepared Local Area Development Plan (LADP) and Draft rural scheme of uMnini Trust traditional council on behalf of the municipality. Moreover, the interviews with the manager specializing in Photogrammetry and GIS specialist from Corporate GIS, and traditional leaders were represented by the chief (*iNkos*i) of uMnini Trust traditional council. The recruitment strategy for these participants was made through phone calls to schedule for an interview because of their other commitments on their busy day-to-day schedule this was a more effective strategy, fortunately there was a strong a communication via emails with some of them which made this process much easier to arrange interviews with them.

*(b) On-Site Observation*

According to Maree (2007), observation is a systematic process of recording the behavioral patterns of participants, objects and occurrences without necessarily questioning or communicating with them. An everyday exercise or activity which allow sensors (seeing, hearing, touching, smelling, etc) to be used to gather data. Gorman and Clayton (2005:40) tried to attempt defining observation studies as those that involve the systematic recording of observable or behavior in a natural setting. Observation is a crucial qualitative data collection method used where the researcher observes or measure the world around them in the purpose of answering research questions. Furthermore, it permits the researcher to gain deeper insight and understanding of the phenomena being observed. The use of this method is of utmost importance as it was used as a verifying strategy to what is on the ground. Therefore, the researcher as he is familiar with the study area undertaken a fieldwork to observe the impact of dense housing or settlement developments on LULCC which are prevalence on the coastal areas either side of the N2 of the study area.

*4.4.2 Secondary Data*

Secondary data sources are defined as data that has already been produced. This study used relevant journal articles, books, newspaper, published and unpublished reports, Statistics South Africa (StatsSA) socio-economic indicators for demographics analysis of the study area, municipal by-law, provincial, and national government policies and legislation using internet and library to access these data sources. This study also used the latest Integrated Development Plan (IDP) and Spatial Development Framework (SDF) of eThekwini Municipality, and the Local Area Development Plan, and Draft Rural Scheme of uMnini Trust traditional council to observe the municipal strategic plans for the provision of facilities and services to the communities that are affected by rapid peri-urban population growth, and that were previously excluded from development mainstream by the apartheid planning like uMnini Trust.

## 4.5 DATA ANALYSIS

In qualitative data analysis, this study adopted a thematic analysis. The data collected was arranged into themes considering the research questions introduced on the introductory section of this study. According to Boyatzis (1998) cited in Braun and Clarke (2006), maintains that thematic analysis is a method for identifying, analyzing, and reporting pattern (theme) within the data. It minimally organizes and describes data set in (rich) detail. For data analysis in the quantitative data, the study used both remote sensing and GIS for visual observation and interpretation of Landsat multidate imagery for 2001, 2006, and 2016 to compare and identity LULC changes, and subsequently comparing results within the study period.

## 4.6 ETHICAL CONSIDERATION

To comply with the UKZN Ethics, the permission for gatekeepers was obtained from the relevant departments to enable to conduct in-depth interviews with the key respondents of this research project. These departments incorporate eThekwini Municipality Development Planning, Environment, and Management Unit, Corporate GIS Unit, Planning consultancy that prepared uMnini Local Area Development Plan and Draft rural scheme, and KwaZulu Natal Corporative Governance and Traditional Affairs (KZN-Cogta) department. Moreover, all the research participants were given informed consent form which highlights that the confidentiality of the participants is guaranteed as inputs were not be attributed to you in person but reported only as a participant member opinion. Also, the involvement of the participant is entirely voluntarily and he/she can withdraw any time from the research. The involvement is purely for academic purposes only, and there are no financial benefits involved throughout the process. The participants have a liberty to choose if they are willing to be interviewed whether they are willing to be recorded or not during the interview. Trustworthiness of this study

was ensured by going back to respondents with the research findings to check if it truly reflects the views of their responses given during the data collection process.

## 4.7 LIMITATIONS OF THE STUDY

There were quite a number of difficulties encountered during this research project, firstly, the respondents were not available during the proposed time slots because of the other commitments that derived in short notice. This kind of arrangement with municipal officials and chief was problematic because they were busy and their availability was unpredictable. Subsequently, the delays on getting satellite imagery delayed the process. These factors resulted to some delays on the submission of chapters as proposed, however, the researcher managed to overcome these difficulties by persuading the respondents to squeeze on their busy schedule and provide the responses. Moreover, the multidate images for 2001, 2006, and 2016 to categorize/analyze LULC within the study period were obtained freely from National Environmental Affairs rather than to wait for South African National Space Agency (SANSA) which took too long to provide requested satellite images as the others years were not available because of faulty tapes on their side which delayed data collection process.

## 4.8 CONCLUSION

This chapter managed to provide with the methods and techniques used to this study for data collection. This study further discussed primary and secondary data sources, instruments for data collection and the sampling method adopted by this study. It also discussed the limitations and ethical consideration. For data analysis, this study adopted the thematic methods for qualitative data, and the adoption of ArcGIS to determine LULCC on the multidate satellites images for quantitative data analysis.

## CHAPTER FIVE: INTERNATIONAL AND SOUTH AFRICA PRECEDENTS

### 5.0 INTRODUCTION

This chapter provides with the international and South Africa precedent case studies about the application and effectiveness of remote sensing and geographical information systems for mapping and monitoring land use and land cover changes for development planning. In this chapter, the precedent case studies to be discussed include three counties (Hanrock, Harrison, and Jackson) within the States of Mississippi, United States as a developed country. Moreover, the chapter will also discuss the case of the study that was conducted in the Tirupati, which is an urban area situated nearby the metropolitan city of Chennai, India. It will further present and discuss the local precedent case study which is the City of Port Elizabeth, Eastern Cape, South Africa.

### 5.1 PRECEDING CASE STUDIES

*5.1.1 Developed Country Case Study: Hanrock, Harrison, and Jackson Counties within the States of Mississippi, United States of America*

The study about the application and effectiveness of remote sensing and GIS for mapping and monitoring LULCC, was conducted in three counties that include Hanrock, Harrisson, and Jackson, within the State of Mississippi in the United States of America. These coastal counties have undergone considerable changes in land use, demographic, socio-economic conditions and environmental stability over the past decades. These drastic changes influenced spatial planning of these counties have been studied by the Mississippi State University, Engineering Research Center in 2002 using both remote sensing and geographical information systems to analyze and quantify changes occurred in the study area over time. These changes have contributed to land use and land cover changes, therefore, in this study remotely sensed multidate imagery between 1990 and 2000 were utilized for effective rate and trends of growth analysis in these counties. This study was conducted to promote sustainable and desirable development in these counties as result of high-density development and settlements.

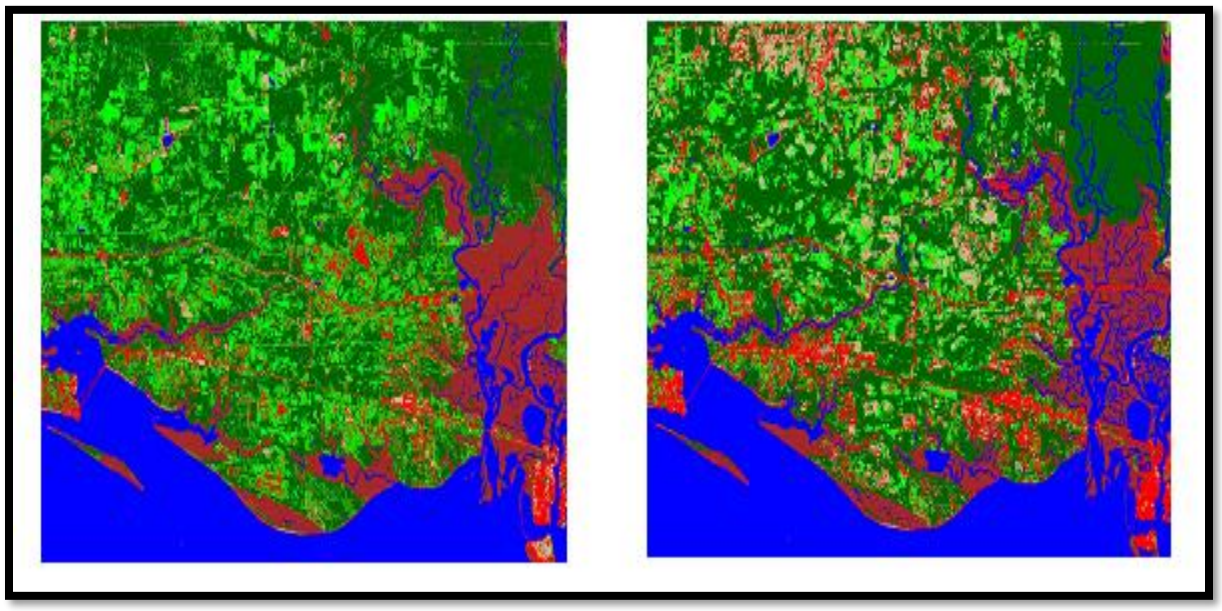
Between this 10-year time period mentioned above (1990-2000), after mapping and monitoring land use and land cover changes using maps and graphs, it was found that these counties experienced an extensive population growth and change from being small fishing communities to a complex mixture of residential, commercial, and industrial urban areas intermixed with a robust industry in the early 1990s. Moreover, changes in land use transformed and degraded natural systems and has a direct impact on biodiversity

through habitat loss. Through these changes, the study has identified a serious decline on open/green spaces and an enormous increase on built-up areas. According to Mississippi State Data Center (2001), research findings has showed that the State had an increase in population density over three decades of approximately 28% (from 2.2 million in 1970 to 2.85 million in 2000), which obviously influenced land use and land cover changes. These three counties experienced a much more accelerated population growth over the past three decades, with the total population increase of slightly less than 240 000 in 1970 to more than 360 000 in 2000, this represented an increase of more than 50%.

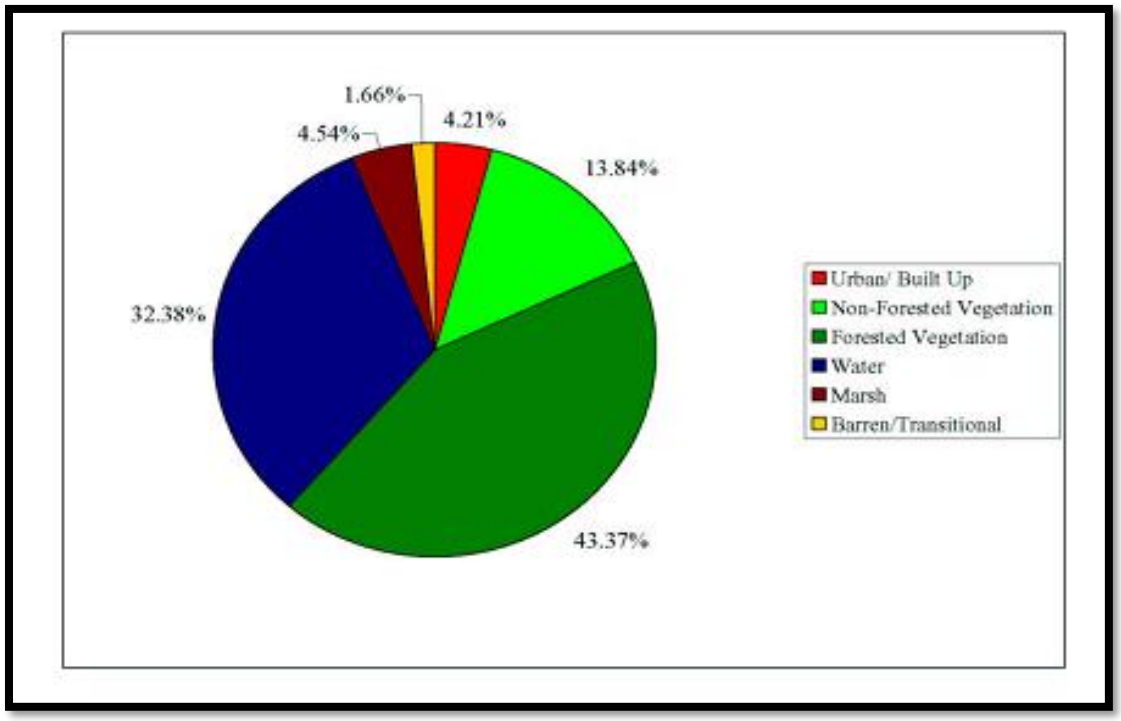
The multidate imagery data for this study to analyze and quantify urban sprawl and trend of growth through a series of maps and tables were obtained from Landsat 5 Thematic Mapper (TM) for the year 1990. Moreover, Landsat 7 Enhanced Thematic Mapper (ETM) provided imagery data for year 2000. These imagery (Landsat) data, were geo-registered to Transverse Mercator for the State of Mississippi using a common set of ground control points, with a resultant Root Mean Square Error (RMSE) of less than 9 meters (less than .33 pixels). These satellite imagery data, and other various spatial data sources were used to gain insight into development patterns, trends, and predict future growth development. For example, this study utilized demographic GIS data, National Land Cover Data (NLCD), existing aerial imagery, Multiresolution Land Characteristics (MRLC) consortium from 1992, and LULC data from Mississippi Automated Resource Information System (MARIS) from 2000.Thereafter, the analysis from NLCD and MARIS LULC data provided variable insights into certain aspects of development trends in the three coastal counties of Mississippi.

For image classification to identify different land use and land cover classes or themes over these different years, Anderson classification system for a level one classification was employed and obtained six LULC classes or theme in the study area which are as follows; urban/built up areas, non-forested vegetation, forested vegetation, marshes, barren, and waterbody. The level one classes were then used to derived level two classes where urban/ built up areas were divided into areas of residential, industrial, and transportation features using leaf-one imagery from August 1990 and July 2000. Figure 5.1 below shows land use and land cover classes or themes in (a) 1990 and (b) 2000

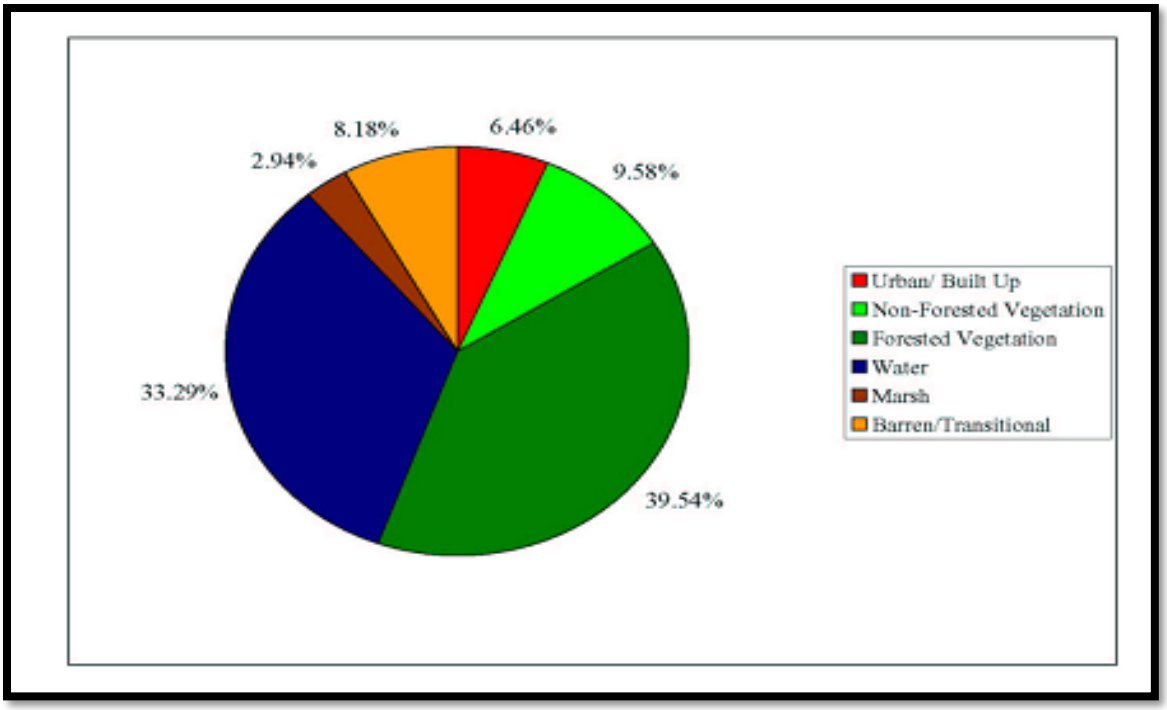
*Figure 5.1: Land Use and Land Cover or Themes for Hanrock, Harrison, and Jackson Counties within the States of Mississippi in the United States in (a)1990 and (b)2000*



(a) LULC classes for 1990 (b) LULC classes for 2000




a)




b)

*(Data Source: Mississippi State University, Engineering Research Center)*

The results of this study showed that LULC changes over the past decade occurred with an accelerated growth rate in urban/built up areas, where an increase of more than 53% was representative of the population increases for these areas. It has presented the largest conglomeration/cluster within these counties of the State of Mississippi spatial landscape. Non-forested types of vegetation and wetlands or marsh features have recorded the greatest decrease in these areas, with forest vegetation decreasing by more than 30% and coastal marshes decreasing by 35%. Accuracy assessment showed limitations in the ability to classify non-forested vegetation and barren land classes for this area.

Such development was often times constricted by various environmentally sensitive or protected areas and existing high-density development. However, the bad lesson on this case study is that Landsat did not provided very high-resolution (VHR) images which affected detailed analysis of themes or classes identified on the multidate imagery between 1990 and 2000 because of its low spatial resolution (30m x30m) capacity in urban sprawl and trends of growth analysis. Despite these shortcomings of the satellite strength, the study managed to show the capabilities of these analytical and innovative techniques and tools such as remote

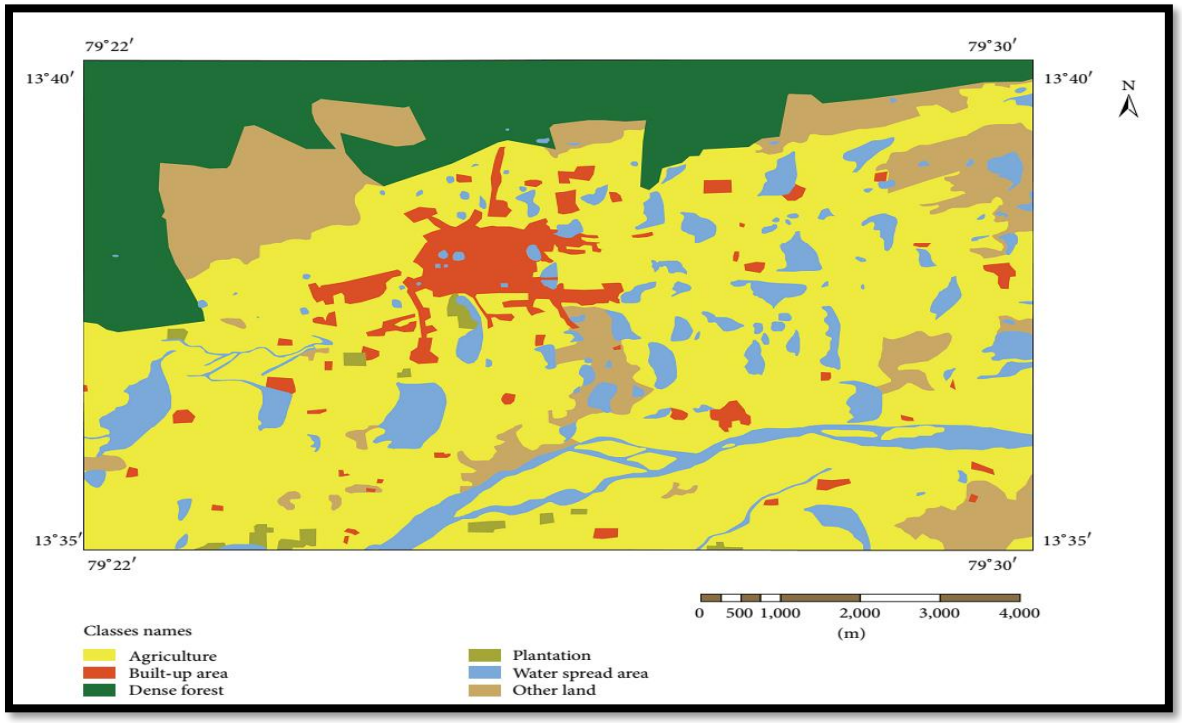
sensing (Landsat images) and GIS for mapping and monitoring land use and land cover changes in these counties for development planning.

*5.1.2 Developing Country Case Study: Tirupati Area, Indian Precedent*

The study was conducted in the Tirupati, which is an urban area situated nearby the metropolitan city of Chennai, India. Rapid influx of population in urban areas to settle for greener pastures experience rapid land use and land cover changes because of diverse socio-economic activities of this rapid increasing population. Therefore, the local government of India undertook a study to analyze and quantify rate and magnitude of changes that had occurred in the study area between 1976 and 2003. Therefore, this study used the multidate imagery from 1976 to 2003. For 1976, imagery data was obtained from Survey of India topographical map (1:50 000) 57 O/6, this map was thereafter scanned to be a digital format, and LISS III and PAN of IRS 1D of 2003 obtained from the National Remote Sensing Agency (NRSA).

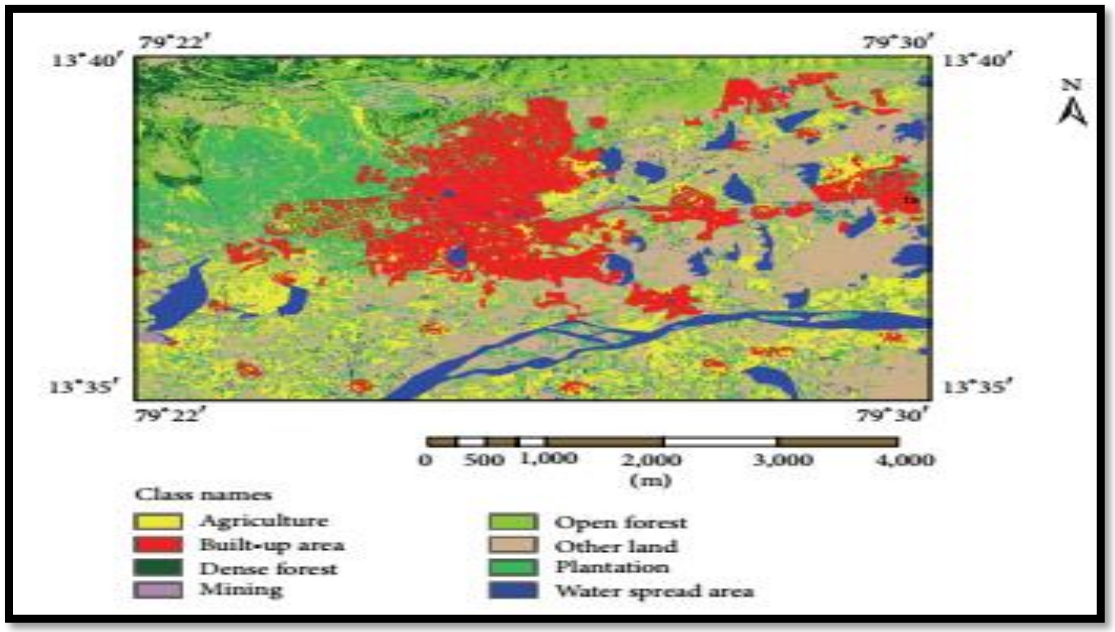
Before the processing and classification of these images, field survey using the Global Positioning System (GPS) was employed to acquire accurate location points for further classification. To classify these multidate images, supervised signature extraction and maximum likelihood algorithm were utilized on the IRS 1D georeferenced, merged LISS III, and PAN for land use and land cover mapping for 2003. These classification algorithms produced 8 land use and land cover classes namely: built-up area, agriculture, water spread area, dense forest, open forest, plantation, other land, and mining. This study found that there was a rapid increased of built-up area or high concentration of settlements and decreasing agricultural potential land and dense forest because of rapid urbanization in the study area over time. Figure 5.2 and 5.3 below shows the land use and land cover classes or themes generated using maximum likelihood classification algorithm in 1976 and 2003 images in Tirupati area, India.

*Figure 5.2: Land Use and Land Cover Classes or Themes for Tirupati Area, India in 1967*




*(Data Source: Mallupattu and Reddy, 2013)*

*Figure 5.3: Land Use and Land Cover Classes or Themes for Tirupati Area, India in 2003*




*(Data Source: Mallupattu and Reddy, 2013)*

*5.1.3 South African (Local) Case Study: City of Port Elizabeth, Eastern Cape, South Africa.*

The study was conducted in the City of Port Elizabeth, Eastern Cape to determine land use and land cover changes during the South African democratic transition between 1990 and 2000 using remote sensing technique. This city experiences rapid increased industrialization and urbanization that has had impacts on the land use and cover dynamics on the city over time, so there was a need to analyze and quantify changes that occurred during the 10-year period in the study area.

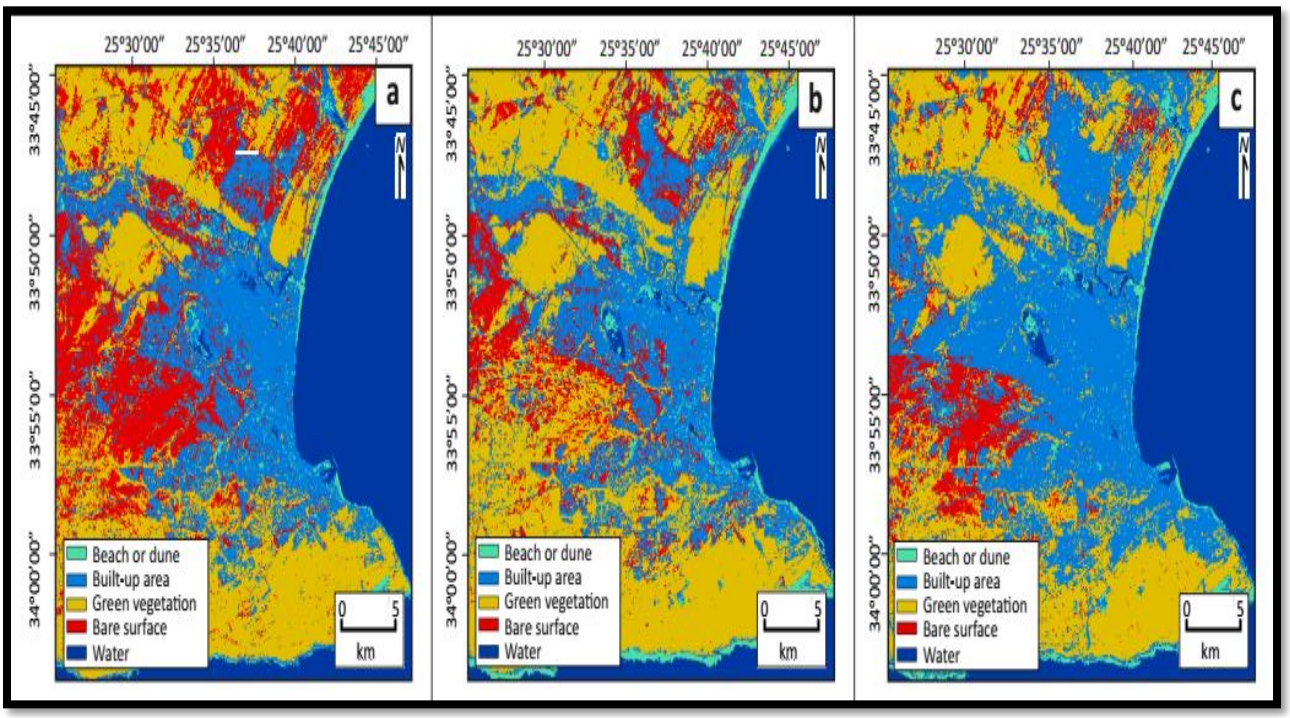
Multidate satellite images for the representation of the results from environmental conditions and human-induced activities were employed. These land use and land cover dynamics had to be analyzed and quantified to determine the rate at which open/green spaces decreases because of the rapid increase on built-up areas which was significant for spatial and development planning. This study about City of Port Elizabeth urban growth was performed using remote sensing technique to analyze and quantify these changes. Multitemporal comparison of delineated classes or themes were utilized. To manipulate remotely sensed data Landsat 5 Mapper Data (that covers 30m x30 m in terms of spatial resolution) was used for the mapping and monitoring of the multitemporal changes in major land use/ land cover types in Port Elizabeth using three sets of images from 1990, 1995, and 2000. The resultants areas within the thematic maps were compared and the study enabled to determine the rate and magnitude for trends of growth to which have been occurring in the study area, and how this influence sustainable provision of infrastructure and services to increasing population. Aerial photos were rectified using the Universe Transverse Mercator and Geodetic System 1984 datum and Global Positioning System (GPS) for reading the ground control points using geo-rectification. Nearest-neighborhood interpolation was also used to improve the accuracy in the multitemporal images.

To determine land use and land cover classes or themes, this study employed hybrid classification method that integrates unsupervised and supervised classification to classify the 1990, 1995, and 2000 satellite images. In the unsupervised classification, iterative self-organizing data analysis (ISODATA) algorithm and K-mean were used to classify these three image data sets. After this classification, ISODATA technique yielded 21 classes. Aerial photos, field survey and GPS readings were considered for roads, buildings to mention but a few to distinguish and label the unsupervised classes and to identify training areas for supervised classification. In addition, maximum likelihood algorithm from supervised classification was employed to detect land use and land cover related theme or classes. The 21 classes that were generated in the unsupervised classification were used for each class to label new spectral signatures. Thereafter,

LULC classes or themes decreased from 21 using unsupervised to 5 using supervised classification namely: built-up area, beach or dune, green vegetation, bare surface, and water.

Classified images using pixel-by-pixel comparison was employed to determine LULC transitions through calculating the pixel numbers differences between the 1990 and 1995 images, and between 1995 and 2000. The study illustrated the efficacy of remote sensing technique for monitoring urban change and shown the potential of remote sensing to aid decision-making in rapidly changing urban landscapes. It had identified a drastic increased on built-up areas because of a rapid increasing population in the study area, this influenced increasing demand for public facilities and amenities, and a sharply decrease in bare surface and green vegetation because of an enormous pressure from increasing population density in the study area. Figure 5.4 illustrates the image that shows land use and land cover classes using maximum likelihood in 1990, 1995, and 2000.

*Figure 5.4: Land Use and Land Cover Classes or Themes for the City of Port Elizabeth, South Africa in (a) 1990, (b) 1995, (c) 2000*




*(Data Source: Odindi, 2012)*

## 5.2 CONCLUSION

This chapter provided an analysis of the international and South African precedents case studies about assessing the application and effectiveness of remote sensing and geographical information systems for mapping and monitoring land use and land cover changes for development planning. For developed country precedent, it used the case of United States, India precedent used as a developing country case study, lastly, Port Elizabeth used as a local (South African) precedent. The following chapter provides with a detailed overview of the study area ranging from its spatial location, status quo analysis, cross cutting issues etc.

## CHAPTER SIX: A CASE STUDY: UMNINI TRUST TRADITIONAL COUNCIL

### 6.0 INTRODUCTION

This chapter provides a detailed overview of uMnini Trust traditional council as the case study area which is administered by the Ingonyama Trust Board (ITB) within eThekwini Municipality. This overview incorporates the status quo analysis, situational analysis, basic service delivery analysis, and cross-cutting issues analysis that includes spatial planning, and environmental analysis of the study area. The LULCC analysis from this study plays a crucial role in the conceptualization and formulation processes of the municipal package of plans that include the municipal Integrated Development Plan (IDP), Spatial Development Framework (SDF) of eThekwini Metropolitan, and Local Area Development Plan (LADP), and Draft rural scheme for uMnini Trust traditional council.

### 6.1 STATUS QUO ANALYSIS

*6.1.1 Geographic Location of uMnini Trust Traditional Council*

The uMnini Trust traditional council is located at about 40 km south-west of Durban City along the railway, N2 and R102 corridors. It is restricted by the uMkomaas River on the south, the Indian Ocean on the east, the Mfume on the west, and the uMsimbazi River on the north (uMnini Local Area Development Plan, 2006). The uMnini Trust traditional councils is amongst the tribal areas situated within the jurisdiction of eThekwini Metropolitan. This traditional council, located in the South side of the City of Durban within the land that was granted to the Amathuli tribe as a special Deed of Grant by Queen Victoria. UMnini Trust traditional council is administered by *Inkosi* Luthuli and has four traditional local regions (also known as *Izigodi*) which are as follows; iHlanzeni under the *Induna* Mbambo, eMgobhozini under *Induna* Ngubane, Danganya under *Induna* Mthembu, and eMagabheni under *Induna* Khomo.

This traditional council is facing rapid population growth as a result of urban sprawl that have led to dense development and settlements occurring along the national road (N2), regional road (R102), provincial roads (P197 and P579), provincial railway, in close proximity to uMkomaas Sappi Saiccor, and within environmentally sensitive areas (LADP, 2006; Ndebele, 2016). This rapid peri-urban densification has negative impacts on the coastal areas of the traditional council, therefore, there was a need for local area development plan and draft rural scheme to ensure the regulation and facilitation of incompatible land uses and improve safety and image of an area. This is a unique traditional council as it is amongst the one of the first areas under Ingonyama Trust Board in which a Local Area Development Plan (LADP) and draft rural

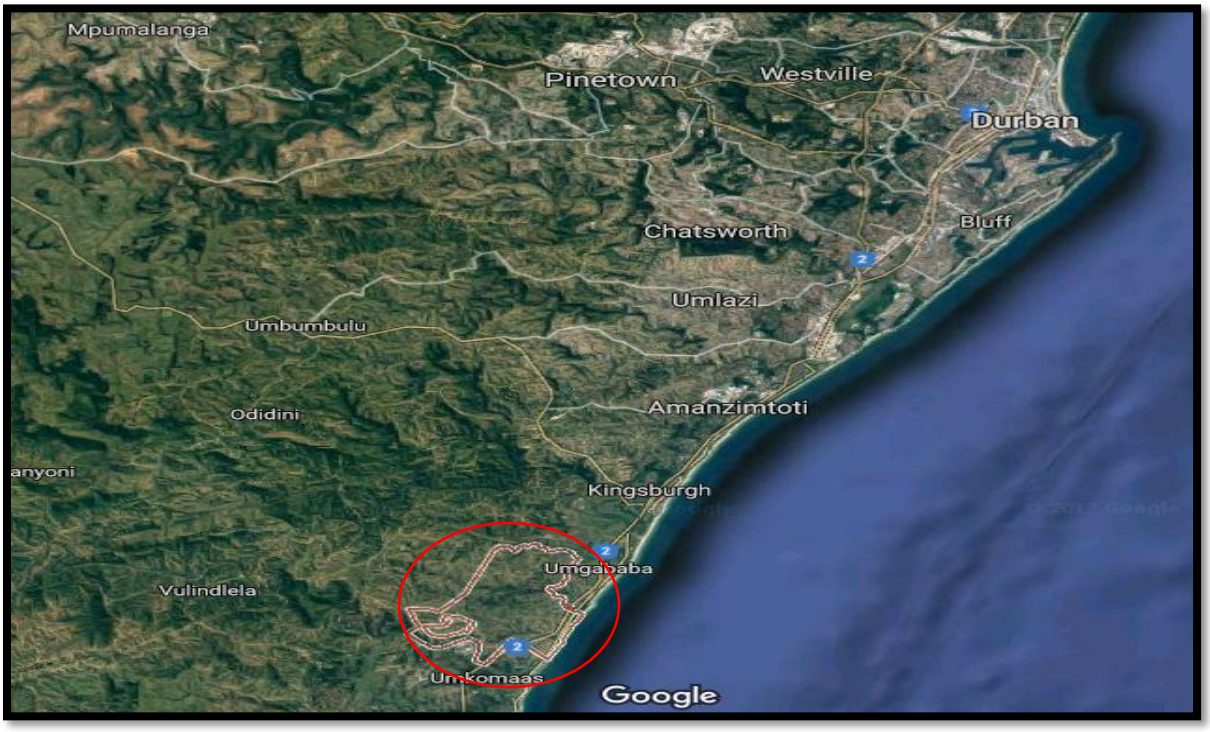
scheme were developed (LADP, 2006; South Spatial Development Plan, 2012-13). Figure 6.1 below shows housing development occurring within a river course which threatened sustainable development goals.

*Figure 6.1: Housing or Settlement Development within Environmentally Sensitive Areas as a result of Rapid Peri-Urban Densification*

*(Source: Researcher, 2017)*

According to uMnini Local Area Development Plan (2006), uMnini is mainly made of tribal or traditional land, which incorporates the main uMnini Trust land. In the mid-19 century, this traditional land was granted by the British Empire in exchange for confiscated ancestral land next to the Durban port. This reward is mainly because of an incredible supportive role played by Amathuli tribe in Durban during the era of colonialization in South Africa (LADP, 2006). Figure 6.2 below illustrates geographical location of uMnini Trust traditional council.

*Figure 6.2: Locality of UMnini Trust Traditional Council*




(Data *Source: Google Earth, 2017)*

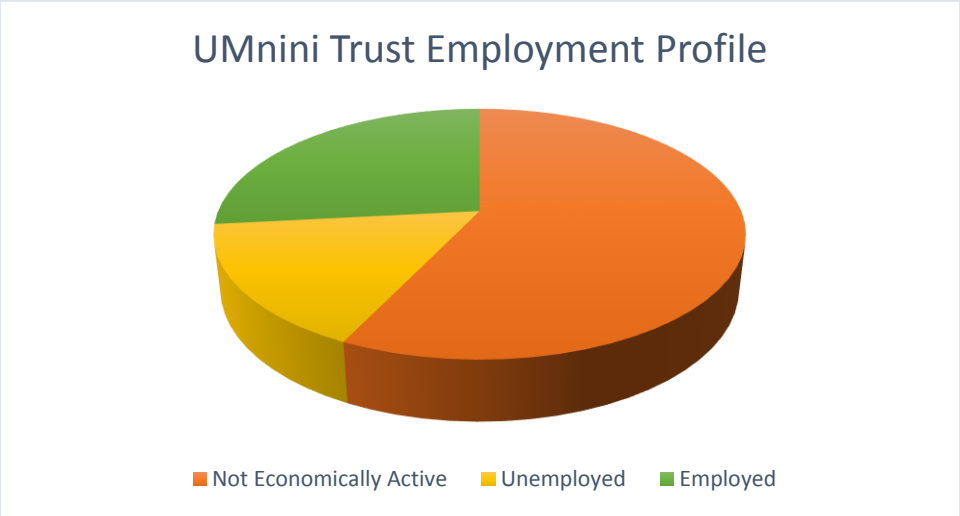
## 6.2 DEMOGRAPHIC CHARACTERISTICS

According to Community Survey (2016), uMnini Trust traditional council has 84 083 inhabitants in an area with approximately 4000 hectares of land with an average of 5 people per household. According to Census 2011, for population density, the population of uMnini Trust traditional council account for approximately 210 person/ha. As this peri-urban densification occurring very rapidly, it provides more reasons for the significance of determining the extent and pattern, to which this growth is occurring (between 2001 and 2016) and its impact on agricultural potential areas and, to the provision of social infrastructure and services to this rapid increasing population. In terms of population projections, eThekwini Transport Authority Demographic study has projected that eThekwini Municipality will have the population of approximately 3.8 million by 2020 based on the 1.1% growth rate. This population increase will eventually affect land uses and land cover trends of the study area which is significant in the study of development planning in the specific area over time (eThekwini Municipality IDP, 2017-2021).

### 6.2.1 Employment Profile

It is utmost important to look at the employment profile of the residents of uMnini Trust traditional council, as the lack of income push the population away from the city to settle on a cheaper farm land. As a result, densification of peri-urban areas contributes to rapid land use and land change. Therefore, despite the diversified nature of the local economy, unemployment in the eThekwini municipal area is of concern as only 992 560 out of 3.7 million inhabitants of the total labour are employed. The unemployment rate is currently sitting at about 430 319 of the population while 873 583 of the total labour force are not economically active (eThekwini Municipality SDF 2017-2018; eThekwini Municipality IDP 2017-2021). Moreover, uMnini Trust traditional council is dominated by the youth population and is situated in close proximity to larger pulp and paper industry (Sappi Saiccor) and travelling distance to the Durban City for employment opportunities. However, despites these promising contributing factors approximately 60% of the total population was not economically active, also about 17% of the total population unemployed where only 26% was employed (Census, 2011; Community Survey, 2016). Figure 6.3 illustrates the employment profile of the population in the study area.

*Figure 6.3: Pie Chart showing Employment Profile for UMnini Trust Traditional Council*



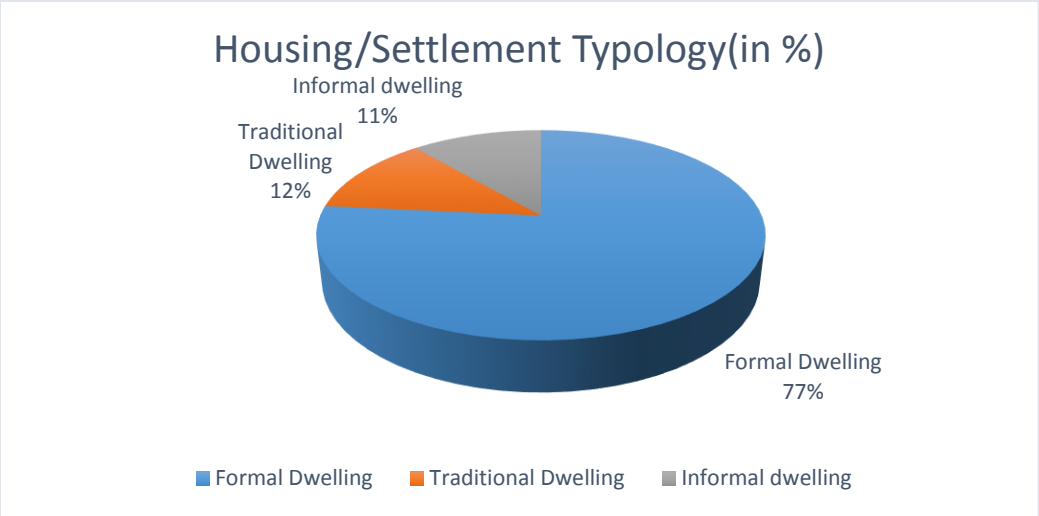

*Produced by the Researcher (Data Source: Stats SA, 2011)*

### 6.2.2 Housing/ Settlement Typology

According to Census 2011, the average household in uMnini Trust traditional council account for 4.8 persons. In this average, approximately 77% of the total population lives in formal dwellings, 12% of the total population resides in traditional dwelling, and 11% situated on the informal dwellings. This section is significant to

understand spatial pattern and distribution, and trends of growth within the study area. It also shows the types of settlements and the rate at which these developments consume agricultural potential areas over time especially along the coastal areas. Figure 6.2 below shows the housing/settlement typologies in uMnini Trust traditional council.

*Figure 6.4: Pie Chart showing Housing/Settlement Typologies UMnini Trust Traditional Council*

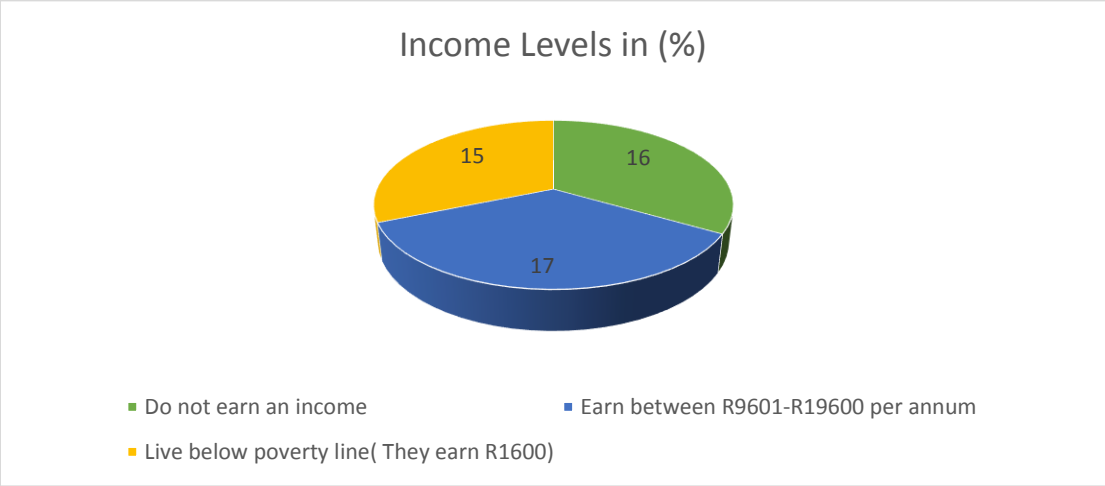



*Produced by the Researcher (Data Source: Stats SA, 2011)*

### 6.2.3 Income Level

Unemployment rate is too high in eThekwini Metropolitan and subsequently in the study area, in terms of income levels approximately 16% of the total population does not earn an income and owned by housewife that influence food insecurity and the lack of means for the population to sustain their livelihoods. According to Census 2011, 17% of the population earn between R9 601 and R19 600 per annum, and 15% of the population lives below poverty line as they earn below national minimum wage of R3500 as they earn R1600. Socio-economic indicators such as income levels determine the spatial location of the people, therefore, insufficient funds which is among other reasons for the population to reside at the periphery of the cities, has a direct influence on the rapid densification of the population on environmentally sensitive areas which results to land use/ land cover changes. Figure 6.5 depict the income levels for uMnini Trust traditional council.

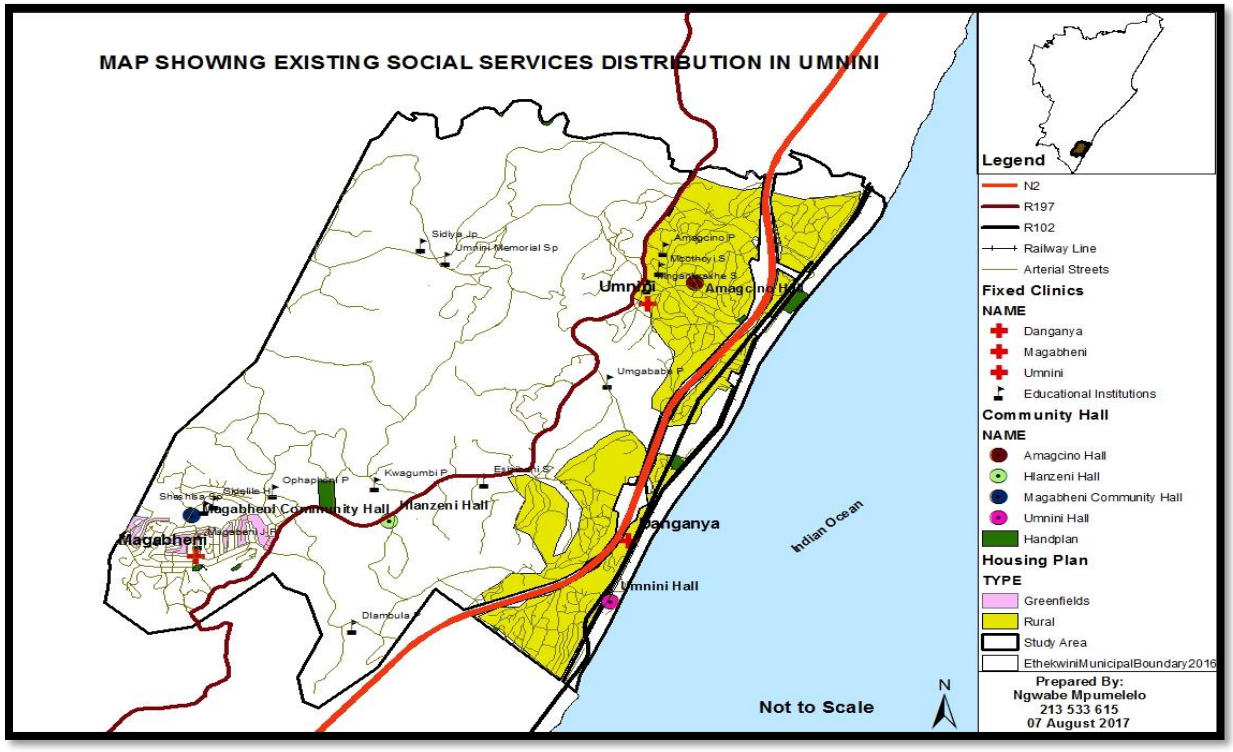
*Figure 6.5: Pie Chart showing Income Levels in UMnini Trust Traditional Council*




*Produced by the Researcher (Data Source: Stats SA, 2011)*

## 6.3 BASIC SERVICES DELIVERY AND INFRASTRUCTURE ANALYSIS

*Figure 6.6: Social Services Distribution in UMnini Trust Traditional Council*




*Produced by the Researcher (Data Source, eThekwini Municipality, Corporate GIS Unit, 2017)*

As highlighted (see Figure 6.6), it is important to determine the rate of changes (land use and land cover) and trends of growth over the time in uMnini Trust traditional council. The issue of land use and land cover change because of rapid per-urban densification needs to be addressed by the municipality to ensure that infrastructure and social services are equivalent to the rate to which the population increases in the study area. Therefore, this section will look at the infrastructure and social services exiting in uMnini Trust traditional council and to determine whether it will manage to accommodate future generations, these existing infrastructure and social services are as follows:

*6.3.1 Fixed Clinics*

UMnini Trust consists of three (3) fixed clinics aimed to service the population residing within the jurisdiction of the traditional council and neighboring communities. These clinics are as follows; uMnini Clinic, Danganya Clinic, and Magabheni Clinic. However, the study area does not have hospitals only rely on the neighboring towns such as Scottburgh, Amanzimtoti, Isipingo, and the Prince Mshiyeni Hospital at uMlazi.

*6.3.2 Schools*

UMnini Trust traditional council comprises of thirteen (13) educational facilities this include 1 high school, 3 secondary schools, 6 primary schools, 2 senior primary schools, and 1 junior primary school. Unfortunately, there is no further education facilities like FET colleges or university within the jurisdiction of the traditional council, therefore, the population has to travel to neighboring towns in search for such institutions to further their education.

*6.3.3 Housing*

According to eThekwini Municipality IDP (2017-2021), eThekwini Municipality has a housing backlogs of about 387 000 units at the end of December 2016. While the municipality has the ability to deliver 4000-6000 ranges of housing unit per annum (eThekwini Municipality IDP, 2017-2021). UMnini Trust traditional council is affected by this housing backlog, eventually this has led to spontaneous settlements which are distributed in close proximity to environmentally sensitive areas, railway and road corridors etc. The key issue to this in the study area and throughout eThekwini Municipality, is the issue of land invasion and houses as a basic need required by the rapid increasing population. The 11% of the population residing in the informal settlements under uMnini Trust is incorporated on the 387 000 eThekwini Municipality population implicated by this housing backlogs.

*6.3.4 Thusong Service Centers*

UMnini Trust traditional council consists of one (1) functional Thusong center, this center is best known as uMnini Thusong Center. It is offering services such as Department of Social Development, uMnini library, uMnini Community Hall, municipal offices like War Room even though some of these services are not currently being functional like Department of Cooperative Government and Traditional Affairs, South African Police Services to mention but the few. According to eThekwini Municipality SDF 2017-18, this service center is regarded as one of the local service node situated along the R102 corridor within uMnini Trust traditional council.

*6.3.5 Community Hall*

UMnini Trust traditional council consists of four (4) community halls, these halls play a significant role as community engagement platform to discuss development and other relevant issues. These community halls are as follows; uMnini Hall, Amagcino Hall, Hlanzeni Hall, and Magabheni Hall. There are also traditional courts which have a significant input for problem solving and discussions of the issues affecting the community at large.

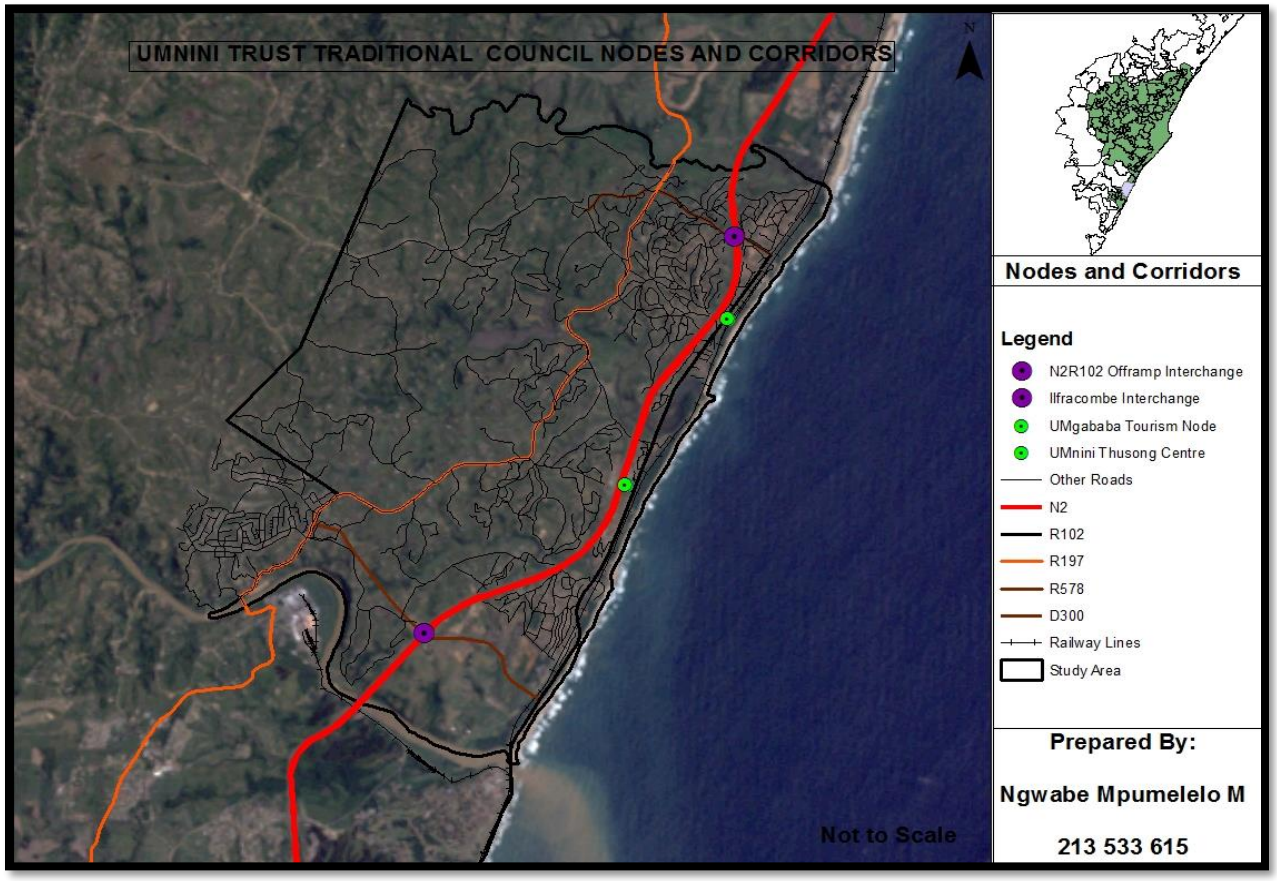
*6.3.6 Police Station*

Despite the fact that uMnini Trust is among the fastest growing traditional council within eThekwini municipality, however, there is no police station within the jurisdiction of this traditional council. The population of this traditional council only rely on the nearby police stations like the one in uMkomaas and Amanzimtoti. The satellite police station that is being proposed in uMnini Thusong Center is yet not functioning which makes the community to be more vulnerable to socio-economic issues like crime and violence.

## 6.4 EXISTING CORRIDORS

There is an extensive road networks existing in uMnini Trust traditional council, this provides a vast number of households with access to road transport. While the national, provincial, and regional roads are in a generally good condition, but the quality of district and local roads is poor within the study area. This is mainly because these roads are gravel they require regular maintenance and upgrading. During the rainy season, some of these roads are particularly bad and hamper access to settlements. The Figure 6.7 below is the map that shows nodes and corridors in uMnini Trust traditional council in the context of eThekwini Municipality.

*Figure 6.7: Nodes and Corridors in UMnini Trust Traditional Council*




*Produced by the Researcher (Data Source: eThekwini Municipality SDF, 2017-18)*

## 6.5 EXISTING NODES

According to eThekwini Municipality SDF (2017/18), uMnini Trust consists of Rural Investment Node (N2/R102 off ramp interchange) and Tourism Nodes (uMgababa beach) along the ocean which have a potential to provide support services (business, agriculture, tourism, and environmental issues and opportunities for local economic development) which are fully displayed on the municipal SDF. These nodes are located within easy access to major transport routes as they are situated along N2 and R102. They should be located where there is already an existing accumulation of activities. Moreover, under the study area there are local service nodes like uMgababa Taxi Rank, and uMnini Thusong Center that provide local services (social, and economic activities, traditional structures, facilities etc) for surrounding communities. Figure 6.8 below shows uMgababa Taxi Rank as a Local Service Node, while Figure 6.9 demonstrates uMgababa Beach as a Tourism Node as per eThekwini Municipality SDF 2018-19.

*Figure 6.8: UMgababa Taxi Rank as a Local Service Node*

*( Data Source: Researcher, 2017)*

*Figure 6.9: UMgababa Beach as a Tourism Node as per eThekwini Municipality SDF 2017-18*

*(Data Source: Researcher, 2017)*

## 6.6 EXISTING CORRIDORS

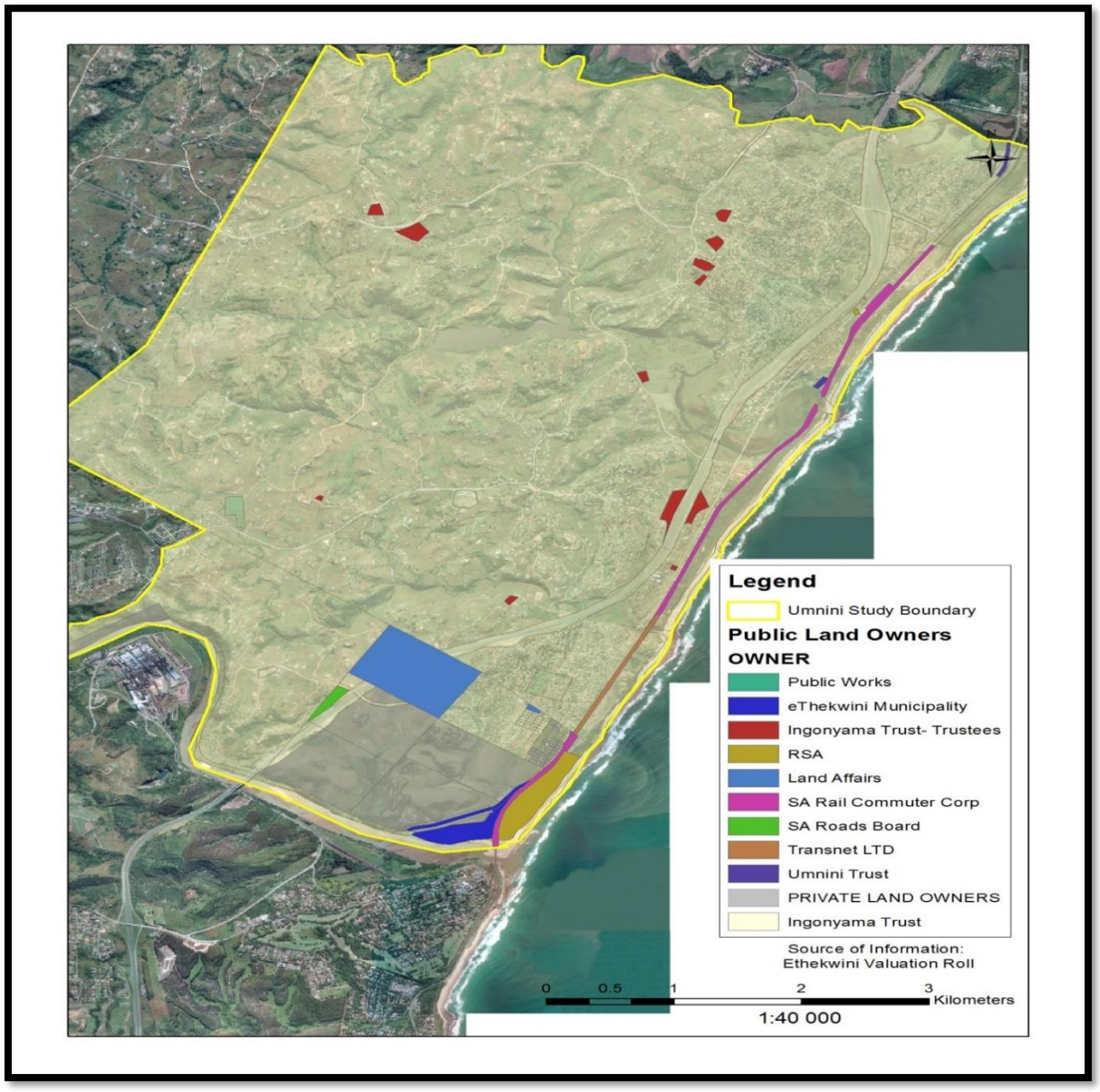
UMnini Trust traditional council is situated within the Port Shepstone-Durban Corridor (N2), this national road passes on the east coast side of the study area. Some of the main regional roads within the study area incorporates the R102, R197, and R578; moreover, there are also provincial roads that include P728, and district road which is D 300. The R102 is termed the "beach road" as its runs along the coast of the study area, linking various coastal towns like uMkomaas, Scottburgh, and Kingsburg. These corridors like N2 and R102 are essential for connectivity of the study area with the surrounding places and as a transportation networks for goods and services to Durban port, Durban City, and King Shaka International Airport and so on.

## 6.7 RAILWAY LINE

On the coastal area of uMnini Trust traditional council, there is a railway line which plays a significant role on the urban development of eThekwini Metropolitan and on the economic development of South Africa at large. This railway line is a route for trains which transport the people to their point of interest and the transportation of goods and services to the market like Durban Harbor, King Shaka Airport and so forth.

## 6.8 LAND OWNERSHIP

*Figure 6.10: Land Ownership Patterns in UMnini Trust Traditional Council*

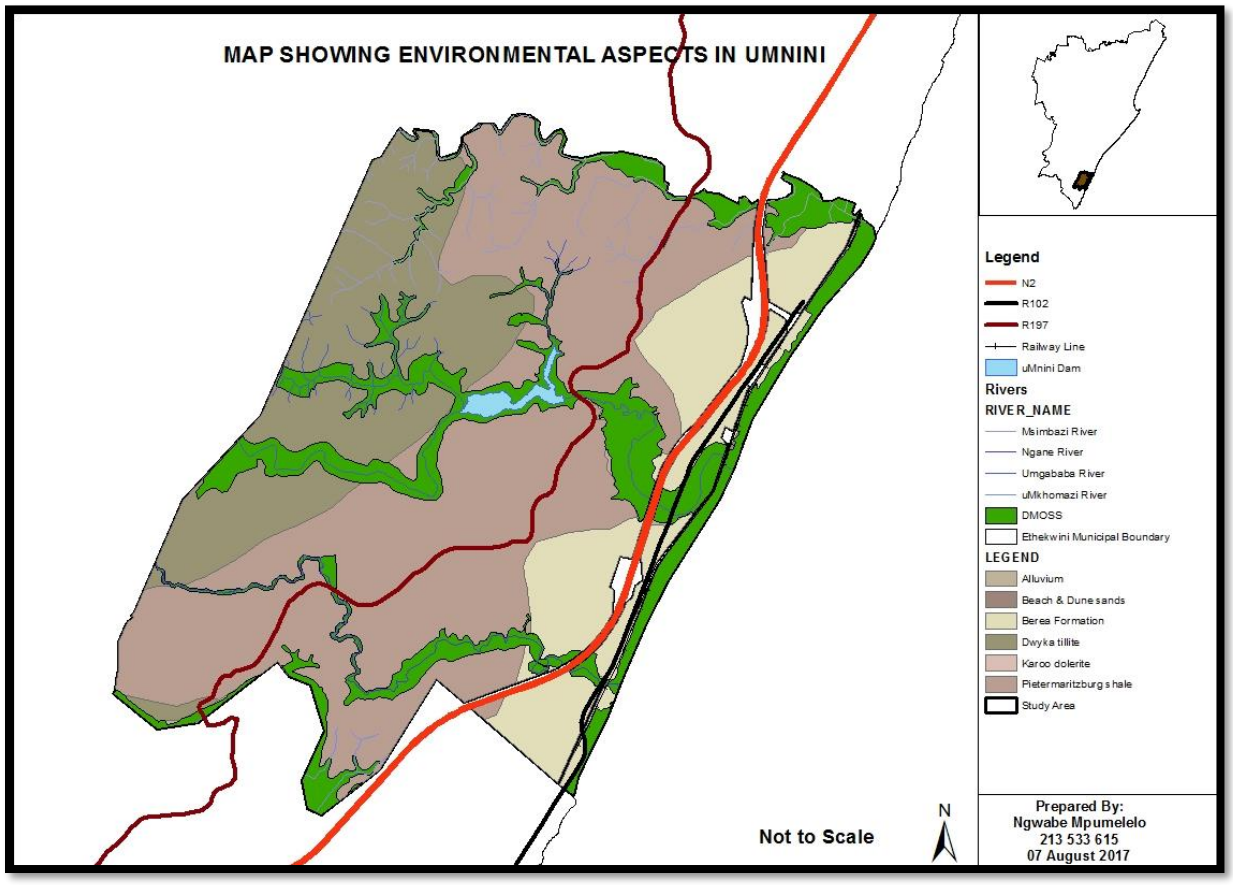



*Produced by the Researcher (Data Source: eThekwini Municipality Valuation Roll, 2012)*

With reference to Figure 6.10, despite the fact that uMnini Trust traditional council falls under the jurisdiction of eThekwini Municipality. Land ownership patterns within this traditional council is diverse but mostly dominated by the Ingonyama Trust Board. Ingonyama Trust is responsible for the administration of land within traditional councils in KwaZulu Natal while Amakhosi are the custodians of land. Some part of land in this tribe is owned by different stakeholders which include uMnini Trust, Ingonyama Trust-Trustees, Republic of South Africa (RSA), public works, eThekwini Municipality, land affairs, SA Rail Commuters corporation, SA Road Board, Transnet LTD. Moreover, other parts of land belong to private land owners within the traditional council.

## 6.9 ENVIRONMENTAL ANALYSIS

*Figure 6.11: Environmental Aspects Analysis of UMnini Trust Traditional Council*




*Produced by the Researcher (Data Source: EThekwini Municipality Corporate GIS Unit, 2017)*

*6.9.1 Geology*

The soil/geology of uMnini Trust traditional council is covered by six geological formations, with the predominant being the Pietermaritzburg shale, followed by Alluvium, Berea formation, Dwyka Tillete, Beach and Dune sands, and Karoo Dolerite.

*6.9.2 D'MOSS*

UMnini Trust traditional council incorporates areas that fall under Durban Metropolitan Open Space System (D'MOSS), these areas cover approximately 74 000 ha of water and land under eThekwini Municipality. Fortunately, uMnini Trust is among those areas that consists of high biodiversity value linked together in a viable network of open spaces. These areas under uMnini Trust include dams, coastal corridors, catchments, and other riverine.

*6.9.3 Dam*

UMnini Trust consist of uMnini Dam which is underutilized, this dam has a full potential of playing a significant role for local economic development of the traditional council and the municipality as a whole. This dam supposed to be amongst the well-known tourism destination but that is not a case as it is not well marketed. Figure 6.12 below shows housing developments occurring along uMnini Dam.

*Figure 6.12: Image showing Housing or Settlement Developments occurring near UMnini Dam*

*(Source: Researcher: 2017)*

*6.9.4 Agriculture*

According to eThekwini Municipality SDF 2017-2018, the National Department of Agriculture Forest and Fisheries together with the KZN Department of Agriculture and Environmental Affairs (KZN AEA) are critically concerned about the food security challenge threatening South Africa as well as drastic decrease of available large plots of land for agriculture. This is mainly influenced by the contributing factors such as global phenomenon of climate change, poor management of agricultural land, urbanization and pressure for development of non-agricultural land uses. EThekwini Municipality has a significant amount of land that falls within the high potential agricultural land categories identified by KZN DAEA, and these areas are under a massive pressure for development. UMnini Trust traditional council is not in exception on this issue of a decline for agricultural land as a result of rapid population growth which increase demand for housing development which increased density for settlements. UMnini Trust traditional council falls under Category C for KZN Agricultural potential land in 2015 (eThekwini Municipality SDF, 2017-2018).

*6.9.5 River Catchment*

Based on Figure 6.11 above, several rivers flow through the area in a west-east direction into the Indian Ocean, these include, from the north to south, uMsimbazi river, and west-east direction into the Indian Ocean the Ngane, and uMgababa which are perennial catchments and on southern boundary the UMkomaas which is the among the largest rivers in KwaZulu Natal. Major rivers and inter catchment linkages are highlighted showing connectivity in the Durban Metropolitan Open Space System (D'MOSS). This is significant to understand land cover of uMnini Trust traditional council, as some of these housing developments because of rapid population growth are constantly occurring within these catchments which threatened environmental sustainability.

## 6.10 CONCLUSION

This chapter managed to provide with a detailed analysis of uMnini Trust traditional council ranging from status quo analysis, situational analysis such as spatial planning, environmental aspects, challenges facing the traditional council, and population growth in the context of the traditional council and eThekwini Metropolitan at large. Chapter seven that follows provides and presents a detailed research findings and analysis.

## CHAPTER SEVEN: RESEARCH FINDINGS AND ANALYSIS

### 7.0 INTRODUCTION

This chapter presents the findings and analysis of the results based on the data collected. The intention of this study was to ascertain the ways and extent to which the integration of remote sensing and GIS; could be used as supplementary planning techniques or methods, for mapping and monitoring land use and land cover trends for development planning in uMnini Trust traditional council, eThekwini municipality.

The findings of this study were mainly based on the on-site observation and in-depth interviews conducted with selected key respondents. Amongst the key informants participated in this study incorporate the manager for integrated development planning, senior spatial planner, senior development planner, remote sensing and GIS expert. Moreover, senior manager for land use management, land use management (LUMS) coordinator (South Region), senior technical planner from eThekwini municipality Development Planning, Environment, and Management Unit. The traditional leaders were represented by the local chief (*iNkosi*) of uMnini Trust traditional council. Manager for photogrammetry and GIS specialist from eThekwini municipality Corporate GIS Unit, senior spatial planner and GIS technician from KwaZulu-Natal department of Corporative Governance and Traditional Affairs (KZN-Cogta). Lastly, the senior town planner from the planning consultancy that conceptualized and formulated the uMnini Trust Local Area Development and Draft rural scheme. In this study, the abovementioned key stakeholder informants were generally involved because of their vast experience and knowledge in the subject investigated by this study.

The findings of this study were guided by the themes that were highlighted on the introductory section of this research. The themes of this dissertation include to determine the current LULCC planning and assessment processes used by municipality in uMnini Trust traditional council, to critically analyze the extent to which remote sensing and GIS have been used for land use planning and management. To identify different land use and land cover types found in uMnini Trust traditional council between 2001 and 2016 and analyse/categorise the changes that has occurred during the study period, and to analyze challenges and constraints of using remote sensing and GIS for mapping and monitoring land use and land cover changes.

## 7.1 TO DETERMINE THE CURRENT LULCC PLANNING AND ASSESSMENT PROCESSES USED BY MUNICIPALITY IN UMNINI TRUST TRADITIONAL COUNCIL

According to Census 2001, uMnini Trust had population estimated to 23 008 with 4329 existing homesteads (households). Census 2011 data further revealed that uMnini Trust traditional council in 2011 had population density estimated at 40 500 people, with 8100 existing homesteads (households) with the occupation rate of 5 people per homestead. The understanding of these densities was quite important as the increase of the population has had an impact on the status of land use/land cover. Thereafter, the 2016 community survey highlighted that the population of the study area was estimated at 84 084, with the occupant rate of about 5 people per homesteads (households). This population pressure and increase could be regarded as an enormous growth which account to more than 100% increase within the period of 5-years (2011-2016), which demands the municipality to analyze and regulate the rate and magnitude of densification in the study area, which is significant in ensuring sustainable provision of infrastructure, and social services to improve living conditions of the population for their development plans.

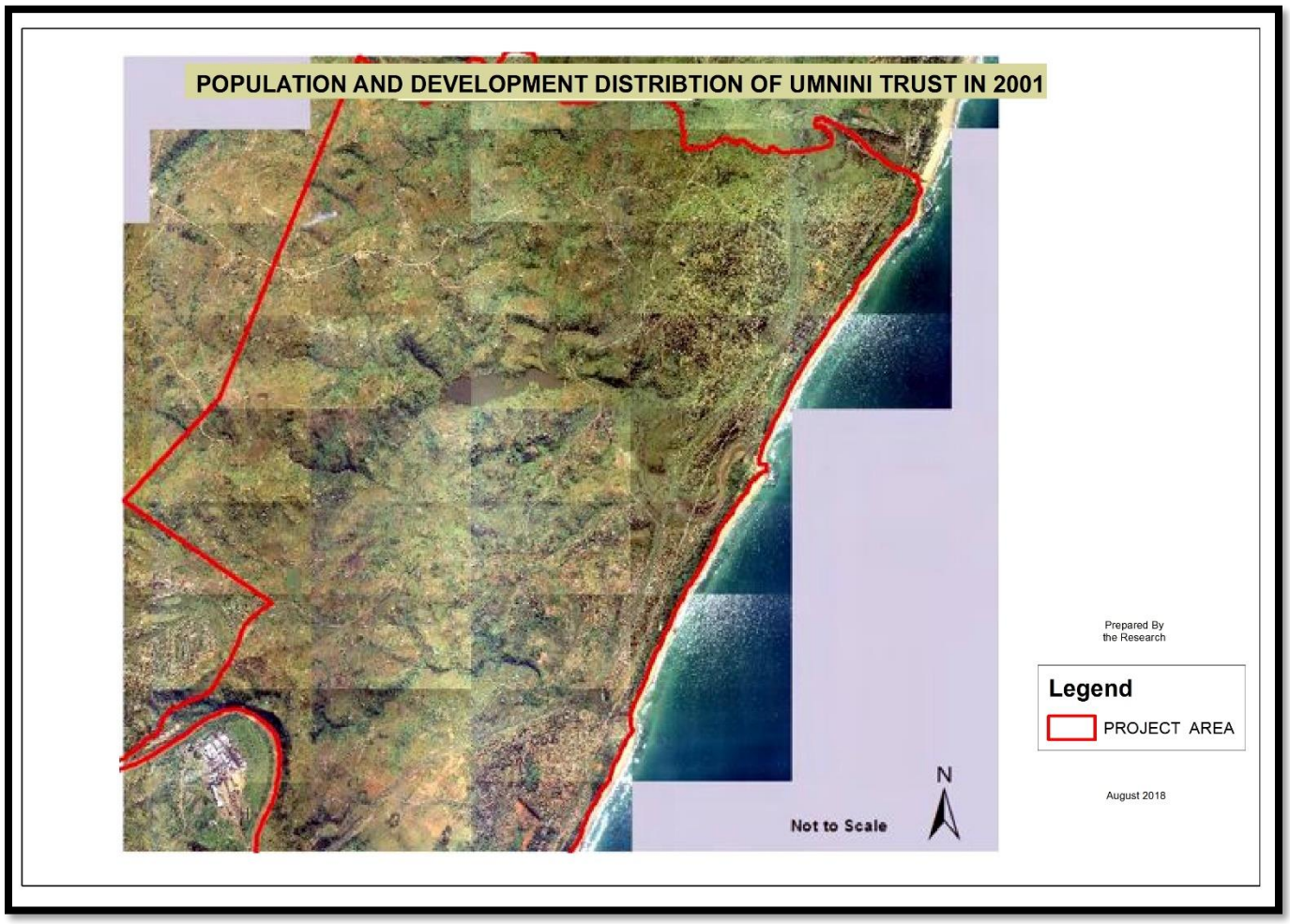
In terms of the current LULCC planning and assessment processes used by the municipality for peri-urban densification and trends of growth analysis, the senior development planner from eThekwini municipality stipulated that *"the Council of eThekwini Metropolitan currently has adopted aerial photographs and vector data from geographical information system (GIS), which are methods that have been entrusted within the municipality for quite some time for spatially-related analysis"*. He further explained that "*aerial photos are gathered on a yearly basis, for a detailed analysis of the spatial distribution of densities in a particular geographic area over a certain period of time. This raster data from aerial photos is converted into the vector data for further detailed spatial -related analysis"*.

Remote sensing and GIS expert from strategic spatial planning expressed the view that "*the municipality currently rely on the aforementioned techniques and methods, the other entrusted geospatial technologies and methods such a Google Earth has been also incorporated for peri-urban densification and trends of growth analysis. This occurs because it is too expensive to collect aerial photographs and sample surveys on a weekly or monthly basis for the entire municipal area, while the population grows on a weekly or monthly basis in peri-urban areas like uMnini Trust traditional council. Therefore, Google Earth assist the municipality to determine the rate and direction at which a particular place (such as uMnini Trust) is densifying as a result of rapid peri-urban densification"*. In the same line of thought, manager from photogrammetry mentioned that "*these geospatial technologies including remote sensing and GIS; could be more effective for peri-urban*

*growth and development analysis and control as they have capabilities of providing required information on a regular basis. The current and accurate models or methods for peri-urban densification and trends of growth analysis could play a pivotal role in the planning and implementation stages of the municipal development plans"*. GIS specialist from eThekwini Metropolitan expressed the view that "*geospatial technologies such as satellite images have capabilities to provide with a frequent synoptic view of any development and use of land that encroaches inter alia environmentally sensitive areas, and corridor servitudes (roads and railway line) which could help the municipality to be proactive in terms of the planning and implementation of development controls to guide and regulate unorderly or 'unplanned' developments"*.

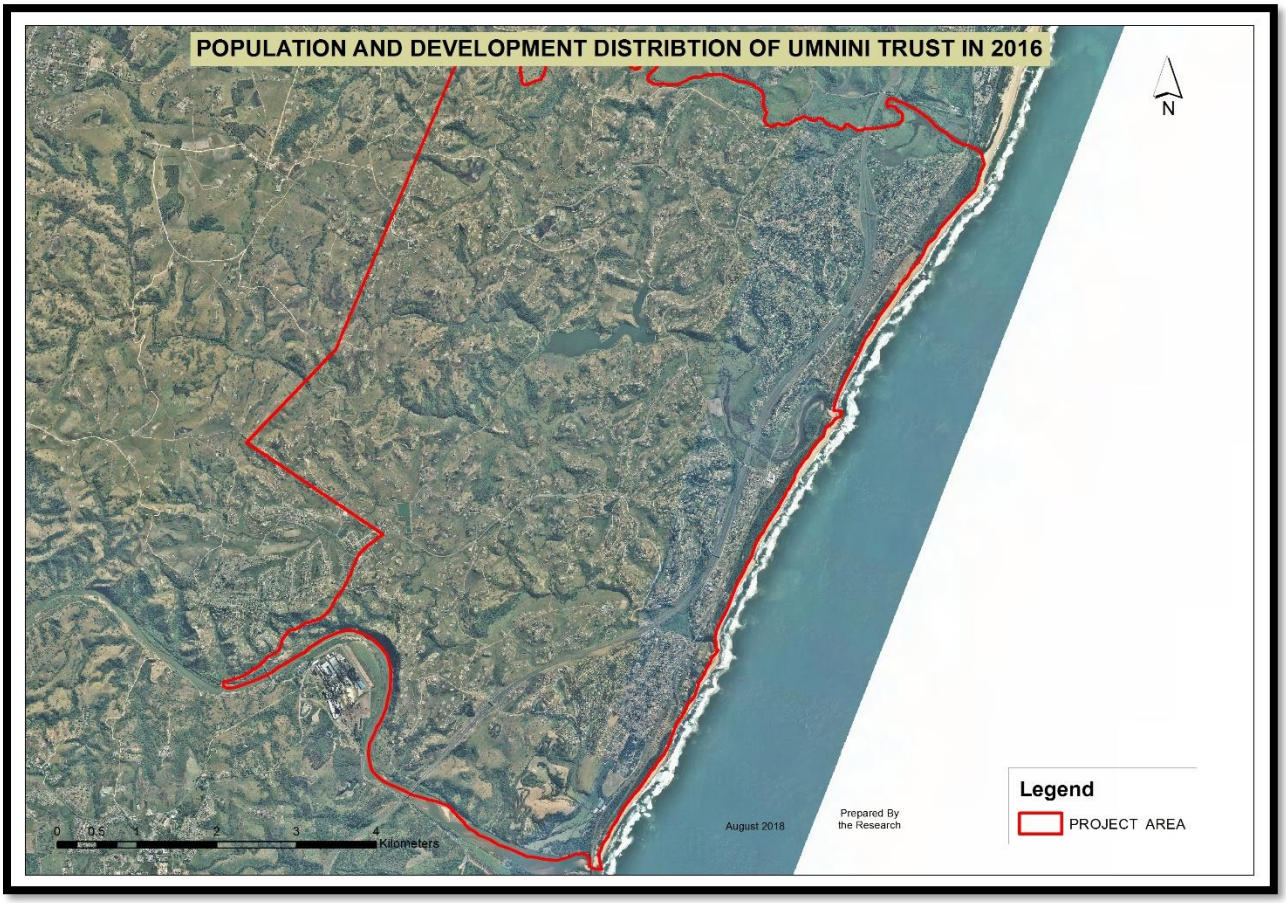
For the researcher's point of view in conjunction with the expert views, abovementioned geospatial technologies and tools are important in peri-urban densification and trends of growth analysis. As the municipality requires information about the development and use of land especially for the preparation and formulation of their development plans incorporating land use scheme. With the help of aerial photographs and GIS which have been entrusted by the municipality, Figure 7.1 below illustrates spatial distribution of housing or settlements development for uMnini Trust in 2001. Whilst, Figure 7.2 shows the latest aerial photograph (2016) from municipality depicting spatial distribution of housing growth and development in uMnini Trust traditional council. Figure 7.3 shows the capabilities of GIS to map the trends of spatial densities of the housing or settlement developments in the study area.

*Figure 7.1: Spatial Distribution of Housing or Settlement Development for UMnini Trust Traditional Council in 2001*



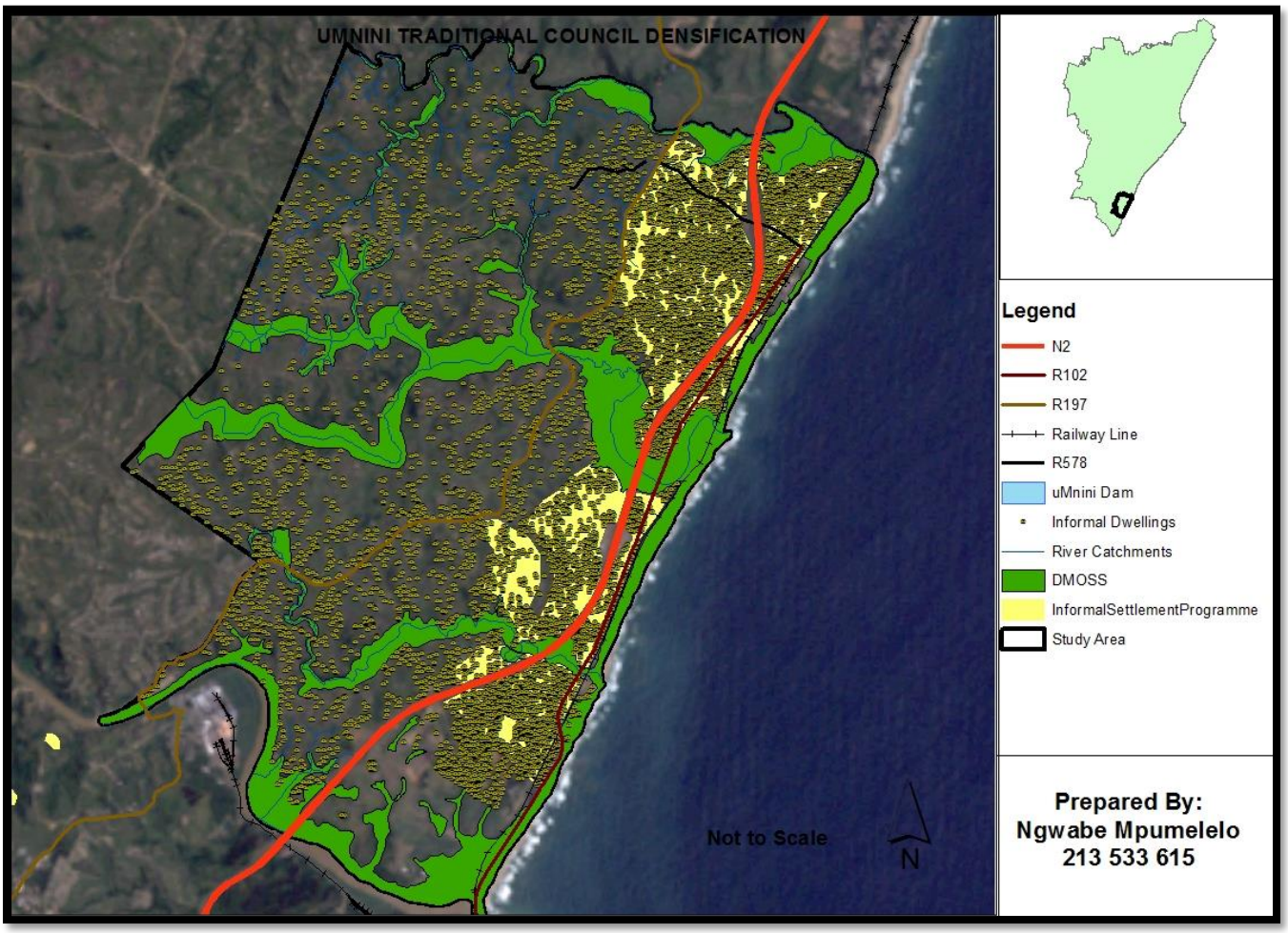

*Produced by the Researcher (Data Source: eThekwini Municipality Photogrammetric Unit, 2017)*

*Figure 7.2: Spatial Distribution of Housing or Settlement Developments for UMnini Trust Traditional Council in 2015*



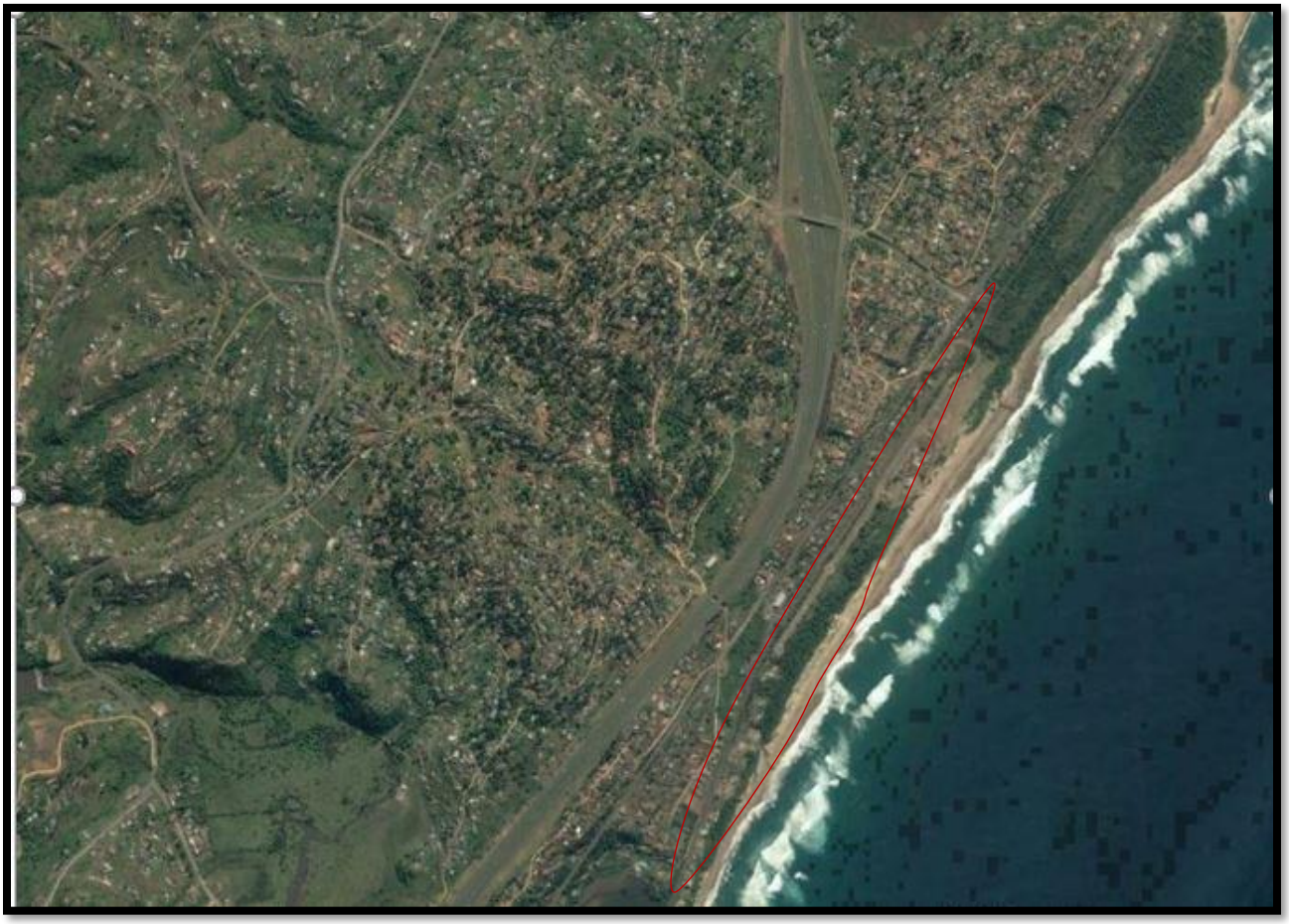

*Produced by the Researcher (Data Source: eThekwini Municipality Photogrammetric Unit, 2017)*

*Figure 7.3: Latest Spatial Data for Housing or Settlement Developments for UMnini Trust Traditional Council*




*Produced by the Researcher (Data Source: eThekwini Municipality Corporate GIS Unit, 2017)*

*Figure 7.4: Google Earth Image showing Coastal Spatial Distribution of Housing or Settlement Developments in UMnini Trust Traditional Council (North Side)*



*(Data Source: Google Earth, Last Accessed: 20 September 2017)*

**Legend**

◯ **Housing or Settlement Developments occurring within Coastal Dunes of uMnini Trust**

*Figure 7.5: Google Earth Image showing Coastal Spatial Distribution of Housing or Settlement Development in UMnini Trust Traditional Council (South Side)*

(*Data Source: Google Earth, Last Accessed: 20 September 2017*)

**Legend**

◯ **Housing or Settlement Developments occurring within Coastal Dunes of uMnini Trust**

Basically, section 7.1 of the study displayed capabilities of the existing geospatial technologies and tools used by the municipality for per-urban densification and trends of growth analysis. Aerial photographs, GIS, and Google Earth have been entrusted geospatial technologies and techniques for LULC planning and assessment processes to determine the extent and magnitude to which housing or settlement developments have impacted land use/land cover over a certain period of time. They also displayed the rates for the encroachment of environmentally sensitive areas as result of rapid peri-urban densification. Also, this rapid peri-urban densification has led to unregulated or "unplanned" developments occurring in close proximity to corridors such as roads and railway line which are often in contradict with municipal development plans.

Moreover, this densification has created immense pressure from the municipality in terms of providing basic social services and infrastructure planning for increasing population.

## 7.2 TO CRITICALLY ANALYSE THE EXTENT TO WHICH REMOTE SENSING AND GIS HAVE BEEN USED FOR SUSTAINABLE LAND USE PLANNING AND MANAGEMENT

The first part, Spatial Planning and Land Use Management Act (No.16 of 2013) stipulates that among other responsibilities of the municipality must after public consultation; adopt and approve a single land use scheme for its entire area. The very same Act further states that the land use scheme must give effect and be consistent with the municipal spatial development framework and determine development and use of land within the municipal area. The KwaZulu Natal Planning and Development Act (KZN PDA) (No. 6 of 2008) also mandates that there must be a wall-to-wall scheme throughout the province that incorporate rural and traditional council areas. The purpose of the land use scheme is to regulate and facilitate land use and promote orderly development, in accordance with the municipality's integrated development plan in the interests of the general public, to promote sustainable development and quality of life (uMnini Trust Draft Rural Scheme, 2012). KZN- PDA further states that the municipality must compile and maintain an up-to-date version of a scheme, in ensuring sustainable land use planning and management. The call for an up-to-date version of scheme for the entire municipal area requires the adoption of techniques and tools such as GIS and other related geospatial technologies, to gather real time and accurate information about land uses/land cover within the municipal area (Appiah *et al*, 2015). This incorporates the conceptualization and formulation of land uses in rural and traditional council areas over time, which have different spatial allocation and management systems with the one used by the municipality.

Furthermore, the interviews were conducted with a Remote Sensing and GIS expert and Senior Spatial Planner from Strategic Spatial Planning Unit about the extent to which municipality has used Remote Sensing and GIS for sustainable land use planning and management. Remote sensing and GIS expert said "*unfortunately in the conceptualization and formulation of the municipal package of plans such as Integrated Development Plan, Spatial Development Framework, and Local Area Development Plan, satellite images (remote sensing) have not been integrated into the mainstream for that aspect of spatial planning*". However, he further expressed that "*for land use planning and management, the municipality employs raster data from aerial photographs that are converted into vector data (GIS) for further spatial-related analysis. The municipality is currently using these techniques and tools for mapping and analysis of any development and use of land that deemed to encroaches on environmentally sensitive areas, and also occurring near road and*

*railway corridors, thereafter; the municipality enable to implement development controls to regulate unorderly development that is in conflict with the municipal development plans as per the purpose of the land use scheme".*

The senior spatial planner further explained that "the *unfortunate part in rural and traditional council areas is that traditional leaders do not use any of spatial plans provided by municipality for land allocation and management where some land uses are in contrary with the municipal development plans. They rely only on the indigenous law or indigenous knowledge systems for land allocation and management, which sometimes contradict with the subdivision principles on the LADP and Draft rural scheme"*. For a researcher's point of view, this reluctancy of the traditional leaders has been the main contributor to "inappropriate" developments as result of rapid population growth that require cheaper farmland to sustain their daily livelihoods in close proximity to urban areas. Senior spatial planner further illustrated that "*aforementioned technologies and tools are employed by the municipality for land use planning and management because of their capabilities to provide the information that is consistent with the Surveyor General Cadastral and SG Diagram. This consistency of providing information makes planning and development easier within the municipality which is why they have been entrusted technologies and techniques by municipality"*.

In the same line of thought with above experts, senior development planner said, "*the use of the abovementioned techniques and technologies is in line with the municipality strategy to acquire real-time information to determine trends and magnitude of changes (LULC) over a certain period of time. She further stated that this kind of information assist the municipality to acquire information in ensuring for up-to-date wall-to-wall scheme as per SPLUMA and PDA to ensure spatial sustainability and justice through equitable and efficient distribution of public services and infrastructure to increasing population"*. Based on this view from the expert, the researcher deducted that the municipality needs updated and accurate information about LULC for land use planning and development, and in the preparation and conceptualization of the land use scheme. Moreover, senior spatial planner said *"GIS as analytical technique has been adopted within spatial planning based on its capabilities of producing land use maps and perform spatial query to identify and display different land use/land cover types found in an area. Also, GIS helps the municipality to determine spatial distribution of those areas with high potential for investments. In terms of this study, N2/R102 offramp interchange and Ilfracombe interchange have been identified as Rural Investment Nodes*". He further stated that *"in land use planning and management, geospatial technologies used by municipality such as aerial*

*photographs and GIS help to identify those areas that need critical interventions in terms of development and use of land".*

In addition, manager for integrated development planning said, "*this detailed spatial analysis from these geospatial technologies helps the municipality to show spatial perspective to see where and how the area experiences the changes based on densification analysis displayed on these maps that is significant for land use planning and management, and to determine where the municipality needs to provide infrastructure and social services"*. Figure 7.6 below shows N2/ R102 offramp interchange which is regarded as a Rural Investment Node of the study area as per Municipal SDF 2017-18.

*Figure 7.6: N2/R102 Off-ramp Interchange as a Rural Investment Node for UMnini Trust Traditional Council*

*(Data Source: Researcher, 2017)*

Furthermore, in conjunction with the view expressed by senior spatial planner, senior manager from land use management unit said, "*the use of these geospatial technologies and techniques helps the municipality for the preparation and conceptualization of the municipal package of plans. They help to show where are the nodes, environmentally delineation areas such as Durban Metropolitan and Open Spaces (D'MOSS), hierarchy of corridors for economic opportunities. Thereafter, those areas identified with high population*

*growth are prioritized on the municipal development plans and budget in ensuring basic social services and infrastructure delivery to increasing population".* She further explained that "*this approach of acquiring information about land uses play an integral role especially in traditional councils as the municipality has no control over land allocation and management".*

Remote sensing and GIS expert argued that "*the presence of analytical technologies such as GIS helps the municipality to provide planning guidelines to traditional councils to avoid incompatible land uses. In addition, to ensure the consideration of compaction, threshold, and range in land allocation to make sure that population density equate to basic social services and infrastructure rendered as they do not pay rates; and to ensure that land allocation is consistent with the future municipal development plans. Despites the use of these innovative and high accuracy techniques for land use planning and management; hegemony of land allocation and management in traditional councils even in the presence of SPLUMA and PDA still entirely depends on the indigenous knowledge systems*". GISc Technician from KZN Cogta further stated that "*these geospatial technologies are used by the municipality because the more information you have, the better decision-making in relation to land use planning and management, therefore; they are not employed to underestimate the critical role of traditional leadership in land allocation and management*".

The senior town planner from the planning consultancy that conceptualized and formulated uMnini Local Area Development Plan and Draft Rural Scheme, expressed the view that "*technologies such as global positioning systems (GPS), aerial photographs, and GIS have been used in LADP and Draft Rural Scheme, which are part of Rural Development Framework"*. He further stated that "*Rural Development Framework has been used to guide and control future investments and facilitate service delivery to improve the quality of life in rural and traditional council areas"*. Site visit and interaction with the headmen (*Izinduna*) was pivotal in ensuring that the land uses shown on the maps (displayed using GIS and aerial photographs) are allocated appropriately.

He further explained that *"these geospatial technologies assist the municipality for appropriate allocation and management of land uses, without the encroachment on environmentally sensitive areas to achieve sustainable development. They also help in the identification of agricultural potential areas and ensuring sustainable and equitable provision of services and amenities to the communities. The encroachment of coastal dunes has been noted in the LADP, which takes place along development zone 3 between coastal strips and either sides of the N2". Moreover,* the town planner from the planning consultancy mentioned that *"geospatial technologies such as GIS played a critical role during the preparation of the strategic plans which,*

*guide and give direction for future development such a settlement plan, environmental plan, in determining development zones within uMnini Trust traditional council, and population density mapping, which are part of the LADP"*.

Furthermore, he emphasized in the same line of thought with the senior spatial planner from eThekwini municipality that "*these techniques play a significant role in the preparation of a scheme, which is informed by the municipal Integrated Development Plan (IDP), Spatial Development Framework (SDF), and South Spatial Development Plan (package of plans). With the assistance from these techniques in the package of plans, the municipality after a change detection and trends of growth analysis over time is enable to guide how, where, and what development should take place in their area of jurisdiction. In the preparation of the package of plans, these techniques also help to establish nodes and corridors"*. Senior town planner from planning consultancy explained that "*because of immense population pressure which attributed by rapid-urban densification, conceptualization and formulation of uMnini Trust LADP was a turning point for the management/regulation of development and use of land in rural and traditional council areas".* He further argued that *"land use planning and management in these areas was not a priority within eThekwini municipality before which resulted to major development occurring in conflict with the municipal development and spatial plans*".

Land use management system coordinator (South region) added that as "*there is a lack of collaboration between the municipal and traditional authorities. So, modern geospatial technologies play a pivotal role in ensuring sustainable land use planning and management in rural and traditional council areas"*. Moreover, he explained that "*in the absence of town planning scheme in rural and traditional council areas, while SPLUMA and PDA promote wall-to-wall planning scheme throughout the municipal area including rural and traditional council areas. The adoption of GIS and other geospatial technologies although remote sensing is not incorporated by the municipality, assist on the conceptualization and formulation of land uses as traditional council areas do not have cadastral, where you can easily throw the scheme as they belong to Ingonyama Trust in KwaZulu Natal*".

He further expressed that "*the use of land use scheme is not applicable in traditional councils as there are no building approvals, coverage, and erf for housing or settlement developments. It is entirely depending on the traditional leaders in terms of land allocation and management which sometimes negatively influence land use/land cover changes. The absence of a scheme in this area diminishes the efforts to provide a strategic land use response to development pressures experienced in uMnini Trust as well as the current*

*and future needs"*. According to eThekwini Municipality SDF 2017-18, the land use management in these areas that fall outside the scheme such as uMnini Trust is a challenge as the municipality does not have authority in these areas, and land allocation can occur haphazardly. Furthermore, the SDF states that there is no proper planning for land allocation of bulk services and social facilities as a result some areas area densely populated and the level of services provided is no longer sufficient. In the absence of a scheme, development has not been managed in a sustainable way in uMnini Trust.

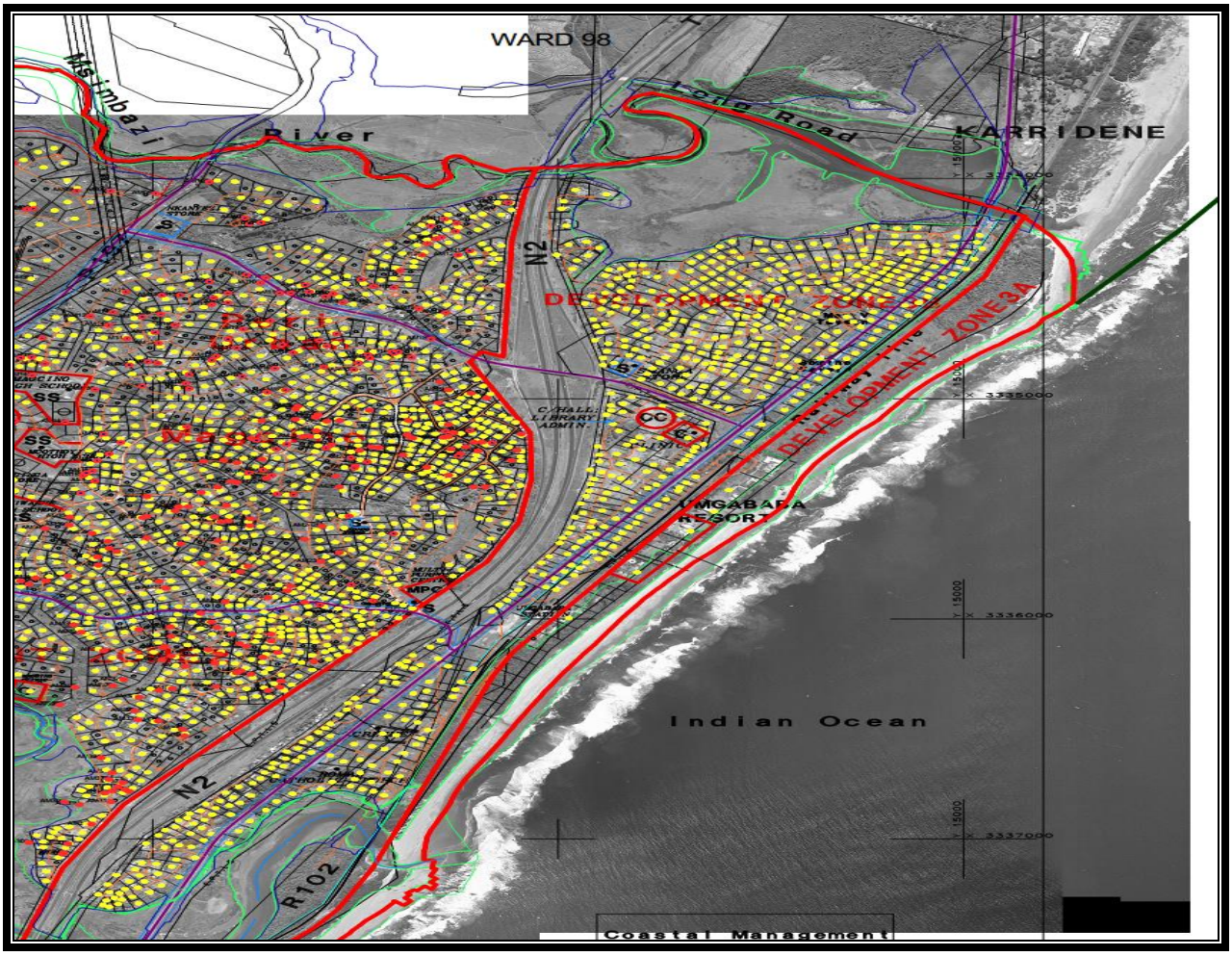
The chief *(iNkosi*) of uMnini Trust traditional council in contrary to the abovementioned responses from municipal officials, challenged that *"the emergence of these geospatial technologies has not been part of land use planning and management within the traditional council, as land allocation and management still take place using indigenous knowledge system/indigenous law, which has been a successful approach over many years. To enhance this traditional planning system for land allocation and management, there has been various workshops by KZN-Cogta to empower headmen, who are regarded as "land use planners"; in ensuring sustainable land use planning and management in rural and traditional council areas"*. Senior town planner from the planning consultancy contended that "*traditional land use management have been in place in these areas for many years, therefore, there is a need to take full cognisance of this existing land use management system and merge with municipal land use management system in the preparation of a municipal land use scheme as required by the Municipal Systems Act (No. 32 of 2000) and KwaZulu Natal Planning and Development Act (No.6 of 2008) as well as SPLUMA"*.

It was also noted from the interview with the senior spatial planner from KZN- Cogta who stated that "*in the wave of modernization, various municipalities have adopted GIS and other related geospatial technologies such as aerial photographs, which are both well established and diverse for land use planning and management*. *However, in ensuring the smooth application and effectiveness of these geospatial technologies, the role of KZN- Cogta is to oversee and help those municipalities like category B and C (local and district municipalities that do not have capacity to adopt full operations of these geospatial technologies)*. *Therefore, the official from Cogta goes with the land use or development planner from the affected municipality for collecting coordinates for those "unknown" land uses, for example, industrial, residential, commercial land uses, which play a significant role during the preparation of land use management scheme (LUMS) of the municipality. However, there is no municipality that is currently using remote sensing imagery for land use planning and management but maybe in the near future it will be incorporated"*.

The researcher as a resident that is familiar with the study area, in conjunction with findings from the LADP and Draft Rural Scheme noticed incompatible land uses more especially along the coastal strips where there was a massive housing or settlement developments taking place within the development zone 3 along the coastal strips and either sides of the N2. It was also noted that within the development zone 2 which is between N2 and P197, there has been a rapid densification. While development in zone 1 between R197 and inland boundary of the study area has been left underdeveloped, which is the zone that mostly falls outside urban development line of the municipality.

During the on-site observation, the researcher noted peri-urban densities of informal settlements occurring along the coastal strips either side of the N2 and railway line with site sizes estimated to 500m2 (10units/ha). as a result of high demand and desperation for cheaper farmland in peri-urban areas. There were also a semi-rural strip along arterial routes running East and West, with site sizes which are approximately around 1500m2 (5units/ha). Furthermore, there was a rural area between the semi-rural strips with the site sizes estimated to 5000m2 (2units/ha). This unplanned development in study area is problematic in land use planning and management, and for equitable and efficient distribution of public services and amenities. In 2012, the planning consultancy with the help of aerial photographs and GIS had created the coastal development zone 3A and 3B, which are the ones that were rapidly densifying in the traditional council. Figure 7.7 below shows uMnini Trust traditional council coastal development zone 3A and 3B (informal settlements along the coastal strips either side of the N2) which are grossly affected by peri-urban densification.

*Figure 7.7: UMnini Trust Traditional Council Coastal Development Zone 3A and 3B as Extracted in UMnini Trust Draft Rural Scheme*




*Produced by the Researcher (Data Source: uMnini Trust Traditional Council Draft Rural Scheme, 2012)*

**Legend**

**Existing Housing or Settlements along the Coastal strips either sides of the N2**

**Potential Housing or Settlements Infills either sides of the N2**

During on-site observation, the researcher witnessed a serious violation of the National Environmental Management Act (NEMA): The Integrated Coastal Management Act (No.24 of 2008), as result of rapid population growth occurring within the coastal dunes, riverine etc. This rapid peri-urban densification occurs against the principles of the abovementioned Act which stipulates that there must be no person who may construct, maintain or extend any structure, or take other measures on coastal public property to prevent or

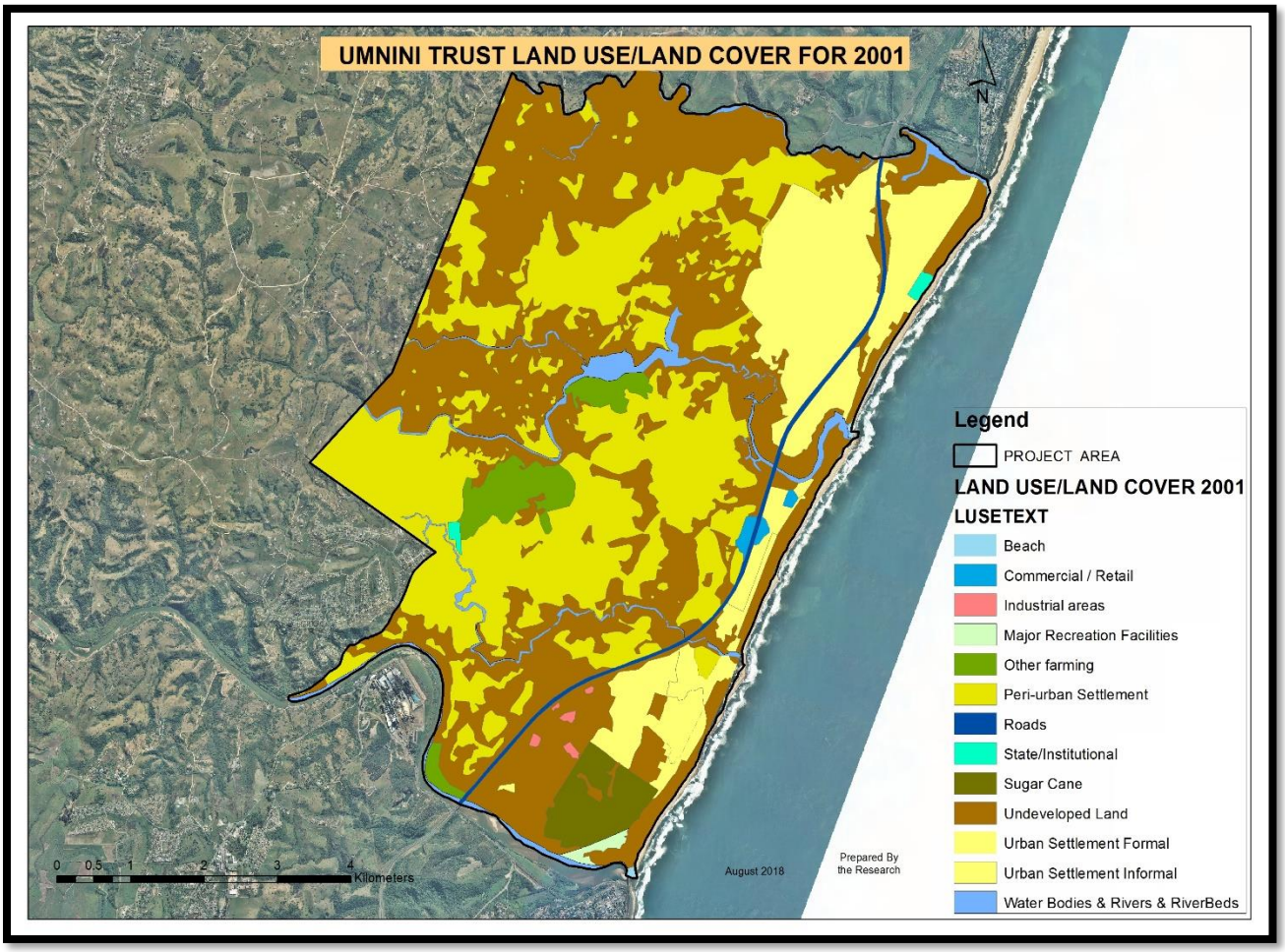
promote erosion or accretion of the seashore except as provided for in this Act. Which simple means there should be no development taking place within the coastal dunes as that is in conflict with the principles of the Act and sustainable development goals. Despite that, the researcher had identified enormous housing or settlement densities developing within the Coastal Management Zone. This is in contrary to the 2006 uMnini LADP, which found little housing or settlement occurring along the coastal areas of uMnini Trust. Moreover, this "illegal" housing or settlement developments threatened Durban Metropolitan Open Spaces (D'MOSS).

In a nutshell, section 7.2 illustrates that municipality currently uses raster data from aerial photographs which are converted into vector data (GIS) for further spatial-related analysis. Detailed analysis of this nature assists the municipality to determine where, how, and when the municipality experience changes which is important for spatial and development planning purposes. This analysis helps the municipality to determine those areas that need critical intervention in terms of development, and those have high potential for future investments. Nonetheless, this section discussed that regular change detection analysis could assist the municipality to be proactive in those area that are affected by rapid densification as a results of rapid population growth which influenced rapid encroachment of environmentally sensitive areas and roads and railway servitudes. However, remote sensing (satellite images) have not been incorporated into the mainstream for land use planning and management by any South African municipalities. This occur despites the facts that remote sensing when integrated with GIS have been endorsed for providing accurate and current information in relation to change detection analysis as discussed in chapter two (literature review) and chapter five (international and South African precedent studies) of this study.

## 7.3 TO IDENTIFY DIFFERENT LAND USE AND LAND COVER TYPES IN UMNINI TRUST TRADITIONAL COUNCIL BETWEEN 2001 AND 2016, AND ANALYSING/CATEGORIZING THE CHNAGES THAT HAS OCCURRED DURING THE STUDY PERIOD

According to the information obtained from Department of Environmental Affairs spatial data (with the help of geographical information system and multidate Landsat imagery for 2001,2006 and 2016) to classify/categorize different land use/land cover types found in the study area, (see Figure 7.8 below) demonstrated that uMnini Trust traditional council was predominated by undeveloped land in 2001. There were three types of land uses classified/categorized as peri-urban settlement, urban settlement formal, and urban settlement informal. Figure 7.8 below illustrates that urban settlement formal was classified/categorized as small portion of housing or settlement development in 2001.

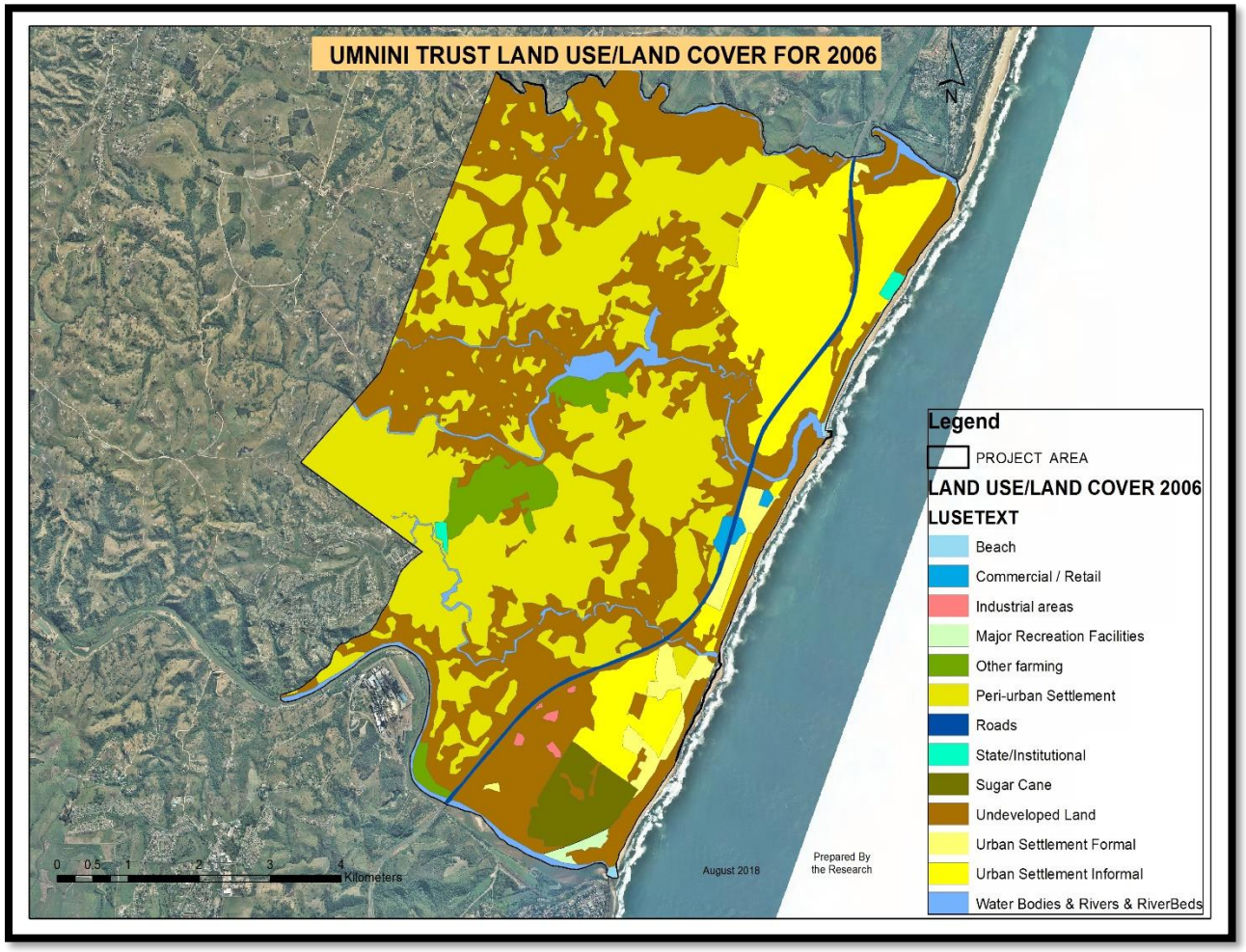
*Figure 7.8: Land Use and Land Cover Classes or Themes for UMnini Trust Traditional Council Area in 2001*




*Produced by the Researcher (Data Source: National Department of Environmental Affairs, 2017)*

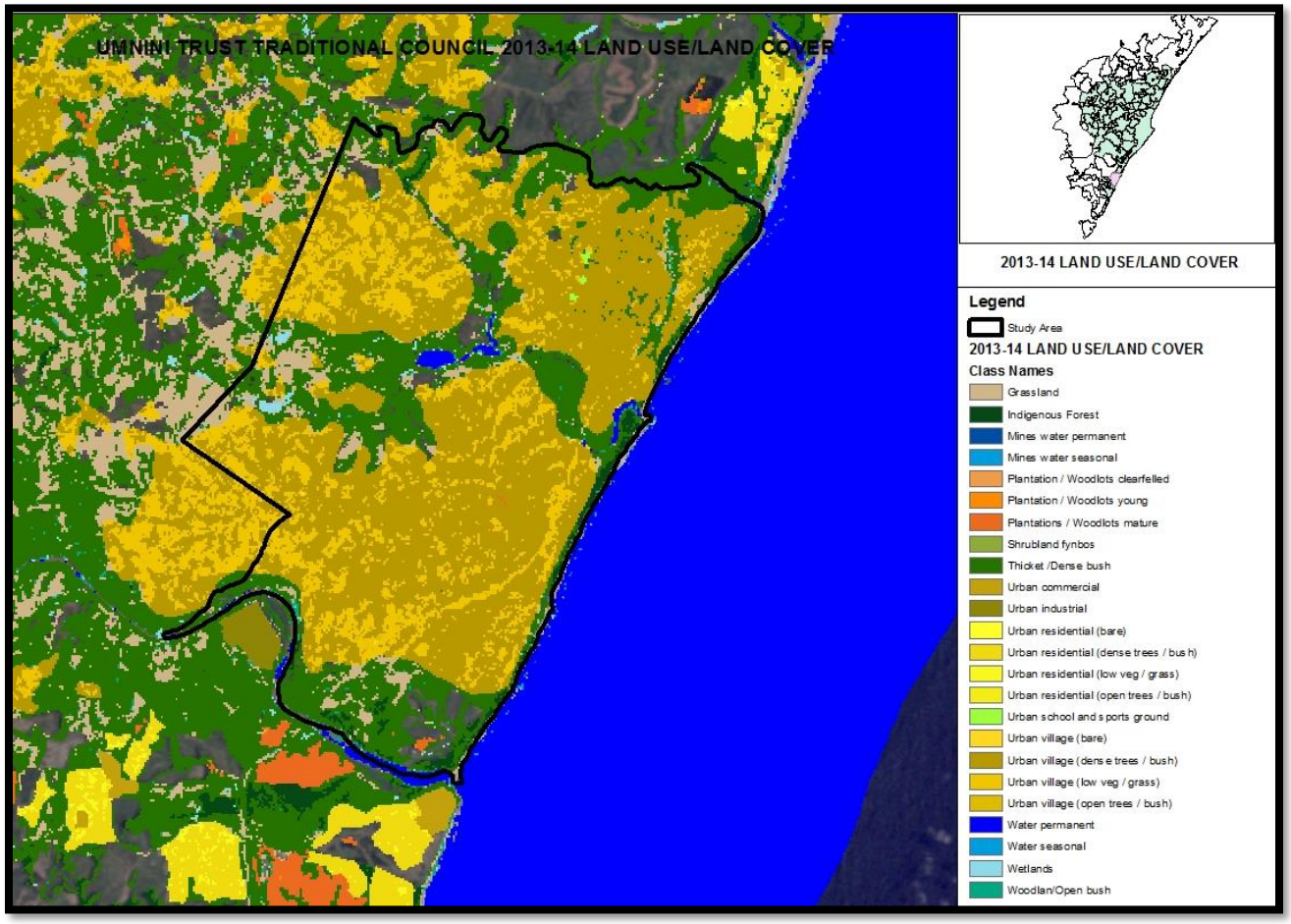
This map perfectly aligns with the findings from the uMnini LADP and Draft Rural Scheme that there were little prevalence of housing or settlements along the coastal strips and major transport routes of the study area. This development has been classified as “informal” urban settlement on the land use/land cover maps as it is constantly occurring within Coastal Management Zone of the study area. In the inland of the study area there was a prevalence of peri-urban settlement which mostly falls outside the urban development line of eThekwini municipality. In addition, there were few spots which represent green areas classified as other farming and sugar cane.

*Figure 7.9: Land Use and Land Cover Classes or Themes for UMnini Trust Traditional Council Area in 2006*




*Produced by the Researcher (Data Source: National Department of Environmental Affairs, 2017)*

*Figure 7.10: Land Use and Land Cover Classes or Themes for UMnini Trust Traditional Council Area in 2016*




*Produced by the Researcher (Data Source: National Department of Environmental Affairs, 2017)*

In contrary to the discussion made in Figure 7.8 (2001), even in Figure 7.9 (2006) there was a prevalence of slight changes in terms of LULC. Moreover, LULC classes or themes in 2016 (see Figure 7.10) demonstrated immense and quite significant changes as opposed to Figure 7.8 and 7.9. The latest LULCC information illustrated in Figure 7.10 shown that built-up areas were dominating land use as yellow colors almost dominated the entire study area with a declined green area (thicket dense bush) showing undeveloped land. This is the evidence for enormous transformation by 2016 as a result of per-urban densification, which has transformed undeveloped land that was dominant land use in 2001, but it was a visa-versa in 2016 where built-up areas became a predominant land use. While 2006 uMnini Local Area Development Plan in conjunction with Figure 7.9 displayed that peri-urban settlements as a result of rapid peri-urban densification were gradually increasing more especially on the coastal strips either sides of the N2 of uMnini Trust. These settlements or housing developments were encouraged by the local government with an intention to promote

densification strategy to revitalize livable and viable communities more especially in close proximity to transportation routes (railway, and national routes).

Peri-urban growth in 2016 (see Figure 7.10) shown the intensive eradication of sugar cane plantation, which was reflected in 2001 (see Figure 7.8) and 2006 (see Figure 7.9). Population increase and pressure has resulted to hard transformation of such land use to provide social services and infrastructure such as housing. Moreover, rapid peri-urban densification does not equate to services rendered by municipality, this has become a headache to the government to provide services and infrastructure to the fastest growing and unregulated places which do not pay rates for such services rendered. In addition, 2016 was predominated by built-up areas, followed by scattered green or vegetation which is not a good indicator as the country striving towards sustainable development goals.

There were few spots/areas which were categorized/classified as undeveloped land, indicating that if peri-urban densification continues at this pace in the study area, these scattered green areas and undeveloped land would be transformed into housing and other related infrastructure to service the increasing population if not regulated. Therefore, if the municipality in partnership with the traditional leadership do not become proactive in dealing with land allocations which are in conflict with the municipal development plans, and implicates green or environmentally sensitive areas, in the near future the municipality would not be able to services and access the increasing population as a result of growth and their spatial location.

In a nutshell, section 7.3 illustrates that there was a decline on open/green spaces and enormous increase on built-up areas (see Figure 7.10), hence, there were slight changes between 2001 (see Figure 7.9) and 2006 (see Figure 7.9) in terms of LULCC. Changes in land use transformed and degraded natural systems and had a direct impact on biodiversity through habitat loss. Moreover, this section shown LULC classes or themes using maps within a study period. Forecasting or predicting rapid peri-urban densification is quite important for municipalities in ensuring that the increasing population are incorporated on their development and spatial plans. However, when municipalities are not proactive in coming up with strategies aimed to deal with unregulated or unplanned development, this could be a recipe for disaster as there would be various developments occurring that are in conflict with the municipal development plans and the municipality also fails to service them as result of their spatial location. Therefore, to keep up with peri-urban growth eThekwini municipality has adopted geospatial technologies such as GIS and aerial photographs to provide information about the patterns and trends of growth. In addition, the above sections highlighted that if the municipalities

could include remote sensing as part of planning methods, which is not the case at the moment in South African, municipalities could acquire up-to-date and accurate information regarding LULC.

## 7.4 TO ANALYSE CHALLENGES AND CONSTRAINTS OF USING REMOTE SENSING AND GIS FOR MAPPING AND MONITORING LAND USE AND LAND COVER CHANGES IN UMNINI TRUST TRADITIONAL COUNCIL

According to the manager for photogrammetry under Corporate GIS Unit from eThekwini Municipality, in terms of using satellite images for land use planning and management. He stated that "*it is impossible to identify land uses on the ground like school, community center, community hall, stand pipe, toilet to mention but the few as it generalizes all these land uses as built-up areas. To identify these land uses it requires the user to complement with the aerial photographs or Google Earth to enable the identification of land uses on the Earth's surface. However, He was of the view that remote sensing could be a supplementary planning method for change detection analysis as it has the capabilities to provide frequent satellite images as oppose to the aerial photographs which are gathered on yearly basis by the municipality"*.

Moreover, the Manager from photogrammetry further stated that *"the other constraint identified include the cost factor of using geospatial technologies like satellite imagery, aerial photographs, and GIS. These decision support tools and other related geospatial technologies are too expensive (in terms software and hardware costs), despite their strong capabilities for providing current and accurate information for land use planning and management. The higher the resolution and real-time information collected, the more cost and time consuming it is that is why the municipality collects aerial photographs and go for sample surveys on an annual basis rather than on weekly or monthly basic"*. GISc technician said that "*cost factor for these geospatial technologies strongly affect Category B and C (local and district) municipalities, which have limited budget allocated to purchase these technologies as mapping and analysis of densification is very costly. These municipalities tended to resort by only spotting those areas that are heavily affected by rapid population growth, rather than to capture the entire municipality on a frequently basis"*.

On the other hand, senior spatial planner from strategic spatial planning argued that "*satellite images are too expensive, in terms of cost factor and are specialized. Therefore, the municipalities including Category A (such as eThekwini Metropolitan where uMnini Trust traditional council falls within its jurisdiction); lack of relevant skills and expertise (human resource capital) to operate these high-tech tools create a major challenge, for mapping and monitoring land use and land cover change trends".* Furthermore, Remote sensing and GIS expressed that *"inadequate and poor infrastructural facilities coupled with a poor*

*maintenance culture and low-level funding on the municipality have greatly contributed to these constraints despite their strong capabilities for land use planning and management"*.

Nevertheless, Senior technical planner from land use management unit entailed that "*the more effective support from KZN-Cogta makes the municipalities with limited staff to enjoy the benefits of these geospatial technologies, as you can find that the entire municipality only rely on one GIS technician/ town planner for the operation of these techniques which delays day-to-day work of the municipality because of human and financial constraints, but the intervention from the department enhances positive results of using these geospatial technologies. He further shared the view that some municipalities have paid huge amount of budget to operate and implement these geospatial technologies which are hardly used. These constraints and challenges are the reason why other municipalities decide to outsource the work to the consultancy because of limited capacity to use these geospatial technologies like satellite images and GIS for land use planning and management within the municipality"*.

Senior spatial planner from KZN-Cogta said that "*despite the difficulties of implementing these geospatial technologies such as satellite images in the municipalities because of being expensive decision support tools. Those municipalities that have capacity to implement these technologies, are grossly affected by the high prices for the maintenance (software and hardware) that requires huge amount of budget*". Notwithstanding, Remote sensing and GIS expert contended that "*one of the biggest problems confronting GIS users, not only in developing countries but also in the developed nations of the world related to getting the required data set in digital format which is still a problem. In fact, even where it is available (required data), security and confidentiality issues continue to delay this process. This challenge slows down the rate at which land use and cover changes analysis over a certain period of time could be understood*".

In the same line of thought, Senior development planner said that "*the other challenge is the timing of these technologies, the use of GIS and aerial photographs do not provide with real time information as aerial photos are collected on a yearly basis because of its high costs. However, this is a huge constraint as the population grows on a daily or weekly basis, therefore, the municipality has to come up with the supplementary planning technologies such as integrating satellite images and GIS which are collected on a weekly or monthly basis"*. In a nutshell, section 7.4 discussed and explained challenges and constraints of using geospatial technologies and techniques such as satellite images (remote sensing) and GIS for land use planning and management. This section acknowledged positive results of adopting these geospatial technologies to the users for their day-to-day work, however, there were some setbacks such as the high costs, lack of digital

data, and lack of personnel with relevant skills and expertise to operate these systems to mention but the few which delayed spatial-related analysis.

### 7.5 IMPACTS OF PERI-URBAN LIVELIHOODS IN LAND USE/ LAND COVER CHANGES

After careful analysis of the data collected from StatsSA, researcher found out that uMnini Trust traditional council experiences socio-economic status that is typical of most peri-urban areas across the world. It further demonstrated that approximately 60% of the population has secondary (Grade 7/Standard 5) and even beyond. However, based on Figure 6.2 about 60% of the total population in uMnini traditional council was not economically active, while only 26% of the population was employed. This could be regarded as a contributing factor to high unemployment despite the diversified nature of local economy and spatial location of uMnini Trust traditional council inter alia near the larger pulp and paper industry (Sappi Saiccor), and close proximity to the City of Durban for better employment opportunities. Figure 6.4 in terms of income levels, approximately 16% of the total population do not earn an income which incorporates children and housewife that influence food insecurity and the lack of means for the population to sustain their livelihoods.

According to Figure 6.2,17% of the population earn between R9 601 and R19 600 per annum, and 15% of the population lives below poverty line as they earn below national minimum wage of R3500 as they earn R1600. This could simple illustrate that people are situated in the peri-urban areas because of a desire to occupy cheaper farmland away from the urban core, as the majority of the population live below poverty line who cannot afford to purchase the property in urban core, while with their economic status they can afford to sustain their livehoods in peri-urban areas. This 16% of the population that do not earn an income which are children and housewife are the beneficiaries of the government's social grants. Desperation for land in the peri-urban areas result to land invasions and uncontrolled population growth mostly through the encroachment of inter alia environmentally sensitive areas, and corridor servitudes (roads and railway) which affect sustainable land use planning and management more especially in rural traditional council areas as they do not have town planning schemes.

This rapid unorderly or "unplanned" development occurring mostly on the coastal areas of uMnini Trust demonstrates urban development trends which are not in line with the municipal package of plans such as SDF and IDP, and Draft rural scheme which is not a good move towards sustainable development goals. Moreover, based on the on-site observation and visual observations from land use/land cover maps, peri-urban densification continues to influence household size in uMnini Trust traditional council as more people are willing to be situated in close proximity to the urban core for diverse opportunities. This rapid peri-urban

densification process has contributed to a growing number of housing or settlement developments within the Coastal Management Zones in the area. Moreover, it has been noted (see Figure 6.6) that because of rapid peri-urban densification in the study area, the threshold and range to infrastructure and social services have been strongly impacted which affected sustainable livelihoods of the inhabitants.

## 7.6 THE IMPLICATIONS OF DENSIFICATION STRATEGY ON LAND USE AND LAND COVER CHNAGES IN UMNINI TRUST TRADITIONAL COUNCIL

It was noted on the South Spatial Development Plan (2013-14), and through utilizing of geospatial technologies (satellite images and GIS) that there was a plan for upgrading of existing settlements, and establishment of Rural Investment Nodes in the study area. "*The municipality identify areas suitable for densification along the road and rail corridors and adjacent suburbs*" (eThekwini Municipality SDF, 2014: 5). The interchange of N2/R102 offramp and Ilfracombe interchange have been identified as the rural investment nodes for uMnini Trust traditional council. In order to attract the investors for future developments and use of land in the study area, the municipality has encouraged sustainable living, compaction and densification of land uses along the major transport routes in the study area. It was evident in Figure 7.7, 7.8, 7.9, and 7. 10 that there were on-going coastal densification processes as per the uMnini LADP (2006) which allowed for residential densification of up to 20 units/ha in the vicinity of the N2 and R102. However, as a result of rapid peri-urban population growth the anticipated residential densification along the coastal strips has been exceeded, which threatened Coastal Management Zone and sensitive coastal dunes. It has also been acknowledged by senior town planner from the planning consultancy that *"there were limited population densities in the inland of the study area which falls outside the urban development line of the municipality. So, if there is working relations between traditional and municipal authorities land allocation should be only encouraged to take place in the inland of the study and discouraged along the coast because it has been already implicated by peri-urban densification*".

This frequent peri-urban densification and consolidation occurring along the coastal strips need to be accommodated in the planning and development principles of the area. The residential densities in uMnini LADP were estimated to be approximately 2500-3000 (development zone 3), 1500-2000 (development zone 2), and 500-1000 (development zone 1) (uMnini Local Area Development Plan, 2006). This strategy of the municipality of densification and consolidation is in alignment with the SPLUMA that promotes mixed land use development approach to overcome the issue of the fragmentation of land uses.

The strategy also helps the municipality in terms of threshold and range in ensuring equitable and sustainable provision of infrastructure and services. It is this strategy that also assist on the reduction in pressure for development on open spaces and environmentally sensitive area which is to evident in the coastal strips of the study area. Therefore, densification and consolidation around major access routes create sustainable communities serviced by public transport in the correct location. It improves accessibility of the communities to the transport and promote social inclusivity. Densification of land uses in coastal strips of the study area aimed at improving citizen's quality of life via access to opportunities, and reduction in travel time to access services and city center. The identified on-going coastal densification in uMnini Trust traditional council has been occurring along the corridors inter alia N2, R102, and railway line. Unregulated or unplanned developments occurring in the coastal strips has diminished the purpose of densification and consolidation as this densification do not fulfil the purpose as there are dense housing or settlements developing within the Coastal Management Zone which some are in conflict with the municipality strategies and objectives.

## 7.7 CONCLUSION

This chapter has presented and discussed the findings obtained using both qualitative and quantitative research methods. This study has shown the capabilities of integrating remote sensing (satellite images) with GIS for mapping and monitoring LULCC over the specified study period. This has also provided challenges and constraints of using geospatial technologies for land use planning and management.

## CHAPTER EIGHT: RECOMMENDATIONS AND CONCLUSION

### 8.0 INTRODUCTION

This study has managed to provide with an assessment and analysis of the application and effectiveness of Remote Sensing and Geographical Information Systems for mapping and monitoring land use and land cover changes for development planning. Particularly, in areas that fall under rural and traditional councils which have different land allocation and management systems to the one used by the municipality. The main objective of the study was to assess the application and efficacy of remote sensing and GIS for mapping and monitoring land use and land cover changes trends in uMnini Trust traditional council between 2001 and 2016 for development planning. This research has discussed the critical issues that incorporates the significance of geospatial related technologies such as satellite images, and GIS in providing accurate and current information about land uses/land cover types in rural and traditional council areas as these areas have different system for land allocation, and management to the one used by the municipality. However, this information about LULCC could assist in the preparation and formulation for wall-to-wall planning scheme as per the SPLUMA and PDA.

The hypothesis of this study stipulated that remote sensing and GIS are efficient and innovative tools which can be used for mapping and monitoring LULCC for development planning in uMnini Trust traditional council. This means that the integration of these geospatial technologies, when they are well administered by the municipalities and other institutions could be supplementary planning methods aimed to improve the performance of traditional planning techniques (such as sampling surveys and aerial photographs). This chapter then provides recommendations and a draw a set of conclusions from the research to assist the municipalities with the techniques and tools that provide with real time and accurate information to determine the extent to which peri-urban densification has consume agricultural potential areas, and the rate and magnitude to which these changes occurring over a certain period of time (in the case of the study ranging from 2001-2016).

These recommendations presented are not limited for use by eThekwini Municipality only. But can also be applied to other local municipalities that are in search for modern methods that should be applied to monitor and map LULCC as a result of rapid peri-urban densification. Eventually, increasing population require sufficient infrastructure and social services from municipality. This generic application of recommendations is based on the fact that other municipalities are facing similar problems with urban sprawl/growth that are

occurring in conflict with the municipal development plans, and thus would benefit from the specific issues addressed in uMnini Trust traditional council, eThekwini Municipality. Moreover, the following section provides the closing summary of the dissertation and will include the highlighting of areas that require further research in relation to this study. It will also provide some recommendations which have resulted from the research findings.

## 8.1 SUMMARY OF RESEARCH FINDINGS

Through the help of geospatial technologies such as satellite images, aerial photographs, and GIS, which have been employed to determine land use/ land cover trends over time (2001 -2016) in uMnini Trust within eThekwini metropolitan municipality, the study has been able to perform change detection analysis (LULCC) within a study period. The study has been able to demonstrate that uMnini Trust traditional council experienced rapid transformation due to physical expansion of urban development and infrastructure. It was evident (see Figure 7.8, 7.9, and 7.10) that this peri-urban expansion was mainly influenced by rapid peri-urban densification that tended to limit agricultural activities within the traditional council.

Research findings revealed that despite the effective and efficient application of remote sensing and GIS in determining the extent to which land use/land cover changes have been occurring in the study area within the study period (2001-2016). However, eThekwini Metropolitan and other municipalities in South Africa have not incorporated remote sensing technique with the intention for land use planning and management because it tends to be not consistent with the Surveyor General Cadastral and SG Diagram. Hence, aerial photographs (raster data), which are converted into vector data (GIS) to conduct sophisticated analyses has been entrusted technologies by the municipalities. These geospatial technologies provide a platform to determine the rate and magnitude to which rapid peri-urban densification implicated environmentally sensitive areas, and sustainable provision of infrastructure and social services. So, the study suggested that by incorporating remote sensing into the existing technologies and techniques within the municipality for LULCC monitoring and analysis could ensure the provision of updated and accurate information as satellites images are gathered on a regular basis while aerial photographs are collected on yearly basis.

This study further demonstrated the importance of regularly mapping and monitoring of land use/land cover trends in the fringes of the cities. The information acquired using the aforementioned geospatial techniques and technologies plays a significance inputs to the land use or development planner and decision maker during the decision-making process, as population expansion directly contribute to environmental

degradation as it was the case in the study. Coastal dunes, forests, and other agricultural potential areas are transformed into housing, industry, and infrastructure as a result of the increasing population pressure. Therefore, the adoption of modern technologies assist so that the municipality could be proactive in dealing with these pressing issues. Moreover, land use/land cover trends information helps the municipality in spatial planning processes such as the conceptualization and formulation of the spatial plans including LAP, SDF, functional area plan to mention but the few which are intended to regulate and control future developments to improve living conditions of the people.

The high rate of peri-urban population growth is a serious cause for concern among eThekwini Metropolitan's urban and town planners. In terms of the spatial perspective, these spatial plans with the help of the geospatial technologies such as GIS, aerial photographs, and satellite images enable to identify and guide how, where and what kind of development should take place in an area which is significant during the preparation of IDP and SDF. This also equips the municipality to determine where and how the area experience changes, and to improve their settlement and environmental planning to achieve sustainable urban development goals. In terms of this study, it was highlighted that N2/R102 off-ramp and Ilfracombe interchange were the areas identified on the municipal SDFs based on their capabilities as high potential investment for the study area. Therefore, in accordance with eThekwini Metropolitan densification strategy, these areas (rural investment nodes) were planned to be densified to ensure compact and viable communities with an intention to attract investors.

With the help of employing aerial photographs, GPS, Google Earth, satellite images from Landsat, and GIS to determine LULCC in uMnini Trust traditional council within the study timeframe. It had been noted that there was a rapid expansion in the study area particularly as a result of unplanned or unregulated dense housing or settlement development, which consumed a huge amount of arable land. With reference to the peri-urban livelihoods experienced by the people in the study area, the researcher deducted that this unplanned and unregulated housing or settlement development has generally contributed to unstable communities and caused livelihoods challenges. The researcher also noticed after a detailed analysis of the findings that built-up areas have expanded rapidly at uMnini Trust traditional, unfortunately, that has been occurring at the expense of agricultural potential land. These findings aligned with the information obtained from StatsSA, which stipulated that peri-urban densification take place frequently in uMnini Trust as the population density was estimated to 40 500, which accounted for 5 people per household in 2011. Whereas,

in 2016 the people were grossly increased to 84 084, which amounts to over 100% population increase over a period of 5 years.

Remote sensing and GIS expert from the municipality contended that this population increase pressure created a huge concern to the municipality. There was a huge reliance on Google Earth as oppose to the aerial photographs and sample surveys which was a norm because of the timing of these technologies, while the population grows on a weekly or monthly basis. However, high costs and time consuming of gathering aerial photographs on a weekly or monthly basis to keep up with rate of population growth has caused the collection of such data to be on an annual basis. This has created a vacuum for the municipality to come up with other means to acquire rate and magnitude of growth frequently to be consistent with population growth. Therefore, the adoption of GIS for planning and development was a strategy to obtained updated and most reliable information. In addition, this study suggested that the municipality should incorporate remote sensing (satellite images), which were fully discussed and presented in chapter two and chapter five. Integration of remote sensing and GIS which will ensure certainty for updated, reliable and accurate information. Based on that point, various authors such as Dewan and Yamaguchi (2009), theorists, practitioners viewed modern technology of remote sensing as that should be endorsed for providing frequent synoptic view of any development and use of land in a specific location over a certain period of time.

This study has illustrated the efficiency and effectiveness of geospatial technologies and techniques for LULCC mapping and analysis such as remote sensing and GIS. However, it has been expressed in chapter seven (research findings and analysis) that one of the reasons why municipalities are reluctant to adopt remote sensing for land use planning and management. It is because this technique has been accused that it tends to generalize classifying/categorizing land uses. When the pixel is dominated by a certain land use, the entire pixel usually is classified as that particular land use neglecting the minority land use. For example, when the spectral signature of the pixel is 70% built-up area and 30% agriculture, the entire pixel is classified as built-up area despite the fact that within the built-up area there are minor elements that belongs to agricultural land use.

The other constraint identified in this study was the issue related to the cost of purchasing software and hardware of these geospatial technologies, these components are too expensive more especially to the municipalities with limited budgets. These decision support tools require huge amount during the purchasing

and maintenance phases, this sometimes push the municipalities to do spotting planning where aerial photographs are gathered only for those areas which are regarded as fastest growing rather than to capture the whole municipality. The costs of these geospatial technologies are related to the fact that the higher resolution data is, the high the cost it becomes. The other concern at the municipal level has been the lack of relevant skills and expertise to use these decision support tools like GIS and remote sensing. Also, when there are sufficient personnel with relevant skills and expertise, the officials also lack competency to operate and implement these geospatial technologies and techniques as result officials hardly used these tools relying on the consultancy to do the work on their behalf. Lastly, the other challenge for effective implementation of these geospatial technologies has been the difficulties related to get the required data set in digital format which is still a problem. In fact, even where it is available (required data), security and confidentiality issues continue to delay this process.

### 8.2 RECOMMENDATIONS

Guided by the findings of this study, recommendations are provided in order to optimize the use of remote sensing and GIS in mapping and monitoring LULCC for development planning. Therefore, this study recommends that since the municipalities and other institutions require up-to-date information about population density and trends of growth, the integration of GIS and other geospatial technologies such as remote sensing prove to be supplementary planning techniques to the existing ones like aerial photographs and sample surveys. Therefore, this study suggests that for the municipalities to be able to ensure sustainable provision of infrastructure and services to increasing population, integration of remote sensing and GIS by the municipal council will ensure that municipal package of plans such as Integrated Development Plan (IDP), land use scheme and Spatial Development Framework (SDF) keep up with the latest developments and trends of growth. This integration of techniques and tools as the additional planning tools could yield good results for planning and development of places. Since aerial photographs and sample surveys which have been used for monitoring and evaluation of trends of growth proved to be insufficient and inadequate as they provide information about trends of growth and development on a yearly basis, while the population in peri-urban areas because of cheaper farmland outside the city grows on daily or weekly basis. Whereas, remote sensing and GIS could provide this information on weekly or monthly basis which will benefit municipalities when this transition is well administered.

Furthermore, this study recommends that despites of the positive results displayed by integrating remote sensing and GIS as supplementary planning methods, the success of this approach will entirely depend on the willingness and unconditional support of the top management for a buy in to spatial technology and its use. Therefore, the support of the top management to venture new technology in the municipality such as remote sensing (satellites) could be of the benefits. This has been derived from the fact that traditional planning methods (aerial photographs and sample surveys) have created a huge gap in ensuring up-to-date spatial data which are provided on a daily, weekly and monthly basis. So, this study recommends that the municipal council explore the venture of using these geospatial technologies (remote sensing and GIS) for mapping and monitoring land use and land cover changes (LULCC) for development planning.

Also, the study further recommends that after the willingness and support from the top management to incorporate these geospatial technologies as supplementary planning methods, the municipality has to deal with the training and hiring of enough staff (human capital). This could help to ensure that the municipality has required capacity in order to yield the benefits of incorporating remote sensing (satellite images) which is currently not employed as part of municipal planning methods. The venture to new technologies requires sufficient human and financial capital with relevant skills and expertise to enable operating these geospatial technologies. Therefore, this simple means that the municipality to ensure that this program is fully operational, they should attract investments to have sufficient budget allocated for these technologies which is crucial for their development plans. These geospatial technologies are too expensive; therefore, the municipality has to make sure that funds are available for other requirements such as purchasing and maintenance of software and hardware.

The study further recommends that after forging a mutual relationship between authorities (municipal and traditional), the intention is to achieve positive outcomes for sustainable urban development and having proactive strategies in place. This intended to ensure full implementation of these well documented spatial plans such as local area development plan, settlement plan to regulate and guide future development. Effective implementation of these spatial plans could eventually guarantee the safety and improved wellbeing of the residents. Furthermore, the implementation of these spatial plans could also be more efficient if there is a dedicated team including traditional leadership responsible for the enforcement of these plans more specially to regulate and facilitate development in rural and traditional council areas as they have different land allocation and management to the one used by the municipality. Therefore, efficient and effective

enforcement will ensure that through the help from available real-time and accurate information, the officials will be able to coordinate and control any development disturbing the status quo of natural environment and limit nuisance and undesirable conditions in the development and use of land.

In addition, this study suggests that the future research should mainly focus on evaluating the extent to which indigenous knowledge systems have been incorporated on the modern planning system. This simple means that even though the SPLUMA encourages the adoption of spatial plans as tools to guide and facilitate future developments, the reality of the matter is that in areas administered by traditional councils, indigenous knowledge systems (IKS) still dominate land allocation and management in these areas especially in KwaZulu Natal. Therefore, IKS should not be neglected in a fight against unregulated developments, which sometimes are in contrary with the municipal development plans as it has been a successful approach many years for land use planning and management. As this current research managed to determine the extent to which geospatial technologies have been used for land use planning and development, the fact of the matter is that these technologies could help the municipality to determine spatial trends and patterns of growth, however, limited working relations between traditional and municipal authorities diminishes the intended purpose as land allocation and management entirely depending on the traditional leadership not government while the SPLUMA promote wall-to-wall planning scheme including rural and traditional council areas.

## 8.3 CONCLUSION

This study has immensely contributed to the body of knowledge, the study of this nature was required to explore supplementary planning methods to enhance the performance of the traditional planning tools and techniques. This study advocates that the integration of remote sensing with GIS when the transition is well administered could yield good results more especially for sustainable land use planning and management. Currently, there is no municipality in South Africa which uses satellite images as a tool and technique for growth and development analysis, hence this study presented and discussed benefits and shortcomings of incorporating such techniques as supplementary planning methods. This study has shown that hard transformation during the construction of high-density development and settlements caused by rapid peri-urban densification contributed and still contributes to LULCC which has negative impact on the achievement of sustainable development goals.

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## LIST OF APPENDIXES

### Interview Schedules

**Appendix 1**

**Semi-Structured Questions: Municipal Officials Interviews**

1. What are the current LULCC planning and assessment processes used by municipality in uMnini Trust Traditional Council?
    - How does these processes help the municipality to acquire updated ad accurate information for LULCC which is essential for conceptualizing and formulating of the municipal package of plans?

2. Which methods or techniques used by the municipality for the future projections of the potential scenarios of change (LULCC) in a specific area over a certain period of time?

3. How the absence of up-to-date and accurate information on LULCC as aerial photographs are collected on a yearly basis while the population grows on a weekly or monthly basis affects sustainable peri-urban densification and trends of growth analysis which useful for municipal development plans?

4. How useful and effective are these current LULCC planning and assessment techniques and tools for sustainable land use planning and management?

5. What are the challenges and constraints of using LULCC planning and assessments techniques and tools for sustainable land use planning and management?

**Appendix 2**

**Semi-Structured Questions: Land Use Management System (South Region) and Planning Consultant**

1. Since the 1st to the 4th generation of Integrated Development Plan (IDP) of the municipality, which current LULCC planning and assessments processes used by the municipality during the integrated development planning processes in uMnini Trust Traditional Council?

2. How applicable and effective are these innovative and high accuracy techniques for drafting the municipality package of plans to improve quality of life and ensuring sustainable livelihoods?

3. With the help of these emerging geospatial techniques and tools, how do the municipality able to identify areas with high potential investments and those that need critical interventions in terms of development?

4. How applicable and useful are these techniques and tools for mapping and monitoring spatial distribution of facilities and services in uMnini Trust Traditional Council?

5. For temporal analysis, which is useful in the integrated development planning process, how applicable and effective are these techniques and tools for predicting growth and development in uMnini Trust Traditional Council (long term-10-20 years)?

6. How applicable and effective are these contemporary geospatial technologies for mapping and monitoring land use and land cover changes for land use planning/development in uMnini Trust Traditional Council?

7. What are the challenges and constraints of using Remote Sensing and GIS for land use planning and development in uMnini Trust Traditional Council?

8. How the municipality authorities integrate with the traditional authorities for land use planning and management in uMnini Trust Traditional Council?
9. How this integration ensures the mutual collaboration between municipal and traditional planning systems for sustainable land use planning and management in uMnini Trust Traditional Council?

## Appendix 3

### Semi-Structured Questions: KwaZulu Natal Cooperative Governance and Traditional Affairs Officials

1. What are the current LULCC planning and assessment processes used by the municipalities for land use planning and management?
2. Do the municipalities have required capacity to employ these effective and innovative techniques such as satellite images, GIS, and aerial photographs for sustainable land use planning and management?
3. How applicable and effective is the integration of municipal and traditional planning systems for sustainable land use planning and management in traditional councils like uMnini Trust Traditional Council?
4. How useful is the package of plans like Local Area Development Plan and Draft Rural Scheme in restricting incompatibility of land uses and promoting safety to attract investors in areas like uMnini Trust?
5. With the help of these emerging geospatial techniques and tools, how do the municipalities able to identify areas with high potential investment and those that need critical interventions in terms of development for sustainable development planning?
6. What are the challenges and constraints of using satellite images, aerial photographs, and GIS in the municipalities for land use planning and development?