University of KwaZulu-Natal

Exploring the spatial expansion of Settlements in Customary Regions – a case study of Adams Rural, KwaZulu-Natal

By

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2015

In fulfilment of the requirements for the degree of a Master of Science in Land Surveying

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2015
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ACKNOWLEDGEMENTS

I would like to extend my gratitude to the following people who played a very important role to the completion of this research.

- GOD for the gift of life.
- My supervisors Dr. Akombelwa and Mr. Chilufya for their vital role in throughout the research.
- The community of Adams Rural for their participation on the research.
- The eThekwini Municipality Photogrammetry and GIS Section for being the source of data and guidance.
- The Chief Directorate: National Geospatial Information also for being the source of data and guidance.
- Last but not least my friends and Family for their support.

Abstract

Adams Rural is one of KwaZulu-Natal's customary regions which falls under the traditional boundaries of the Ingonyama Trust Board. In this rural area traditional customs are still being practiced. The major land use was previously dominated by agriculture and very few residential settlements. This study reflects on the increasing recognition of the expansion of human settlements in this customary region. The expansion of human settlements is observed to have increased over the past decade and is confirmed by annual aerial imagery of the area captured by the eThekwini Municipality. The historical images captured by the National Geo-Spatial Information (NGI) suggest that there has been a substantial land use change in the area, resulting in loss of land previously used for sugarcane plantation. Therefore the study utilised spatial analytic techniques to quantify spatial changes in Adams Rural and map the land use / land cover change between years 2001-2004, 2004-2006, 2006-2008, 2008-2010 and 2010-2012 in Adams Rural. The research employs a post-classification change detection technique performed on selected orthophoto imagery, to assess spatial change patterns, to quantify the amount and the rate of change in human settlements of Adams Rural during the period 2001 to 2012. The results show that spatial extent of human settlements has more than doubled with commensurate loss in agriculture. Demographic data for 2001 and 2011 obtained from Statistics South Africa (Statistics SA, 2001 and 2011) also confirms that the population of the area has more than doubled over the same period. The rate of increase in settlements varied between periods considered with the population increasing proportionately. A closer inspection of the area was conducted using a questionnaire administered to the community. The questionnaire shows that the major contributor to the population increase in the area is the majority of people relocating from urban areas to this customary region. The questionnaire results further show that people are attracted to the development occurring in the area, larger parcels extent and the low cost of living with no bond payments, as there are no property rates payable on customary land. An attempt was made to project the spatial growth of built-up areas over the next 10 years using the change rate obtained from change detection verifying the prediction using the results from a questionnaire survey of the residents in the study area. It is observed that change by 2022 may likely follow the trend in 2001-2012. The present study shows that spatial analysis based on land use mapping using orthophoto imagery is very effective in monitoring the spatial features in customary regions.

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Chapter 1

Research Background

1.1 Introduction

Land administration is more than the representation of feature attributes of geographical and Geographical Information System (Mithofer, 2006). Land represents social relations and has meaning in a society. Geographical Information System (GIS) has a special relationship with the land; one could say that the existence of GIS depends on land. Nowadays GIS is widely used for analysing and interpreting spatial information on land, for example, comparing what is currently in existence and what existed previously. Various GIS studies have been conducted on urban land. The findings have been supportive towards urban land development and the software has been developed to formulate a computer-based land interpretation (Mithofer, 2006).

The use of GIS has been integrated with cadastral survey whereby, geo-referenced orthophoto images are overlain with parcel cadastral boundaries (e.g. general plans). ESRI, a GIS software company, has produced software which enabled the birth of GIS Cadastre. The GIS Cadastre System has an up to date land information system containing a record of interest in land. The system enables the user to view parcel information such as boundaries, restrictions, rights and parcel extents using GIS (e.g. eThekwini Municipality adopted this tool and uses it on their website for parcel viewing). This is one of the supporting results from various GIS studies carried out in urban settlements and in other fields of study. There are also on-going projects on urban areas such as informal settlement management, spatial growth analysis, and land cover analysis based on the capabilities of GIS (Mithofer, 2006).

However, little research on this topic has been conducted in the customary regions as there have been little developments in these areas. Sonneveld et al., (2005) conducted research based on sub-catchment scale of land degradation in Okhombe, one of KwaZulu-Natal`s customary regions. The changes were identifiable in historical images from 1945 to 2000 which were based on erosional features. The spatial pattern at this scale showed fluctuating behaviour. Sonneveld et al., (2005) additionally found that the Okhombe spatial patterns were attributed to grazing pressure. The increasing presence of unpalatable grass species characterised these grazing pressures at the expense of their palatable counterparts. Sonneveld et al., (2005) findings support Meadows and Hoffman`s (2002) views that soil degradation in customary areas is generally aggravated by grazing practices. Grazing, which was identified as common practice in these studies, was cited as contributing to the loss of vegetation cover, resulting in land cover change. This study evinces that through spatial analysis, using appropriate analytical tools that provide a broad resource management opportunity, customary regions can be mapped and monitored periodically.

This research therefore uses GIS and remote sensing software in conducting a spatial analysis of land cover change under customary land, arising from the change in land use. This study intends to shift the perspective on urbanisation to customary population growth, which results in settlement expansion using one of the customary regions under the eThekwini Municipality.

1.2 EThekwini Municipality Customary Region Development Plan

The eThekwini Municipality published a final draft on development in the customary regions located in the southern regions of Durban in KwaZulu-Natal in May 2012. The South Spatial Development Plan (SSDP) seeks to establish the ability of the existing resources and natural environment to create sustainable investment. The SSDP has earmarked Adams Rural as one of the areas to be prioritized in terms of development. Gabhisa Planning and Investments team was appointed on the 24th February 2011 by eThekwini Development Planning and Environmental Management to prepare a local area plan for the incorporated customary regions. Figure 1 shows the project area of the South Spatial Development Plan customary regions.

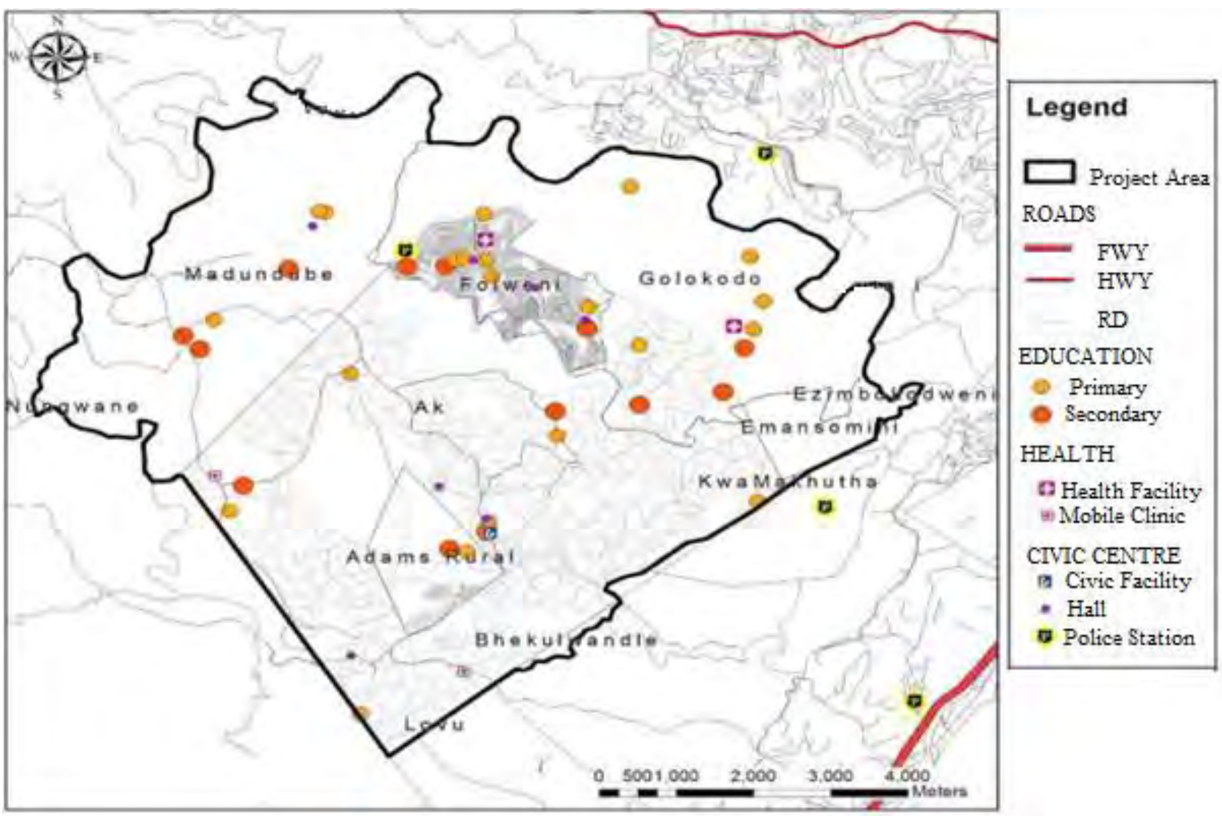


Figure 1: Project area of the South Spatial Development Plan. Adopted from the eThekwini Development Planning and Environmental Management SSDP (2012).

The project team consists of:

- GABHISA PLANNING responsible for project management and planning issues;
- SIMAMISA responsible for housing and social issues;
- BVI Consulting Engineers Pty Ltd responsible for transportation and engineering issues;
- URBAN ECON responsible for economic analysis;
- EESIA Environmental Consulting responsible for environmental assessments and
- GIScom Consulting responsible for GIS support.

This development draft prompted an observation of what was needed. Some of the common factors in these customary regions selected for development are economic factors and an increase in population and residential settlements over the past ten years. This draft identified Adams Rural as one of the sites that are strategically suitable for rural densification and the potential formalization of informal settlements and rural upgrade. The major planning principles and concepts suggested in the SSDP include a sustainable development plan that will ensure sustainability in terms of environmental considerations, physical and social service provision and local economic development, with particular reference to the areas of substantial informal densification. The SSDP also includes an integrated development plan that will facilitate the integration of various formal, informal, traditional and urban components including their interlinkage and accessibility.

A significant portion of land, approximately 80% within the development, is under the Ingonyama Trust. Ingonyama Trust is a board organisation which governs the KwaZulu-Natal customary regions. The arrangements for this development come with its own dynamics in terms of land management mechanisms and what the municipality can or cannot do. Developments within the Ingonyama Trust have been known to be conducted through the Rural Housing Subsidy approach. Additionally, all housing developments allowed on land owned by the Ingonyama Board do not translate into freehold titles, but are rather lease hold which is understood to have replaced the 'Permission to Occupy' arrangement. For many years rural communities have been migrating to urban areas, seeking better lives. This plan is part of reducing migration by developing rural areas in accordance with the SSDP (2012).

1.3 The South African History of Migration

Turok (2012) stated that South Africa's experience of urbanisation was unusual in several respects. In South Africa there was government intervention in the process of urbanization until 1990, to accelerate a form of rural–urban migration. Subsequently this intervention was to restrict people moving to the cities. A wide range of policy instruments, laws and institutions was used to influence household mobility, including racially discriminatory government controls on people's ability to own land, their ability to settle where they wished and the regulation of employment and the education and training system (Turok, 2012). Urbanisation has been a source of controversy for over a century, posing problems for successive governments and resulting in wide-ranging interventions to manage in various ways. In the late 19th and early 20th centuries, a form of racially segregated urban development was put in place, reflecting the needs of the economy for cheap migrant labour to support rapid industrialisation, but there was political nervousness about permanent rural-to-urban migration. The main effect was to fracture the physical form of cities and disrupt the lives of black residents through forcing them to the periphery (Turok, 2012).

Turok (2012) stated that the process of urbanisation in the late 19th and early 20th centuries was closely associated with industrialisation and involved the exploitation of both natural and human resources. The discovery of diamonds in the interior of the country in 1867 and gold in 1884 stimulated rapid industrialisation at a large-scale nationally (Yudelman, 1986). This was due to the mining industry requiring a large scale of workforce, and there was a need to assemble a bigger labour force through rural immigration (Wilson, 1972). Since then, people have continued to move towards the cities in search of better livelihoods or improved public services.

1.4 Settlement Expansion in Customary Land

The pattern of land use and land cover for an area is the product of socio-economic, natural factors and their exploitation by man in time and space (Lu and Weng, 2007). Due to human activities, the earth's surface is utilised significantly. This has resulted in an observable pattern in land use and land cover change over time, and has a profound effect upon the environment. Similarly there is an observable land use and land cover change in the customary region of Adams Rural in KwaZulu-Natal, which is due to numerous people accessing the area. The change of land cover is due to change in land use by people accessing Adams Rural. However, at the beginning of the study it was not established that the expansion of settlement and the population increase was due to people relocating from urban areas to Adams Rural. The study aims to prove this at a later stage of the investigation.

The connection, whether legally or customarily defined among people as individuals or groups with respect to land, can be used to define the term land tenure. There are rules of tenure which define the means of using property rights and how those rights are allocated to land within societies. These rules and laws define how access to land is granted to be used, transferred, and controlled as well as the associated responsibilities and restrains. In simplest terms, to determine who can use which resources on land and for how long, and under what conditions, is through the use of the tenure system. The way in which these rules and laws are applied and made operational is through land administration (Cotula, 2007). Land administration is made efficient through sets of procedures to manage information on rights and their protection. Therefore poor land administration results in an unreliable land tenure system. Thus those who access land under such conditions would have done so under a livelihood which lacks or has no tenure security. The spatial analysis can be applied to monitor and manage the access of land through the use of GIS and remote sensing software for a reliable land tenure system.

1.5 Spatial Analysis in monitoring the land

There has been a significant change on the earth's surface, and that there are few landscapes which are still in their natural states. Qualitative analyses of multi-temporal data sets can be used in the process of detecting changes and to determine the effects on land. This is an active method which is used to monitor land cover features. Change detection has a number of applications which includes vegetation change, damage assessment, wet land change, land use and land cover change (Vincent, 2009).

This research reflects on the increasing recognition of the expansion of settlements in customary areas. Using the spatial analysis, the expansion of settlements in these regions can be monitored over a chosen period of time. Photogrammetric data such as orthophoto imagery cover large areas and provides an overview of the study area. This imagery is very useful and an essential tool in this research. The growth patterns of settlements in customary areas pose a need for investigation in order to properly plan for land developments in the customary regions. Therefore there is a necessity to understand spatial patterns of Adams Rural that show how land cover and land use has changed over time. This will include incorporating ideas and theories from a diverse range of subjects including proper basic services, sustainable planning, land rights, economy and population growth. GIS and remote sensing provides advanced tools to explore and understand small scale rural change on a disaggregated level in geometric space. There are various spatial monitoring and modelling approaches which can be used to achieve the research objectives. These include post-classification change detection and modeling which is based on the result obtained by simulating future customary land cover change (Vincent, 2009).

Fazal (2000) used GIS Techniques in a study to determine the loss of agricultural land due to urban expansion in Saharanpur district in India. Fazal (2000) analysed the urban expansion using remote sensing and GIS tools. The results showed that in Saharanpur there had been a rapid conversion of agricultural areas to non-agricultural use over a period of 10 years.

Opeyemi (2006) examined the use of GIS and remote sensing in mapping land use and land cover in Ilorin (Nigeria) between 1972 and 2001, detecting the changes that took place in this period. Opeyemi (2006) also made an attempt to project the observed land use and land cover patterns in the following 14 years. The result of the work showed a rapid growth of built-up structures in 1972 and 1986, while between 1986 and 2001 a reduction in this class was witnessed (Opeyemi, 2006).

This shows that it is possible to use GIS and remote sensing tools in carrying out the spatial analysis in analysing the settlement expansion and highlighting the resulting trends. Methods used by Opeyemi (2006) and other researchers cited in the literature have been replicated in this research. This methodology was executed to understand the spatial land use decision in the context of the expansion of settlements and the loss of agricultural land in Adams Rural.

1.6 Research Problem

Spatial features are greatly used in land development and can be monitored in an urban area. This is due to the sustainable planning in urban areas practiced when developing land, such as designing a layout plan for settlement development. The spatial change detection, due to continuing housing development programmes in customary areas poses a vital need pertaining to the demand for an efficient land management system based on the modern Geographic Information System (GIS) technology.

In the early 1990s Adams Rural was less populated, with very few houses and the majority of hectares were used for agricultural purposes, but after the millennium the area has experienced land use change. The growth of residential settlements is the apparent cause of land cover change in the area. This can be viewed through the simple utilization of the Google earth Historical image viewer tool. Fazal (2000) suggested that there is a need to understand human activities and the social forces that drive them in changing the land use of their environment. This idea will assist in acquiring a broader understanding of spatial changes, monitoring environmental changes and also in responding to such changes in Adams Rural.

There is a trend in customary areas where young adults prefer to work in cities and then return to rural areas - not to farm but to build and improve their homes. This trend, which is continuing, became evident through conversing with customary settlers. This also seems to attract people from urban areas who require land in customary regions. This triggered the interest to investigate the extent to which this trend had spread and subsequently necessitating to check on Google earth. Therefore the increase in residential settlements in Adams Rural was spotted by utilizing the latest Google earth historical images tool.

The KwaZulu-Natal customary regions fall under the Ingonyama Trust Board (ITB), which is against land alienation, which resulting in no formal layout for these areas. The utilization of Remote sensing and GIS tools can be helpful in the land management of such areas. It might have been easier for the customary headman to manage customary land as most of these customary areas have been less populated when compared to urban areas. In customary areas, individuals in the community know each other and there are very few land demarcations. Using natural features as reference makes is easier for the stakeholders to manage land affairs (Chimhowu and Woodhouse, 2006).

The increasing population in customary regions (Adams Rural for example), results in growth in the number of settlements. Therefore this will make it difficult for customary land managers to manage the affairs of individual parcels and to solve boundary disputes. Therefore the use of spatial analysis to detect change, and to monitor and highlight the resulting trends is vital. This might lead to the creation of a GIS cadastre for customary land in KwaZulu-Natal, whereby the customary land stakeholders (Ingonyama Trust Board) can be the custodian of the cadastre.

1.7 Research Motivation

The motivating factor in this research is the eThekwini Municipality Development Planning and Environmental Management final draft plan (South Spatial Development Plan) which seeks to develop customary regions. Further the observable expansion of residential settlements in customary regions particularly Adams Rural, makes for an interesting study.

Land use and land cover change, due to the expansion of settlements in customary regions (Adams Rural for example), should be monitored to provide an understanding of residential settlement expansion. This will also help in establishing the role of Geographic Information Systems in the management of customary land use and development. The information obtained will assist in monitoring the dynamics of land use change, resulting from detected land use and land cover change due to the changing demands of an increasing population in customary regions.

1.7.1 Land cover and land use change due to settlement expansion in customary land

Urban areas are experiencing severe problems of managing the expansion of informal settlements, which is due to an inherited system of poor land distribution. Customary regions can also be affected by problems experienced in urban areas if the distribution of land is not monitored. The self-planned settlements on the customary land will result in an area that is difficult to manage, as no proper layout plans exist. It may, in the past, have been easier to manage customary land affairs as the areas may have been less populated may have had fewer settlements. However, with the observable growth of settlements from aerial images, the management of customary land affairs will need an effective management system. Customary land use and management are different from urban land, especially as there is no existing cadastre. The chief holds the power over land use and is not interested in any form of formalization of land. GIS based studies on the expansion of settlements can provide methods of managing customary land properly and creating a GIS based cadastre (Fazal, 2000).

1.7.2 The loss of agriculture in Adams Rural

The change of land use has resulted in the loss of agriculture and the study is motivated by the need to determine the loss of land previously used for agriculture and which has now been converted to a different land use. In the context of this study agriculture refers to sugarcane plantations and the minor grass lands in Adams Rural. Unlike urban areas and farms, agricultural land in customary tenure is not protected by the subdivision of the Agricultural Land Act 70 of 1970 legislation. This Act regulates the use of land reserved for agricultural use. Human shelter has shown to be the most important need. This prompts the questioning of Adams Rural customary land holders regarding the importance of protecting the sugarcane plantations and open spaces. Development of customary land is mostly observed as an improvement, but from the perspective of sugarcane farmers this particular transformation can be viewed as land degradation (Fazal, 2000).

1.8 Research Question

How can spatial analysis be adequately utilised to monitor spatial changes of land use and land cover and to measure spatial patterns of the settlements in the customary region of Adams Rural in KwaZulu-Natal?

1.9 Aim and Objectives

1.9.1 Aim

The aim of this research is to use spatial analysis to assess the changes of land use and land cover and to subsequently estimate likely future changes that might take place in Adams Rural in KwaZulu-Natal.

1.9.2 Objectives

1. To create a land use classification scheme. This was achievable by identifying different land use on the ground and in the orthopotho imagery.

2. To map land use and land cover change between the years **2001-2004, 2004-2006**, **2006-2008, 2008-2010** and **2010-2012** in Adams Rural by performing change detection analysis with the use of GIS and Remote sensing techniques.

3. To determine the drivers of relocating from urban areas to Adams Rural and understanding the current land use in the region. The information is obtained from the land use surveys with the use of a questionnaire.

4. To forecast the future status of land use in the area, by building a conceptual model, using results obtained from change detection analysis and the questionnaire.

1.10 Summary

The exploration of the settlement spatial pattern in Adams Rural concept is introduced in this chapter. The section addresses the issue of settlement expansion in customary land and discusses the spatial analysis concept. This is followed by the motivating factors which are discussed under the concept of land use change and loss of sugarcane plantation. The research question to be answered and the aim of the study have been addressed based on the research topic. The chapter also outlined the objectives of the research and the problem statement based on the research aim and questions. Lastly it outlined the structure of the chapters.

1.11 Chapter Outline

Chapter One

This chapter discusses the background of the research and outlines the purpose of this study by defining the problem statement. The chapter also describes the rationale and motivation for the study; describes the research context; discusses the aim and objectives of the study and presents the research question.

Chapter Two

The concept of customary Tenure is discussed in this chapter. The chapter draws on the customs of customary land practices. The allocation and administration of land in customary tenure is discussed.

Chapter Three

The extant literature closely related to this study is discussed in this chapter. The concept and the application of GIS, followed by the concept of customary tenure and land use in the customary regions are discussed. This chapter also discusses the concept of land use, land cover and change detection. The literature on the selection, processing of data and different image classification algorithms are also cited and discussed in this section. Chapter two further defines and discusses the post-classification and data modeling techniques. Lastly, case studies which are closely related to this study are discussed.

Chapter Four

This chapter describes the study area used for this research.

Chapter Five

The materials used and data generated are explained. This chapter further discusses the methodology of this study, the pre-possessing of images and how these images were classified and checked for accuracy. Chapter five also discusses the procedures followed in carrying out change detection and the land use survey with the aid of a questionnaire. Data collection procedures and the method used to develop the model are also discussed in this chapter.

Chapter Six

Chapter six presents the results obtained from the fieldwork in the form of tables and graphs and discusses these findings. . Each result presented is analysed and the finding are explained in detail. The findings are analysed and address the research questions and objectives. The spatial analysis result from the image pre – processing through the classification result are presented and analysed first. These results are followed by the findings of the questionnaire which is analysed using SPSS software. Lastly the development of a basic land development model is constructed from both image processing and questionnaire findings.

Chapter Seven

The discussion presented in this chapter is based on the results of the research from both the primary data and secondary data. The results are compared and contrasted with the findings of other researches cited in this study. The data pre-processing is discussed and maps are presented for further explanation. Thereafter, the discussion makes reference to the aims and objectives of this research. This chapter contains a land use classification and mapping discussion. Further, the relocation drivers and the land developments are discussed and explained.

Chapter Eight

This chapter draws final conclusions based on the results and findings The conclusion addresses the aims and objectives of this study, which is the creation of a classification scheme, mapping land use change, determining the relocation drivers and predicting the likely future changes. The overall conclusion and recommendation are also offered made in this chapter. Chapter six also contains the limitations of the study. The next chapter discusses the concept of customary tenure and land use in the customary regions.

Chapter 2

Customary Land

2.1 Introduction

South African land laws have always been controversial on account of its divisive nature (Johnson, 2004). The past laws of apartheid brought about patterns of landownership that were foreign to traditional land arrangements among African groups. Blacks were not allowed to become lawful landowners in a large part of South Africa. Because of the history of discrimination, many South Africans still lack secure title deeds to the land on which they live or which they have occupied for a long time (Johnson, 2004). The Communal Land Rights Act was going to be the most recent addition to the legislation drafted in terms of section 25(5) of the 1996 Constitution. The state is positively aiming at providing the effect to section 25(5), (6) and (9) of the Constitution. Through section 25(5), (6) and (9) of the Constitution, the Department of Land Reform and Rural Development (DRLR) attempts to give effect to tenure security, and redistribute state-owned land to its current occupiers. It specifically aims to provide access to land and secure title for those who live in rural areas, specifically in respect to land that is vested in the Development Trust.

Customary land falls under the ownership of indigenous communities and is managed in accordance with their customs (Ubink and Quan, 2008). Traditional authorities are the custodians of customary lands. In customary lands, traditional methods are still being practised when accessing and managing land. The land in customary regions is managed largely through traditional authorities and community associates (Bennett et.al, 2013). The chief is the main traditional leader of a particular customary land in a village. The chief is responsible for appointing the headman (induna) for each village. The role of the headman is to support the chief with issues such as land administration and land disputes. The key role of the chief is to maintain the law and order in customary land. Therefore permission to occupy residential land is issued by the chief in most cases through the headman. In sub-Saharan Africa, between two and ten percent of land is held under freehold ownership, therefore the outstanding 90% of the land is held under customary tenure (Chimhowu and Woodhouse, 2006). Freehold is the total and complete ownership of interests in land. This suggests that in sub-Saharan Africa, access to land is generally determined by customary systems of land tenure (Chimhowu and Woodhouse, 2006). In South Africa, in the KwaZulu-Natal province, most rural regions fall under the customary tenure system. The KwaZulu-Natal province has a board that acts as the custodians of customary land on behalf of the King. The Ingonyama Trust Board regulates the use of land and provides tenure to the communities in the villages. The word Ingonyama refers to the king. Customary tenure can be defined as a system which rural African communities usually use to communicate or express an order of ownership, right of entry and to control the use and transfer of land (Chimhowu and Woodhouse, 2006).

Adams Rural is one of the customary regions on the south coast of KwaZulu-Natal. This rural area has attracted numerous people to reside here and is amongst other customary regions which are within the eThekwini Municipality radar for service developments. It is for this reason that interest was developed and led the analyst to investigate change in this area.

2.2 Customary Land Tenure

According to Ubink and Quan (2008) the international land policy emphasizes the importance of recognizing and building on customary tenure systems. The recognition and building on customary tenure systems aims at achieving fairness in land management in developing countries. The lack of fairness in land tenure is evident in Ghana where customary transactions have become increasingly monetized (Ubink and Quan, 2008). According to Ubink and Quan (2008), the equity of customary systems under the control of traditional chiefs is being questioned. The major issues regarding customary tenure systems are: who has the authority to allocate land rights and who is entitled to acquire land in these regions. Generally, in customary systems, land is passed on through kingship; therefore, there is an uncertainty with regard to customary rights. In this way, customary land tenure is a positive feature that ensures continuing access for the poor (Chimhowu and Woodhouse, 2006).

Fonmanu (1990) states that the incorporation of the customary land tenure system within the modern system of land allocation results in land disputes, because the changes are not understood or accepted by the people. The customary regions are not demarcated or mapped precisely, since they were not subject to individual ownership. Thus the statement made by Fonmanu (1990) of land disputes may show to be true in developing customary regions, for example Adams Rural. In Fiji, common land disputes in customary regions often involve land boundaries, the location of property and the spatial area of interest in land (Fonmanu, 1990). Therefore, to provide a secure tenure system in customary regions, monitoring these areas by mapping may provide a solution to land disputes and strengthen the customary tenure system.

According to Fonmanu (1990) land boundary disputes arise usually when the features that were used as land boundaries of a property are destroyed or when they are no longer identified. In most cases, the elders of the community are the ones who have the knowledge of boundary locations and after they passed on, the young generations who are left behind at times do not have knowledge about the property boundaries. This leads to property boundary disputes. Therefore, land disputes arise as a result of uncertainties in location of boundaries and the spatial area of customary interest in land (Fonmanu, 1990).

This suggests a question of uncertainty pertaining to the security of tenure in the customary tenure system. These challenges suggest that the customary land tenure system must not be ignored, but rather be improved in such a way that it will accommodate those who are residing in rural areas. Land use mapping is one of the useful approaches in land management which can be adopted in the management of customary regions. In customary regions the public rights in land are vested in the king of that community of which he is the custodian. Meek (1957) stated that the custodian or administrator of customary land is not the owner of the land but he is a mediator through whom all transactions in land take place. According to Meek (1957) the chief allocates land to members of the customary land in accordance with their requirements and he has the right to take land back in the case where land has been abandoned or if a person has been dismissed in that region. Generally, the chief receives payments or compensation for land which has been sold or taken by the government authorities for public purposes. The chief has the right to cancel the grant of an occupier and to remove the occupier, for instance in the event of misbehaviour. The major argument regarding customary tenure has been security in land holding. Mudenda (2006) argues that customary tenure hinders commercialization; it is insecure, lacks certainty and frustrates rural land markets. This has led to the call for land tenure reform, attempting to replace customary tenure with a modern secure tenure. Land tenure security is often associated with land titling and land registration. It has been argued that lack of land titles in customary lands bring about insecurity because individual land rights are not recognized and protected by law.

2.3 Customary Land Use

The use of land in customary regions has generally been observed as focusing on agricultural aspects, mineral resources and conservation. The communities in customary regions use portions of land as residential areas as well as for cemeteries. There has been a change in some customary regions over the past few years. The land is now viewed as appropriate for residential purposes; consequently the farming use has declined. Customary communities also have rights in land, including the right to occupy and use land. South Africa has different types of land tenure rights, for example, freehold, permission to occupy and customary tenure. A customary tenure practice does not cater for freehold, hence, as there is no ‘`formal’ title to land and land alienation. This raises the question on the methods used for land management, for making land available for residential purposes in customary regions, and the effectiveness of the Land Use Management System. (Kalabamu, 2000; Foukona, 2010; Biesele et al., 1991; Mudenda, 2006)

2.4 Customary Land Use Management System

Foukona (2010) asserted that there are certain countries that have tried to move away from the customary land management system, while others have taken less fundamental approaches of introducing modest land management systems in their rural communities. Kalabamu (2000) viewed customary land tenure systems as going from better to worse while statutory or modern land tenure systems are considered alien, discriminatory, complicated and unfavourable to rural communities. Before colonization, land in most parts of Africa was governed by traditional procedures. The rules on land utilization, access and transfers are commonly known as tribal, traditional or customary land tenure.

According to Biesele et al., (1991) new households would usually be allocated their own pieces of land for erection of homesteads or cultivation out of the family or clan reserves, or the chief and headman would provide from the general tribal reserves. Land that was acquired through the chief or inheritance remained the chief's land. Despite the fact that land was administered by chiefs, headmen, clan or tribal elders, ownership was vested in the respective community such as a tribe or clan (Biesele et al., 1991).

In customary land, the chief is responsible for the land that is within the area of his authority in a region (Meek, 1957). The 'title' to land is vested in the chief on behalf of the people. He has no power to alienate or take possession of any land that is not his own personal property except with the consent and at the pleasure of the owner. According to Meek (1957) no king or chief can give authority to anybody regarding what he or she should do to his or her land. The chief allocates land or reallocates vacant lands to members of the community who require land or to approved strangers who wish to settle in the community (Meek, 1957). Meek`s (1957) findings on customary tenure showed that grants of land made to members of the community are complete grants which cannot subsequently be withdrawn except in the case of abandonment or for some criminal offence and the chief is the judge in all land disputes. According to Meek (1957) if strangers are given land by someone other than the chief, the person who gave the land to the stranger must inform the chief and his approval must be obtained since he becomes responsible for the safety and good behaviour of the community (Meek, 1957).

The Municipal Systems Act 32 of 2000 introduced a major change in the manner in which municipalities will function. Municipal boundaries have expanded to incorporate customary areas. Therefore the requirements for a Land Use Management System (LUMS) for the whole municipal area became a matter of importance. The Land Use Management System refers to all the actions required by the municipalities to manage land. The LUMS aims at promoting coordinated, harmonious and environmentally sustainable development, both in rural and urban areas. Integrating customary land into the new system is not an easy task to accomplish. Every resource available which can be used will be needed and GIS studies on customary regions can provide a solution. Customary regions have not been exposed to a formal system of land use, which means they have not been subjected to formal planning. This becomes a challenge as to how the Land Use Management System will be applied in these areas as the settlement growth continues in several rural areas. It is therefore imperative to understand the changes occurring in customary areas and their driving forces, and this can be achieved with the use of spatial analysis techniques.

One of the challenges in the implementation of the Municipal Systems Act 32 of 2000 and LUMS is that in customary regions there already exists a system of land allocation and land management. Therefore attempting to change from practices that have been employed for a long period of time will be very difficult. The change will have an implication on the leadership of the rural areas. In customary tenure, land management and allocation are the leader's responsibility. However the new Municipal Act suggests that the municipality is supposed to take over responsibilities and the Ingonyama Trust Board (ITB) does not support the change Adams Rural has been implementing and and disputes will arise if more people continuously access these areas. The lack of understanding of how customary land management operates, and the stakeholders not implementing measures that will be up to date with the increasing population, will result in a land management crisis.

Kalabamu (2000) posits that the traditional land tenure system considers the holding of the traditional system as one way of preserving African or indigenous culture and values. This results in contrasting views as to whether modern land tenure and management systems are better than traditional systems. . Traditional land tenure systems promote peaceful living and survival for everyone. On the other hand, modern or statutory land tenure systems, especially those based on Roman law, freeholds for instance, are criticised for promoting poverty and socio-political instability. Access to land is very critical to Africans since most families in Africa today depend on both wage and subsistence farming (Kalabamu, 2000).

Kalabamu (2000) argues that the traditional land tenure and management systems do not fit well with modern socio-economic realities because:

(a) Decision-making is controlled by traditional elderly people who are not receptive to modernisation or the introduction of new ideas and techniques in the use of land.

(b) Communal land ownership does not encourage individuals to invest substantially in land improvements. It instead encourages shifting cultivation and lack of commitment to land betterment.

(c) Individuals are unable to use land as security and are therefore, unable to access credit finance.

(d) Chiefs, headmen and other land administrators have their own indigenous beliefs of power and procedures.

However Foukona (2010) argues that secure land rights will promote increased investment into agricultural and commercial production of goods and services which will in turn stimulate other national markets and production systems leading to improved earnings and living standards. Furthermore, well-defined and secure land rights promote social stability as well as proper land management, utilisation and orderly developments. Foukona (2010) states that land administrators must gain knowledge of customary land principles and government should provide a system for the resolution of customary disputes which is financially viable and efficient.

2.5 Customary Land Allocation System

The chief of a customary region makes decisions on the allocation of rights to use land under customary land tenure. The allocation is credited to tradition and customary law. According to Levin and Weiner (1997) in the future land should be allocated and distributed more democratically. Levin and Weiner (1997) conducted research in Mpumalanga Province and found that people wanted a committee to be established to allocate land and further wanted the committee to consist of people from outside the area who will not have favourites. The role of the chief or headman was uncertain and as a result, the idea of establishing a committee was suggested. In Levin and Weiner`s study (1997) people felt that the chief or headman should not allocate land because they were failing to meet the community's needs. Therefore they suggested the chief should not control any land but there should be a committee which is elected and controlled by the people. Levin and Weiner`s (1997:154) recommendations on the allocation of land in customary areas are as follows:

a) The chiefs should continue to allocate land and should be in control of additional land;
b) The state in place of the chief should allocate land through elected community committees;
c) A proper system of land ownership and registration should be introduced and be controlled by the local state; and
d) In the case of residential land, this should be allocated by the state through mechanisms involving local community participation.

However, Bennett et al., (2013) argues that in deciding matters of land allocation or management, only the traditional authorities are the ones who allocate and administer land. Bennett et al., (2013) further states that the traditional authorities empower the committee and councillor to issue permission to occupy (p.t.o) residential land in customary regions. The issuing of rights to land involves the applicant appearing before a village meeting headed by the headman to approve the site allocation. The allocation of land does not involve formal land surveys or the issuing of title deeds. Therefore, security of land rights is provided locally through the approval that is given by the community and officially through registration of the allocation by the headman. In the registration of the land rights, the role of the headman is made more essential in resolving future land related disputes (Bennett, et al., 2013). The traditional leaders in the villages also play a key role in the allocation of land for development purposes. In Zambia, customary practices such as inheritance systems contribute to the inequality of land distribution (Mudenda, 2006). However Dougan (2004) states that in Ghana most chiefs make no attempt at keeping records on allocations and transfers of land which result into a poor land management system.

Bennett, et al., (2013) stated that in customary tenure, access to land is available to everyone. However there used to be a limitation on women's rights to hold land. According to the Food and Agriculture Organisation (2010) the limitations on women to respect of holding land was because of the awareness of the women in land conflicts and land 'titles' were often only registered in the name of a male head of household even if it was purchased by a woman. Bennett et al., (2013) state that there are still customary regions where access to land does not consider gender equality in the allocation of land. Women hold rights through male family members and in the case of divorce or where the man migrates, they usually lose their land (Bennett, et al., 2013). Customary regions in KwaZulu-Natal seem to consider gender equality as women are accessing land in various customary regions of KwaZulu-Natal. Customary regions in KwaZulu-Natal, South Africa are considered as part of state land as the ITB receives funds from the state for customary land management (Bennett, et al., 2013).

Mudenda`s (2006) research showed that the conversion of customary land to state land has created conflicts in many rural areas. Records on the size and dimensions of plots of land have been key problems in the administration of customary land in both Ghana and Botswana. In Botswana rough sketches of the dimensions of plots are created during site visits before issuing customary land certificates. Since most people who acquire and transfer customary land do not register these holdings, there exists no written information on the size and dimensions of the majority of plots of land (Dougan, 2004). Information on customary land is not easily accessible by the public. Land owners seem to lack knowledge of their land records (Foukona, 2010). Customary land practices does not require registration to prove ownership. The influence of colonial administration and the rigid rules that accompanied the right to transfer land prevented the traditional transfer system from being completely included within the colonial administrative system. The dual systems created confusion and caused some disputes (Foukona, 2010).

2.6 Summary

The maintenance of peace and order within any community is clearly essential. Therefore there should be some method of land management and an efficient and acceptable way of resolving disputes about who is entitled to what rights to land. This also applies to customary land where there are methods of land management which are specific to a particular customary region. Assuming that the law is able to make adequate provision for the determination of rights to customary land and the resolution of disputes about these rights, should the law go further and regulate or control the way in which the right holders use their land? Simply because the customary regions are not isolated to modern change or civilisation. The population and customary infrastructure are growing, thus customary communities also require more basic services as these regions develop.

Chapter 3

Literature Review

3.1 Introduction

Every land cover of a parcel is unique on the earth's surface (Meyer, 1999). The term land cover has incorporated various features such as soil type, surface, biodiversity and human structures. However, this term originally referred to the vegetation state such as forest or grass cover (Giri, 2012). There are many shifts in land use which affect the land cover in particular regions. These changes in land can be monitored and managed through spatial analysis. Through spatial analysis tools changes in land use and cover are monitored, inventorised, analysed and managed in various aspects of the world (Giri, 2012). Spatial analysis also assists in decision making and providing answers to questions such as how, why, what and where with regards to location information (Giri, 2012). Therefore with geographic literature knowledge one can make better decisions on land management. The following outlines examples of Geographic Information System (GIS) practical applications in six areas of interest as one of the sptatial analysis tools (Giri, 2012).

i.	Street network	- Address matching
		- Location analysis and site selection
ii.	Facilities management	- Locating underground pipes or cables
		- Facility maintenance planning
iii.	Land parcel	- Zoning, subdivision plan view
		- Land acquisition
		- Ownership of maintenance
		- Land-use planning
iv.	Natural resource	- Agricultural management
v.	Social	- Infrastructure planning
		- Public policy
vi.	Business	- Strategic and tactical planning

GIS is one of the key tools in determining vast spatial information in land available today and is also used to understand what the spatial information means. The maps produced with GIS are coded by values from the database. This helps with illustrating the patterns on land. Moreover, GIS can also be used in monitoring and depicting changes in these patterns (Giri, 2012).

3.2 Remote Sensing and GIS

Remote sensing can be defined as the science and technology by which characteristics of objects of interest can be identified without direct contact. The technologies and methods of remote sensing have evolved dramatically in the last three decades. Nowadays, remote sensing includes a suite of sensors operating at a wide range of imaging scales with potential interest and importance to planners and land managers (Lunetta, 1998). The evolution of remote sensing technology is promising to make an even greater impact on planning and land management initiatives involved in monitoring land cover and land use change at a variety of spatial scales. The current remote sensing technology offers a collection and analysis of data with linkages to GPS data, GIS data layers and functions, and emerging modelling capabilities. GPS and GIS integrated remote sensing can form the information base upon which planning decisions can be made, while remaining cost-effective (Franklin et al., 2000).

Remote sensing techniques for measuring urban areas and estimating urban populations have been used since the 1950s (De Bruijn, 1991; Bocco and Sanchez, 1995). A successful utilization of remotely sensed data for land cover and land use monitoring requires careful selection of an appropriate data set and image processing technique(s) (Lunetta, 1998). Remote sensing tools and analysis techniques are now providing detailed information for detecting and monitoring changes in land cover and land use. The change detection technique has become increasingly apparent over the last decade in monitoring changes of land use and land cover change. However, in the first decade of data availability, the change detection technique was not used widely (Franklin, 2001). This could have been due to a general lack of familiarity and experience, with a lack of understanding among researchers about the spatial and temporal dynamics of the landscapes under investigation. Fortunately these disadvantages have gradually been diminished over time, due to advances in sensor performance, image processing techniques, and informative research applications. Today, remote sensing and GIS technology has enabled ecologists and natural resources managers to acquire timely data and observe periodical changes.

Land use and land cover maps produced from conventional ground methods are labour intensive, time consuming and are done relatively infrequently and they become outdated with the passage of time, particularly in a rapidly changing environment (Opeyemi, 2006). Olorunfemi (1983) stated that monitoring changes and time series analysis is quite difficult with traditional methods of surveying. Recently remote sensing and GIS techniques have been developed, and they prove to be of immense value for preparing accurate land use land cover maps and monitoring changes at regular intervals of time. GIS and remote techniques are of most value in cases of inaccessible regions in obtaining the required data for mapping on a cost and time-effective basis (Opeyemi, 2006).

3.3 Data Used for Mapping Land Cover and Land Use Change

The primary purpose of the land use and land cover mapping is to provide a generalized view of how developed land has changed in an area; primarily capturing the conversion of resource land to development and characterizing the type of development. There are various land use and land cover (LULC) tools and methods for collecting and analysing information that have been developed to satisfy the user requirements and the information demand. Eiden`s (2002) research illustrated different data collection tools available for analysis of LULC. The emphasis was made on technical aspects of remote sensing, aerial photo interpretation and frame sampling surveys. Since the birth of remote sensing, a number of satellite missions have been dedicated to the observation of the earth which demonstrated a great potential of remote sensing imagery far beyond mapping LULC.

Eiden (2002) stated that the knowledge of remote sensing principles makes it easier to understand the use of data collected for LULC mapping. Eiden (2002) further states that it is important to understand that all objects on the earth's surface are interfering with the radiation as the target reflects, transmits, and absorbs the incoming electromagnetic waves depending on the tool used to capture information on the ground. The physical structure of the targets atmosphere and the image capture sensor determines the process that take place during imagery capture. Earth's objects such as water have stronger reflectance at a shorter wavelength thus it is visible as blue or darker near infra-red wavelength. The vegetation characteristics change depending on the season the imagery was taken. During summer the vegetation appears green and in autumn it appears red or yellow. The soil and minerals` reflection pattern exhibit stronger spectral features. The reflection depends on organic content, location and time, and atmospheric conditions during the image acquisition. Tappan and Cushing (2004) define different types of geographic data which are mostly mapped, monitored, and modelled:

1. Climate data
2. Soils data
3. Vegetation data
4. Land Use and Land Cover data
5. Population data
6. Land Management data
7. Land Productivity data

The spatial analysis tools have made it possible to integrate multi-source and multi-date data for the generation of land use and land cover changes involving information such as the trend, rate, nature, location and magnitude of the changes (Adeniyi et al., 1999). There are various data sources that can be used to map LULC, the examples are.

a) LANDSAT – This tool has been developing since 1972 and delivers multispectral imagery of the earth's surface. Since 1999 the payload of LandSat 7 was operational consisting of an Enhanced Thematic Mapper sensor (ETM). In addition to the multispectral band, the ETM sensor scans the earth in a panchromatic band with a pixel size of 15m -15m. LandSat 8 images have a large file size, at approximately 1 GB compressed. LandSat 8 images consist of nine spectral bands with a spatial resolution of 30 meters for bands 1 to 7 and 9 (U.S. Congress, July 1993 and Eiden, 2002).

b) SPOT – The SPOT satellites were initiated in 1986 and developed to SPOT 2 in 1990 and SPOT 3 in 1993. SPOT 3 has an Haute Resolution Visible (HRV) sensor on board, which delivers imagery within three spectral bands with a pixel size of 20m * 20m and a panchromatic band with 10m * 10m pixel size taken from an orbit altitude of 830 km. In 1998, SPOT 4 was launched, with a 1 km * 1 km pixel size and SPOT 5 was developed to improve the spatial resolution of the imagery to < 3 m. The newest satellites, SPOT 6 and SPOT 7, collect a combined 6 million square kilometers per day. SPOT 7 launched in 2014 with a 1.5m resolution suitable for 1:25.000 scale topographic mapping (U.S. Congress, July 1993 and Eiden, 2002).

c) IRS – This was the first Indian remote sensing satellite launched in 1988. IRS produced a panchromatic image with a 5.8m * 5.8m pixel size, a four-band imagery with 23.5m * 23.5m pixel size and two-band imagery with 188m * 188m pixel size (U.S. Congress, July 1993 and Eiden, 2002).

d) IKONOS – This was the first high-resolution satellite operational since the end of 1999. This satellite carries two independent sensors, scanning earth's surface in a strip of 11km width and up to 1000km length flown at a height of 681km. Panchromatic images were produced with 1m * 1m resolution and 4m * 4m multispectral images. The images produced by the sensors are of high quality and are close to aerial photography (Eiden, 2002).

e) NOAA-AVHRR – National Oceanic and Atmospheric Administration (NOAA) – Advanced Very Hh Resolution Radiometer (AVHRR) was constructed and originally designed for meteorological purposes. This satellite works differently, as it records the spectral reflectance in the red and near infrared wavelength and the emitted energy in the middle and long infrared region. The 1.1 km, the wide scan angle of 55 degrees and the technical properties allows for continuous monitoring and daily coverage of the earth particularly the weather forecast and other meteorological subjects (Eiden, 2002).

f) RADARSAT, ERS – This satellite sends signals that penetrate through the clouds and record a portion of the reflected signals, thus limiting the atmospheric errors. Eiden (2002) states that these are minor and important in land use and land cover change detection. These are mostly used for geological purposes such as sea-ice and oil spill detection.

g) Camera - Nowadays analogue cameras are being replaced by digital aerial cameras, which is a major change for the industry in various aspects. Various organizations that offer work around aerial photo flight projects will need information about new sensors on the market and their characteristics. These new digital cameras come with big differences in accuracy, image quality and data format. Now the challenge is to select the right sensor which will address the need at best. There are many types of aerial cameras, namely, aerial mapping camera (single lens), strip camera, panoramic camera, multi-lens camera, and the multi camera array multiband aerial camera and digital camera (Neumann, 2008). Neumann (2008) states that the acquisition of a digital aerial camera is a major investment with no comparison to the old analogue world. A digital aerial camera provides an opportunity for more companies to step into the photo flight business. The digital aerial camera vendors have the challenge to address the demands of a market which changes rapidly every year. Development of a good digital sensor is expensive and requires long development cycles (Neumann, 2008).

3.4 Different Types of Land Use and Cover

3.4.1 Urban or Built-Up Land

Urban or built-up land consists of areas of rigorous use with much of the land covered by structures. This category comprises of cities, towns, and villages, strip developments along highways, transportation, power, and communication facilities. These include areas occupied by mills, shopping centres, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas (Anderson et al., 1976). A village in KwaZulu-Natal (Adams Rural) possesses some of these characteristics such as villages and commercial complexes. Anderson et al., (1976) assert that as development progresses in this KZN region, land having less intensive or non-conforming use may be located in the midst of urban or built-up areas and will generally be included in this category.

Agricultural land, forest, wetland, or water areas on the fringe of urban or built-up areas cannot be included except where they are surrounded and dominated by urban development. The urban or built-up category takes priority over others when the criteria are met in a particular area on an image. For instance, residential areas which are located in places with tree cover that meet forest land criteria shall be categorised as built-up areas (Anderson et al., 1976).

3.4.2 Agricultural Land

Land used primarily for production of food and fibre is defined or classified as agriculture or agricultural land. On high-altitude imagery, the main indications of agricultural activity are mostly the geometric field road patterns on the landscape and the traces produced by livestock or mechanized equipment. However, these characteristics do not always exist as in grassland and other lands. Where such equipment is used infrequently it may not show as well-defined shapes as in other areas. Thus site visits to Adams Rural to confirm land uses was very important before the classification scheme was developed. Urban activity indicators and the associated concentration of the population should make it possible to distinguish between agricultural and urban or built-up areas. In agricultural land, building complexes are smaller and the density of the road and highway network is much lower than in urban or built-up land (Anderson et al., 1976).

The parks, open spaces, undevelopable land and large cemeteries may be mistaken for agricultural land, especially when they occur on the periphery of the urban areas. The border of agricultural land with other classes of land use may sometimes be a transition zone in which there is an intermixture of land uses. In cases where farming is restricted by wetness, the precise boundary may also be difficult to pinpoint (Anderson et al., 1976).

3.4.3 Forest Land

Forest land usually can be identified on high-altitude imagery, although the boundary between it and other categories of land may be difficult to delineate precisely. Land from which trees have been removed for production is part of forest land because in the near future these will grow again. The forest land pattern can at times be identified by the presence of cutting operations. Areas of little forest growth are usually categorised as forest land classes. Basically, where the dominant activities are forest-related and there has been extensive forest land grazing, those areas should be included in the forest land class (Anderson et al., 1976).

3.4.4 Bare Land

Bare land usually consists of sites visually dominated by considerable areas of exposed gravel on the ground. Such conditions are common in desert regions where combinations of sandy areas, bare rock, surface extraction, and transitional activities could occur in close proximity and in extent too small for each to be included at mapping. There are cases where there existed forest land or agricultural land but those land types have been removed causing the exposure of bare land. These should be carefully studied for their later use, if there would be built-up land or agriculture (Anderson et al., 1976).

3.5 Land Cover and Land Use Change

The earth's surface land cover has been changing since ancient times and is most likely to change in the future (Ramankutty and Foley, 1998). The changes in land occur at a range of spatial scales from local to global and temporal frequencies of days to millennia (Townshend et al., 1991). Natural and man-made features are both responsible for land cover change. The examples of natural forces are continental drift, glaciation and flooding (Giri, 2012).

The man-made examples would be conversion of forest to agriculture, urban sprawl, and the forest plantation would change the dynamic of land use and land cover types throughout the world (Giri, 2012). The man-made land cover and land use change has been proceeding much faster than natural change. There are two main forces responsible for the man-made changes; namely technological development and the growing human population (Lambin and Meyfroidt, 2011).

Land cover change plays a significant role in the exchange of greenhouse gases between the land surface and the atmosphere. The outcome of land cover and land use change can have either a positive or negative effect on humans (DeFries and Belward, 2000; Hansen and Defries, 2004). In the context of this study, a positive result of land cover and land use change would be the expansion of settlements in customary regions as it provides shelter for humans, and a negative result would be the loss of land reserved for agriculture. The land use and land cover mapping is one of the popular applications of GIS and remotely sensed data (Giri, 2012). Generally, there is confusion between land cover and land use, as they have been used interchangeably in this literature and also in daily practice. Therefore, it is important to define and understand the meaning of both these terms in order for them to be used correctly (Giri, 2012).

3.5.1 Land Cover Change

The land conversion or land modification can be used to define land cover characteristics. Changing one land cover to another defines the term land conversion and when the condition of land cover is modified, the term land modification is used (Meyer and Turner, 1994). In the context of this study, an example of land conversion is whereby the land cover has changed from agricultural land use to built-up areas. Monitoring and measuring land conversion using remotely sensed data is simpler than monitoring and measuring land modification. When dealing with modification, it is usually a long term process that may require multi-seasonal and multi-year data for accurate qualification. Vegetation and artificial construction covering the land are examples of land cover (Lu et al., 2004; Burley, 1961).

3.5.2 Land Use Change

Land use change is the human management change in the use of land. The land use may be independent of land cover change, as the land use may change but the land cover stays the same; not converted or modified (Giri, 2012). Agricultural use is a good example of this, whereby there is land use change in the farming of oranges to naartjies, but the land cover will stay green in both cases so therefore it has not been changed. Giri (2012) states that a change in land use is more likely to cause the land cover change. However, this research aims to determine the land use change from land cover change.

3.5.3 Challenges Mapping Land Use Land Cover Change

There are major environmental concerns in West Africa as outlined by Tappan and Cushing (2004). These concerns include the diversity of the West African land cover (Figure 3.1). Other major environmental concerns in West Africa include the declining rainfall and the degradation of natural resources under increasing human pressure. The increasing population is not an isolated occurrence in West African Countries as this is also experienced in other countries including South Africa. Adams Rural also seems to be experiencing an increase in population and this is proven by Statistics SA (2011) data. The mapping challenges further include the land use and land cover changes occurring at unprecedented rates in West Africa, where forest cover is diminishing and biodiversity has been declining (Tappan and Cushing, 2004).

Figure 3.2 is an example of land cover changes through time in Mali, specifically the diminishing of a lake. Therefore, for better land development and management there should be an understanding of land use and land cover change and land management will help countries balance food production with preserving their natural resources (Tappan and Cushing, 2004).

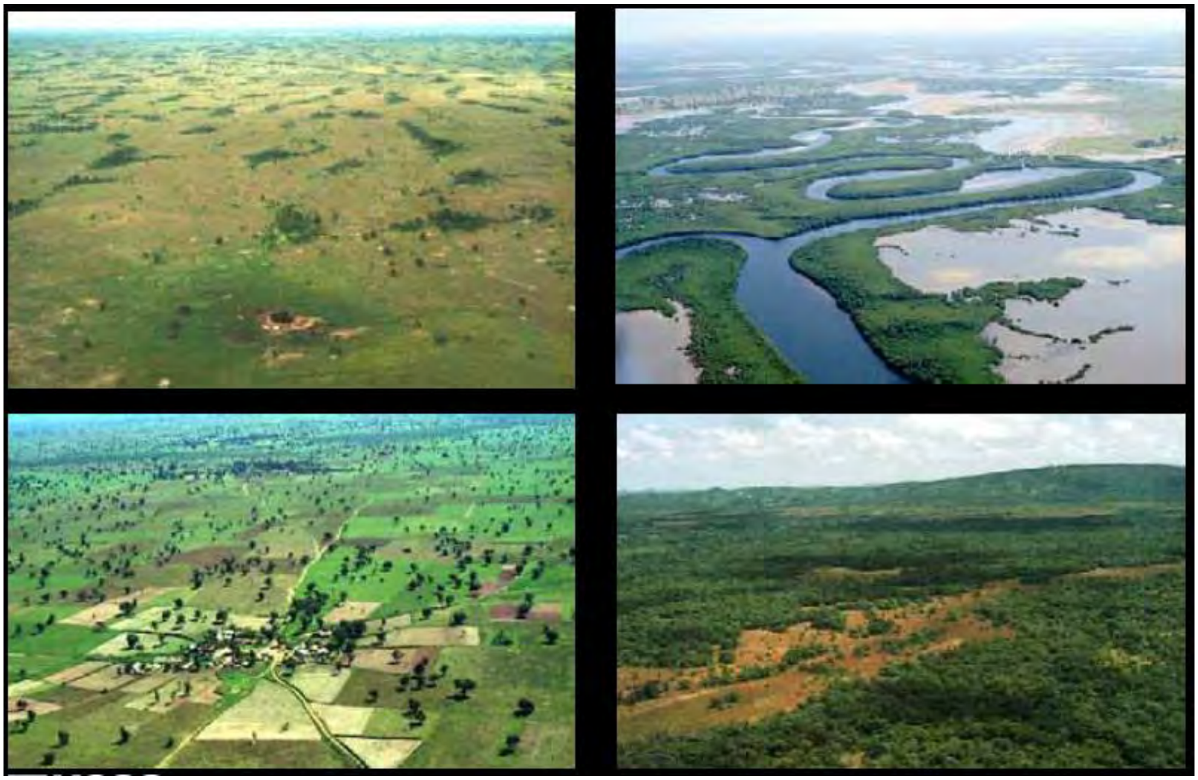


Figure 3.1: Image showing the diversity of Western Land Cover types. Image Adopted from Tappan and Cushing (2004) presentation of Survey Experiences of Mapping Land Use and Land Cover and Deriving Trends over the Vast West African Region.

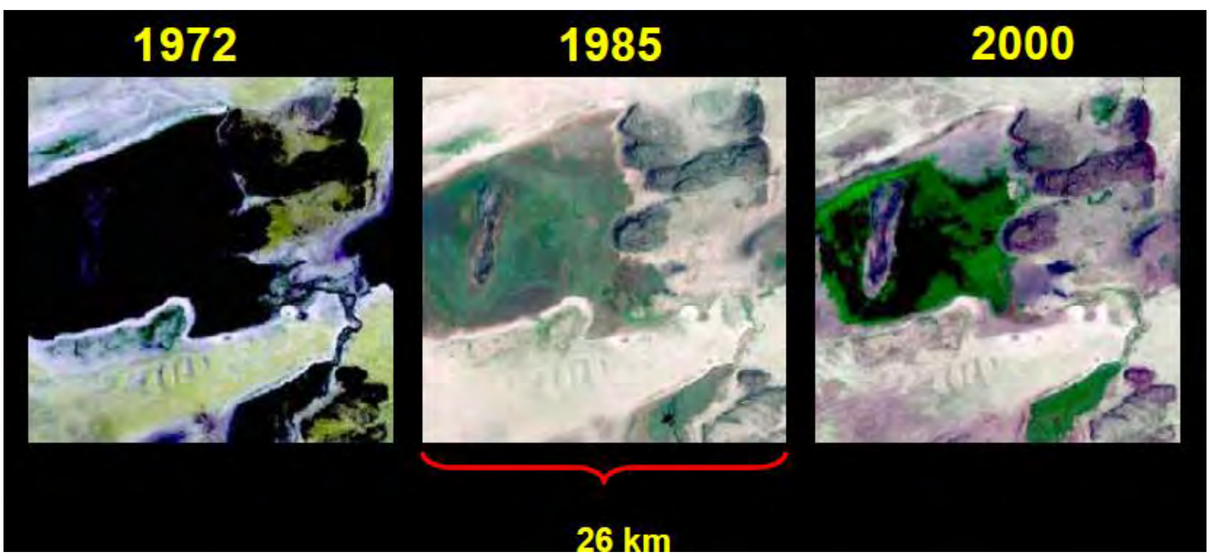


Figure 3.2: Image showing Lake Faguibine, Mali: A view through time with Landsat imagery. Image adopted from Tappan and Cushing (2004) presentation of Survey Experiences of Mapping Land Use and Land Cover and Deriving Trends over the Vast West African Region.

There are also challenges in the data used to define changes in land stated by Tappan and Cushing (2004). Land cover data are often not up-to-date and the time-series mapping of land cover is also problematic. Land cover classifications are not consistent and the spatial resolution of land cover data is often inadequate. The accuracy of data is also called into question (Tappan and Cushing, 2004). Moreover, there are difficulties of manually classifying several images. There are also issues of seasonality and the difficulty of identifying land cover classes. The time-series mapping presents another set of challenges (Tappan and Cushing, 2004).There exists challenges on the types and rates of land cover and land use change, and even less systematic evidence on the causes, distributions, rates, and consequences of those changes (Loveland et al., 2002). When using the rural-urban fringe as an example, the large tracts of undeveloped rural land are rapidly converted to urban land use. This land-use dynamic makes it difficult for planners to obtain or maintain up-to-date land-cover and land-use information, where typical updating processes are on a yearly interval (Chen et al., 2001).

3.6 Change Detection

The earth's surface is continuously changing by an array of man-made and natural forces. These changes can be monitored through a variety of change detection techniques (Coppin et al., 2004). The applicability of each technique varies with the intended application. This implies that there is no universal change detection technique (Coppin et al., 2004; Lu et al., 2004; Lu and Weng, 2007). Every surface of a solid earth is changing as we see coastlines shift, forests grow and shrink, human and international environmental expansion, variations in agricultural productions and natural disasters that greatly alter human and natural systems. There are general conditions that must be satisfied before such changes can be monitored (Lu et al., 2004).

Techniques to perform change detection have become numerous as a result of increasing versatility in manipulating digital data and increasing computing power. A wide variety of digital change detection techniques have been developed over the years. Singh (1989) and Coppin and Bauer (1996) both provide excellent and comprehensive summaries of methods and techniques of digital change detection. Coppin and Bauer (1996) cited eleven different change detection techniques. These include: mono-temporal, change delineation or post-classification comparison, multidimensional temporal feature space analysis, composite analysis, image differencing, image ratioing, multi-temporal linear data transformation, change vector analysis, image regression, multi-temporal biomass index and background subtraction.

The change detection method uses the image-handling technique to monitor change over a different period of time (Huang and Hsiao, 2000). Mapping changes in an area is one of the applications of spatial analysis, as we need to understand our evolving geography. Imagery is amongst the best suited data sources for accomplishing this task, for a number of reasons (Huang and Hsiao, 2000). Thus this research will make use of orthorectified aerial imagery. There are a number of available data sources; we can get data capture practically anywhere on demand, from optical infrared, thermal and from radar platforms (Lu et al., 2004). Imagery is also one of the most precise data sources with an ever increasing spatial resolution in geometric accuracy (Lu et al., 2004). Imagery is an objective source; raw imagery has not yet been interpreted into a derived source of information (Lu et al., 2004). Thus imagery is truly an inherent part of many spatial analysis applications and serves as a source of data to any spatial analyst.

Tappan and Cushing (2004) posed five questions that one needs to ask when determining change.

- What are the rates and magnitudes of change?
- How are the natural and human landscapes changing?
- What impacts are the changes having?
- What are the causes and mechanisms of change?

Lu et al. (2004) listed five steps that must be certified before change can be detected from imagery. These are precise registrations between multi-temporal imagery, precise radiometric and normalisation between multi-temporal imagery and selection of the same spatial and spectral resolution imagery. Image calibration and normalisation is very helpful in reducing effects such as shadowing, illumination and view angle (Lu et al., 2004). Change detection can provide possible measurement for specific types of changes in an area, such as vegetation health or specific differences in a single band of reflectivity and land cover types (Lu et al., 2004; Lu and Weng, 2007).

There are eight factors that detection of change accuracy depends on, which includes precise geometric registration of multi-temporal imagery (Singh, 1989; Coppin et al., 2004), the classification technique applied, knowledge of the study area, quality ground truth data availability, complexity of the landscape, the method used for change detection, as well as time and cost restrictions (Lu et al, 2004; Lu and Weng, 2007). Lu et al. (2004) defined four steps of detecting the change process: assessing the spatial pattern of change, image pre-processing, identifying the nature of the change and measuring the extent of the change. Lu et al. (2004) classified change detection techniques into seven categories namely: algebra, transformation, classification, advanced models, Geographic Information Systems (GIS), visual analysis and other techniques. Table 3.1 elaborates on these techniques. Lu et al. (2004) further highlighted that it is important to select a suitable change detection technique for a specific geographic area, and then outline a general change detection work flow. Thus the following are essential in carrying out change detection, ensuring that the images are co-registered accurately and which type of change is to be measured. Depending on the method chosen, an appropriate algorithm can be selected, and the parameters adjusted accordingly (Lu et al., 2004; Campbell, 2007; Lu and Weng, 2007).

Table 3.1: Summary of change detection techniques categories (Lu et al. 2004).

i. Algebra	- Image differencing - Image regression - Image rationing - Change vector analysis - Vegetation index differencing
ii. Transformation	- Principal component analysis - Tasseled cap (KT) - Gramm–Schmidt (GS)
iii. Classification	- Post classification comparison - Spectral change pattern analysis - Hybrid change detection - Expectation Maximisation detection - Unsupervised change detection - Artificial neural network
iv. Advanced Models	- Spectral Mixture analysis - Li–Staler reflectance model
v. Advanced Models	- Spectral Mixture analysis - Li–Staler reflectance model
vi. Geographic Information Systems	- Integrated GIS and remote sensing method - GIS approach
vii. Visual Analysis	- Visual Interpretation
viii. Other	- Regression analysis - Knowledge-based expert systems

3.7 Data Selection

Remotely sensed data is essential for monitoring the change of an area and the success of the process depends on careful selection of data sources (Giri, 2012). The spatial, spectral, temporal, and radiometric resolutions are important attributes of remotely sensed data (Lu et al., 2004). The selection of data also depends on the methods of land cover analysis and the targets of land cover analysis. Local scaled high spatial resolution images generally have an advantage of better geometric details of land cover (Giri, 2012). Low spatial resolution images with high frequency and revisit coverage are often best in characterising broad-scaled phenomena that cover large areas (Giri, 2012). Thus the high spatial resolution data is used in the detection of land cover change where high levels of spatial details are required (Lu et al., 2004).

3.7.1 Orthorectified Images

All imagery, whether it is obtained from airborne or space-based sensors, has inherent problems. There are distortions experienced during the capture. These distortions are caused by the angle between the camera or sensor and the ground, distortions from the movement of the camera through the air or space, and distortions created from variations in terrain. Therefore, manipulating the images through the process of orthorectification is the solution. Given the appropriate inputs, a rigorous model can be computed that corrects for the distortions introduced by the camera optics, viewing angles, and terrain relief. This means that when you measure a distance between two points on an orthorectified image, the result will be accurate. The application of orthorectified images includes mapping, urban planning and environmental management (Baltsavias, 1996).

3.7.2 Historical Images

The use of digital photogrammetry in recording and documentation of archaeological sites, historical structures and objects, nowadays offers a wide range of possibilities in terms of data acquisition dat3.7.3a processing and representation. The conservation and restoration activities of cultural objects are possible by means of historical images and these images are often the only way to reconstruct and study the past. Together with the simple qualitative analysis of some object characteristics, the powerful tools today offered by the digital photogrammetric systems permit the reconstruction of the past using historical imagery (Bitelli et al., 2001; 2002).

The historical images have various problems including the low quality resolution and radiometry, the lack of information about the images (acquisition period and method, camera information), the difficulty in finding accurate data like constraints or control points considered valid also in the epoch of interest and, the difficulty of correcting all the distortions suffered by the images in the time course. Therefore, the first problem is the difficulty in finding appropriate material in a good conservation stage, evaluating its quality and making it available for photogrammetric elaboration (Bitelli et al., 2001; 2002 and Coralini et al., 2006).

3.7.3 Aerial Photography

The term aerial photography means photography from the air. Photography means the art, hobby, or profession of taking photographs, and developing and printing the film or processing the digitized array image. Therefore photography is the production of permanent images by means of the action of light. They enable the detection of small scale features and spatial relationships that would not be found on the ground (Lillesand et al., 2004).

Aerial photographs are virtually permanent records of the existing conditions on the earth’s surface and these are also used as historical documents. Aerial photographs are readily available at a range of scales for much of the world. Aerial photographs can be produced with any type of camera. However, for large areas, high geometric and radiometric accuracy are required and these can only be obtained by using cameras that are purpose built. These cameras usually have a medium to large format, a high quality lens, a large film magazine, a mount to hold the camera in a vertical position and a motor drive. The aerial photo interpreters usually make use of seven tasks, which form a chain of events. They are change detection, recognition and identification, analysis, deduction, classification, idealisation and accuracy determination (Lillesand et al., 2004).

3.8 Data Processing

Change in land cover can be related to digital change between two images. It is vital to note that the change can be related to a range of other parameters, such as different atmospheric condition, image mis-registration, sensor differences, and different viewing conditions (Giri, 2012). Processing is applied to minimise the biased effect arising from various changes attributing to “noise” and instrument “artefacts” (Giri, 2012). The two most important data processing steps for change detection are multi-temporal image geometric correction and radiometric correction, which applies to a specific type of data collected (Giri, 2012).

3.9 Image Classification Techniques

Organising knowledge into order is an act of classification. In the spatial information case, classification is an abstract representation of features of the real world, by using classes or terms derived through a mental process (Giri, 2012). Classification requires defining the class boundaries, which should be clear, precise, and possibly quantitative and based on objective criteria (Giri, 2012). The purpose of image classification is to organise themes of land use and automatically assign pixels into one land use type in imagery (Lillesand et al., 2004).

There are two mainly used classification approaches namely, the supervised image classification and the unsupervised classification. These classification techniques work differently and the supervised classification has different methods. Anderson et al., (1976) describes the criteria that should be met when conducting a land use and land cover classification system which can effectively employ orbital and high-altitude remote sensor data:

3.9 (i) The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.

3.9 (ii) The accuracy of interpretation for the several categories should be equal.

3.9 (iii) Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.

3.9 (iv) The classification system should be applicable over extensive areas.

3.9 (v) The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.

3.9 (vi) The classification system should be suitable for use with remote sensor data obtained at different times of the year.

3.9 (vii) Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.

3.9 (viii) Aggregation of categories must be possible.

3.9 (ix) Comparison with future land use data should be possible.

3.9 (x) Multiple uses of land should be recognized when possible.

Anderson et al., (1976) states that some of these criteria should apply to land use and land cover classification in general, but some of the criteria apply primarily to land use and land cover data interpreted from remote sensor data. Recently, various advanced image classification approaches have been widely used (Lu and Weng 2007). The image classification approaches include, training data distribution, algorithm, pixel class, membership, parametric, non-parametric, unsupervised, supervised classifier, hard classifiers and soft classifiers. The pixel-based approach is referred to as a 'hard' classification approach and each pixel is forced to show membership only to a single class. The oft classification approach is thus developed as an alternative because of its ability to deal with mixed pixels (Jensen et al., 2005). An understanding of the problem and the application of available technologies, the integration of GIS and remote sensing with the aid of models and additional database management systems (DBMS) is technically the most advanced and applicable approach today (Ezeomedo and Igbokwe, 2013).

3.10 Supervised Image Classification techniques

The supervised classification approach allows the user complete control on the classes created from different land cover and land use (Campbell, 2007). The training stage and classification stages are general stages in the supervised classification procedure, and during this process the user is in control to decide which land cover types are of interest.

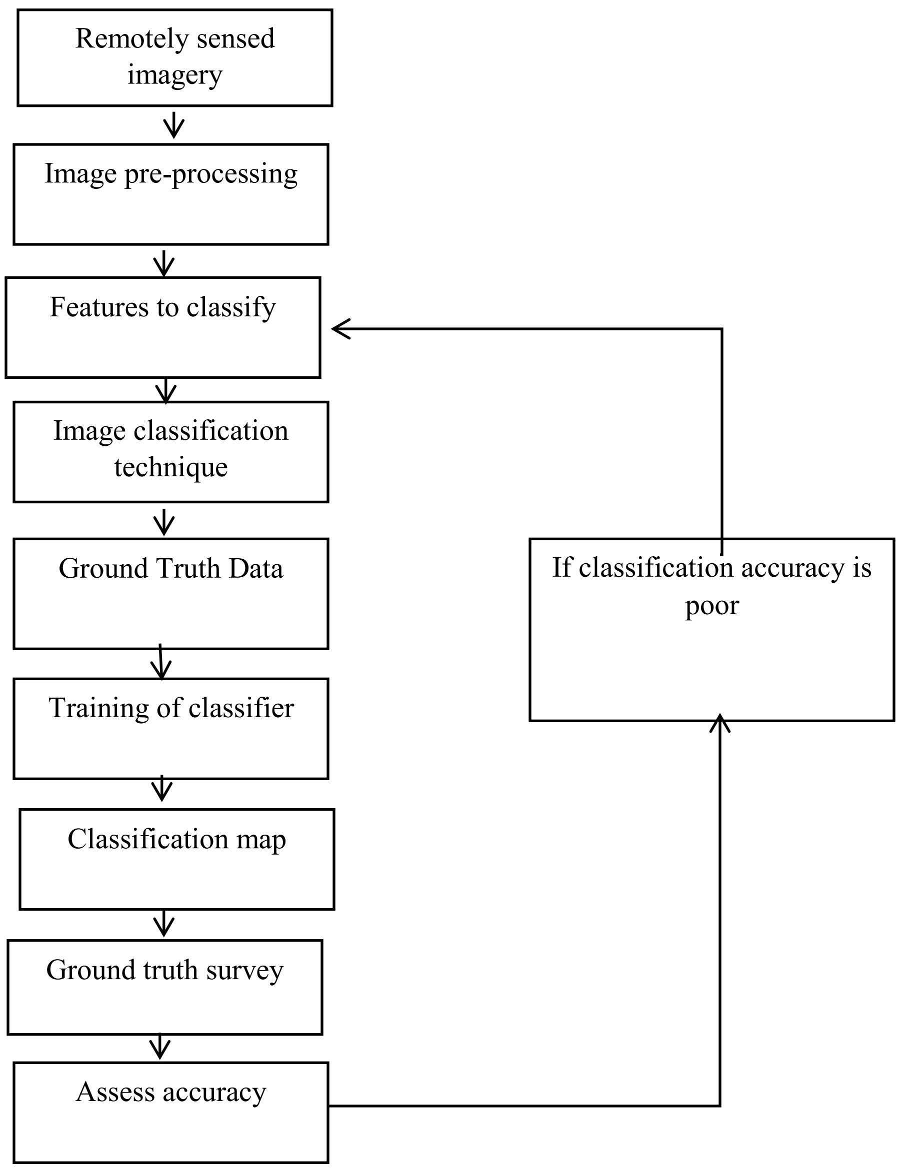


Figure 3.3: Brief outline of supervised image classification process (Singh, 2013:18)

The development of numeric description for spectral attributes of each land cover type is achieved through the use of pixel information in the training stage of supervised classification, whereby the pixels information is derived from analysing pre-defined pixel data sets and statistical techniques (Mather, 2001; Jensen, 2005; Campbell, 2007).

Once the classification system receives the pixel information, those pixels with similar characteristics are then categorised into the same class and those with different characteristics are rejected. The allocation of pixels into the same class is achieved by a decision rule used in image classification techniques. This technique allows pixels into a cluster or classes. The supervised image classification has four approaches, namely, the maximum likelihood classifier, and a minimum distance to means classifier, mahalanobis classifier and the parallelepiped classifier (Mather, 2001; Jensen, 2005; Campbell, 2007). Figure 3.3 summarises the supervised image classification process recent research done by Chen and Stow (2002) compared the performance of three different calibration strategies for supervised classification (single pixel, seed, and polygon).

The study showed that the calibration set size, the image resolution, and the degree of autocorrelation inherent within each class influenced the performance of these strategies, and polygon-based calibration performed best in areas of heterogeneous land cover types. The majority of approaches of monitoring land cover and land use change have used traditional image classification algorithms (e.g. maximum likelihood), which assume: (i) image data are normally distributed, (ii) the images are H-resolution and (iii) pixels are composed entirely of a single land cover or land use type (Franklin et al., 2003).

Conversely, L-resolution approaches have employed empirical models to estimate biophysical, demographic and socio-economic information (Rashed et al., 2001). Recently, researchers have investigated scenes using a combination of L and H resolution approaches (Roberts et al., 1998; Rogan et al., 2002). For example, Spectral Mixture Analysis (SMA) can be used to estimate sub-pixel information about both natural and urban or suburban scenes (Phinn et al., 2002). Fuzzy sets approaches, where an observation can have degrees of membership in more than one class, have also shown promise (Foody, 1999).

3.10.1 Maximum Likelihood Classifier

The Maximum Likelihood classification assumes that spectral values of training pixels are statistically distributed according to a multi-variety normal probability density function. The method considers not only the class centres, but the shape, size and orientation. Based on statistics (mean; variance or covariance), a probability function (Bayesian) is calculated from the inputs for classes established from the training site. The maximum likelihood establishes the probability that a given pixel belongs to a specific class and if a threshold value is not set all pixels will be classified. The advantage of this approach is that it takes into account the variance and covariance of spectral response patterns when classifying an unknown pixel. However, this technique requires many samples to calculate reliable variance-covariance matrices and a large number of computations to classify a pixel (Eras field guide, 2010).

3.10.1 Minimum Distance Classifier

This method uses Euclidean distances of unknown pixels from cluster centres (means). Each training cluster has the mean distance calculated. The unknown pixel is assigned to the closest minimum distance. This approach is faster than the maximum likelihood approach and is also simpler and computationally efficient. However, this approach does not account for the spread of data, particularly spectral direction. Since covariance data is not the spread, the class models are symmetric in the spectral domain. The other disadvantage of this process is that it does not take class variability into account, the pixel values differ but maximum distance classifier does not treat these pixels equally (Eras field guide, 2010).

3.10.2 Mahalanobis Classifier

The mahalanobis classifier takes the sample variability into account. It is based on correlations between variables by which different patterns can be identified and analysed. It gauges similarity of an unknown sample set to a known one. This approach weighs the difference by the range of variability in the direction of the sample point. Mahalanobis does not treat all values equally when calculating the distance from the mean point. It constructs a space that weights the variation in the sample along the axis of elongation less than the shorter axis of the ellipse. For example, point A will be closer to the mean than point B since it lies along the axis of the group that has the largest variability. Therefore A is far more likely to be classified as the same material as the group. The mahalanobis does not only look at variation (variance) between the responses at the same wavelengths, but also the inter-wavelength variation (co-variance). This is the disadvantage of this approach, which is the problem of over fitting (ellipsoid feature space) when more bands are used (Eras field guide, 2010).

3.10.3 Parallelepiped (Box) Classifier

This is the simplest but hardly ever used classifier. The upper and lower limits are defined for each class based on their minimum and maximum or mean and standard deviation, defining a box in the feature space. The unknown pixels are labelled according to the class that they fall in and pixels which do not fall in any of the boxes are classified as unknown (usually a zero value). The advantage of this classifier is that it is computationally fast and efficient. The disadvantages are on the overlap of classes whereby the pixel is assigned the label of a class that is first encountered. There exists undefined pixels due to gaps between the parallelepiped and prior probabilities of class membership and they are not taken into account (Eras field guide, 2010).

3.11 Unsupervised Image Classification

Unsupervised image classification techniques require little input from the user. This means that the unsupervised image classification techniques results will be hard to interpret; it may not represent classes that the users recognise. The cluster pixels in the feature space are based on some measure of their proximity. The study area is divided into a specific number of statistical clusters. These clusters are then interpreted into meaningful classes (Eras field guide, 2010).

3.12 Classification based change techniques

Classification based change detection technique is a commonly used technique in GIS and remote sensing applications (Lu et al, 2004). The classification based change detection techniques incorporates unsupervised change detection, spectral-temporal combined analysis, post-classification, hybrid change detection and artificial neural networks and expected maximisation (Lu and Weng, 2007; Lu et al., 2004). In classification based change detection technique, if corresponding pixels across corresponding epochs have to be categorised by different land cover type then change has taken place (Lu and Weng, 2007). Overall accuracy of classification based change detection techniques can be determined by taking a multiple of all the accuracies for each classified image (Singh, 1989).

3.13 Classification Accuracy Assessment

Giri (2012) states that the derivation of data source weighting parameters from classification accuracy measurement, is an instinctive approach. Thus the product of classification accuracy should be assigned a higher weight, and an unsatisfactory product should be considered unreliable and be assigned a lower weight (Giri, 2012). The accuracy determination to which it represents the real world is assessed from the classified image (Mather, 2001; Jensen, 2005; Lillesand et al., 2004).

An orthorectified image together with ground truth survey can be used to assess the accuracy of the classified images (Campbell, 2007; Jensen, 2005). The information needed for statistical analysis is provided by ground truth survey, which can be achieved by random sampling methods used to determine which sites to visit in order to verify classified images (Mather, 2001; Lu and Weng, 2007; Lillesand et al, 2004). This study adapted the error matrix accuracy test method for ERDAS output. The ERDAS software has a tool that provides for accuracy assessment, and which requires points to be entered by the user for each land cover class. ERDAS software also automatically produces an error matrix, and allows the user to perform accuracy assessment.

A statistically significant analysis needs a large number of (ground truth) observations per class. These ground (assessment) points should be randomly chosen. The relationship between known reference data (ground truth) and the corresponding results of the classification is assessed. This uses confusion matrix and reports as a percentage, Chi-squared, RMSE, Kappa (Batty, 2012).

3.14 Post-Classification

Coppin et *al*., (2004) and Lu et al., (2004) define post-classification change detection technique as a process that involves the comparative analysis of independently-produced spectral classifications for two or more epochs. Classification reduces the impact of atmospheric and environmental differences between the multi-temporal images (Singh, 1989; Coppin et al., 2004; Lu et al., 2004; Lu and Weng, 2007). Classification of spatial information requires a large amount of training sample data (Lu et al., 2004; Lu and Weng, 2007). The more training sample data, the higher the accuracies attained, and the accuracy of the change map created depends on the individually classified images (Lu and Weng, 2007; Coppin et al., 2004). The time of data capture has an effect on the method used for performing the change detection analysis, for instance when using multi-date imagery that was captured in different seasons. Using the post-classification change detection may be more advantageous than spectral temporal combined analysis (Pakeman et al., 1996). This results from a different spectral reflectance pattern of land cover type in different seasons which may affect the result of classification negatively (Pakeman et al., 1996).

3.15 Data Modelling

The term modelling might be used in various different contexts in the GIS environment, thus it would be wise to start with an effort to clarify its meaning in the contet of this research. Porter (2005) defines GIS Modelling as the process of creating new GIS products from existing spatial data. Goodchild (2005) defined two particular definitions of GIS modelling. Firstly, a data model, which can be defined as a set of expectations about data. A table is a typical example of such a model, and in a way tables are often used in GIS, the arrows correspond to a group or a class of real world features or attributes which is a GIS term to define features, that is, lakes and trees, thus the columns correspond to various characteristics of attributes (Goodchild, 2005). The table is therefore a very useful tool, as it provides a good fit in the context of data in many GIS applications. Data models allow the modeller to simulate how the world would or should look (Goodchild, 2005).

Secondly, there exists a model without the data qualification; this is a real word occurrence representation model, thus it is a representation of how the world works. With a model, a digital presentation of a real world is taken from one aspect and transforms it to create a new representation like (Goodchild, 2005). When the input and the output of a model both correspond to the same point in time, the model is defined as static model like (Goodchild, 2005). A model can also be dynamic if the output of a model is a representation of a later point in time than the input like (Goodchild, 2005). The operation of GIS in multiple stages is a common element in both these models; this is regardless of what their use may be (Goodchild, 2005).

A combination of various inputs to develop a useful output in the creation of a model is an example of a static model. Wischmeier and Smith's (1978) study of Universal Soil Loss Equation (USLE) combines mapped information about slope layers, the quality of soil, agricultural use, and other properties to estimate the loss of soil due to erosion from a unit area in time, is one real life example of a static model.

A dynamic model has a different undertaking, as it represents a process that transforms or modifies certain aspects of the earth's surface through time (Batty, 2012). Weather forecast representation is an example of a dynamic model, as it predicts weather conditions based on atmosphere; flooding is also an example as it is predicted from the storm (Goodchild, 2005).

Models are generally no longer built for prediction but as much as to inform general scientific inquiry over what the future might hold. An example is building a model projecting future patterns of land use in a region. These kinds of models are as much to structure debate and dialogue as to provide measures of how the future might turn out, for example the cellular automata model (Batty, 2012). There are other approaches of projecting the future pattern but a basic hierarchical model is of interest in this research.

The hierarchical data models were the first Information Based Models (IBM) called Information Management System (IMS) released in 1960. The hierarchical models contain large amounts of data as they are normally large data bases. Hierarchical data models are basically a system of arranging data into ranks and are easily understandable models. This method uses one too many relationships. This method is adopted in this study and will be constructed with the use of the land survey and image analysis results. There are no statistical assumptions about the data in this tree-like structure model (Provost and Kohavi, 1998; Witten and Frank, 2005; Quinlan, 1992).

3.16 Land Use and Land Cover Mapping studies

There are various studies which have been carried-out based on the capabilities of spatial analysis tools and techniques. The studies have analysed changes occurring on land due to man-made structures and natural changes.

The studies have been used to determine sustainable land development and management systems. With the advent of remote sensing and GIS many land cover and land use study have been undertaken. These studies are conducted in various areas which include urban areas, agricultural areas, and mining areas. For example, Chitade et al., (2010) conducted a study on the impact analysis of open cast coal mines of the Chandrapur district on land use and land cover using remote sensing and GIS technique. The study was conducted using multi-temporal satellite data (IRS-P5 data of 2009 and 2010 and LANDSAT-5 data of 1990) to create a land use and land cover mapping of the area; and reported a 67% increase in mine area.

Shoshany et al., (1994) investigated the advantages of remote sensing techniques in relation to field surveys in providing a regional description of vegetation cover. The results of their research were used to produce four vegetation cover maps that provided new information on spatial and temporal distributions of vegetation in this area and allowed regional quantitative assessment of the vegetation cover.

Arvind et al., (2006) conducted a study on land use land cover mapping of the Panchkula, Ambala and Yamunanger districts and Hangana State in India. They observed that the heterogeneous climate and physiographic conditions in these districts has resulted in the development of different land use and land cover in these districts. The digital analysis evaluation of satellite data indicated that the majority of areas in these districts are used for agricultural purposes. The findings indicated that the hilly regions exhibit fair development of reserved forests. The land use and land cover pattern in the area were observed and are generally controlled by agro-climatic conditions and ground water potential.

Ololade et al., (2008) worked on land-use and land cover mapping and change detection in the Rustenburg Mining Region using LandSat images. This was carried out using remote sensed data; LandSat MSS in 1973 (4 bands), TM 1989, 1997, 1998 (6 bands) and ETM 2002 (6 bands) and topographic maps of 1969 and 2005, used as reference base maps of the region. Standard image enhancements and registration were performed on the images. Supervised classification was carried out using the maximum likelihood method. Land-use classes; woodland, grassland, cultivated land, bare soil, rivers, dams, water ponds, built-up area, tailing dams and open cast mines were identified from satellite data and field surveys. Results showed an extensive increase in the last three decades of the tailing dams; mine dumps and return water in the Rustenburg region. The vegetation showed a decrease and woodland and grassland have been converted to cultivated land. The expansion of the built-up area was explained by the fact that there was increase in the settlements developed over the years due to the immigration of mine workers in the area.

Daniel et al., (2002) made use of traditional post-classification cross tabulation, cross correlation analysis, neural networks, knowledge-based expert systems, and image segmentation and object – oriented classification in their comparison of land use and land cover change detection. A combination of direct Time1 and Time2 change detection as well as post-classification analysis was employed. Daniel et al., (2002) observed that there are merits to each of the five methods examined, and that, at the point of their research, no single approach can solve the land use change detection problem.

Also, Adeniyi and Omojola, (1999) in their land use land cover change evaluation in Sokoto-Rima Basin of North-Western Nigeria based on archival remote sensing and GIS techniques, used topographic map, aerial photographs, LandSat MSS, SPOT XS and to investigate changes in the two dams between 1962 and 1986. The study revealed that there was no change before the construction in land use and land cover of both areas while settlements alone covered most part of the area.

Mallupati and Reddy (2013) performed a land use and land cover change detection study using GIS and remote sensing tools on an urban area in India. A post-classification change detection method was adopted in the study. Mallupati and Reddy (2013) acquired topographic maps and satellite images to develop a classification scheme and employ a supervised classification method using ERDAS software. The results clearly show that LULC changes were significant during the period from 1976 to 2003 in built-up areas. However, there was a decrease in agricultural area, water spread area, and forest areas. Mallupati and Reddy (2013) indicated the impact of the population growth in the area leading to the growth of settlements and decrease in agriculture. This study proved that the integration of GIS and remote sensing technologies is an effective tool for urban planning and management. Mallupati and Reddy (2013) stated that the quantification of LULC changes in the Tirupati area is very useful for environmental management groups, policy makers and for the public to better understand the surrounding.

Diallo et al., (2009) assessed the changes in land use and land cover in this southern part of Yunnan over a nine year period. The study made use of LandSat imagery of 1990 and 1999. The images were classified using the maximum likelihood classification method in ENVI 4.3 and mapped using ArcGIS. Diallo et al., (2009) preferred the supervised classification technique because the data of the study area was available and they had prior knowledge of the study area. This study highlighted the importance of digital change detection in understanding and managing the environmental situation.

Prakasam (2010) undertook a land use and land cover change detection through the remote sensing approach. The main objective was to analyse the nature and extent of land use and land cover changes in Kodaikanal Taluk (the study area) in the past 40 years and to identify the main forces behind the changes. The materials used in this study were the multi-temporal satellite data set observed by LANDSAT 5, Thematic Mapper (TM), LANDSAT 4, Multi Spectral Scanner (MSS) and a survey of India Taluk map drawn on 1:63360 scale, were used for the analysis. Arc GIS 9.2 and ERDAS Imagine 9.2 were used for processing, extracting the land use, land cover layer, and for image analysis. Once again this study adopted supervised classification approach. Prakasam` s (2010) study also showed that GIS and remote sensing can be used for spatial analysis and the supervise classification approach yields good results.

3.16.1 Land cover mapping in an agricultural setting using multi-seasonal Thematic Mapper data

Willamette River Basin (WRB) agricultural and other related land cover was characterised by a multi-seasonal LandSat Thematic Mapper (TM) data set which consisted of five different image dates from a single year. Cohen et al., (2000) registered these images by using an automated ground control point selection programme. Radiometric normalization was achieved by using a semi-automated method based on the identification of pixels in forest, urban, and water classes which did not change. Cohen et al., (2000) developed reference data by using existing data sets which consisted of low level 35mm colour slide photographs, 1:24000 colour air photos, and ancillary Geographic Information System (GIS) coverage.

A preliminary examination of the data structure was conducted and this included plotting of training set temporal trajectories in spectral space with reference to existing crop calendars. The mapped cells were labelled by using a subsequent stratified, unsupervised classification algorithm, in combination with a geo-climatic rule set and regression analysis. Thus a map of 20 land covers was developed. These classes included agricultural crops and orchards, forest and natural cover types, and urban building densities. Common classes were developed in the Cohen et al., (2000) study, and those which exist in Adams Rural. These include agricultural crops, forests and urban buildings. Therefore, it was important to understand how these were developed and used in the Cohen et al., (2000) study. Cohen et al., (2000) obtained an accuracy assessment error of only 26% of a final map. This map was then used to model present and future landscapes for the basin. This was another interesting aspect of this study; to model the present and future landscapes because this research also aims to achieve the same goal that is to predict the future land cover of Adams Rural.

The purpose of Cohen et al., (2000) was to produce a land cover map that would serve to characterize the existing conditions of the WRB, both as a baseline for later research and as the starting point for the development of futures scenarios. Thus a map of 20 urban, agricultural and natural land cover classes was produced. This work was almost solely on predicting land cover from TM imagery, therefore they had to augment the map with available ancillary data such as the US census data. Thus, for this research, the SA census data was collected and the method used by Cohen et al., (2000) to integrate the data with the imagery results for projection was carefully studied. In addition to US census data, Cohen et al., (2000) amended the map using an agricultural projection model that employed current knowledge of irrigation withdrawal permits and county cropping statistics to predict spatial agricultural patterns for a given year.

The result consisted of features with 60 classes, representing a wide variety of urban, forest, and non-forest land use and land cover types. Cohen et al., (2000) concluded that from their experience a land cover mapping project across a large region with many diverse land cover types, could be accomplished with the analysis of multi-seasonal tasselled cap imagery.

3.16.2 Mapping and Analysis of Land Use and Land Cover for Sustainable Development Using High Resolution Satellite Images and GIS

Ezeomedo and Igbokwe (2013) undertook land use mapping work focusing on depicting a quick and practical approach to mapping and analysis of land use and land cover patterns using high resolution satellite images. Ezeomedo and Igbokwe (2013) expanded their study by conducting change detection also using high resolution satellite images. The data used in this research consisted of existing topographical maps, SPOT-5, and IKONOS images. Ezeomedo and Igbokwe (2013) used spatial analysis tools to process the data by resampling, geo-referencing, classification and post-classification overlay. Hence the patterns and extent of land use and land cover in the study was mapped and the area was measured to determine the magnitude of changes between the years of interest, 1964, 2005 and 2008 respectively.

This study employed an image differencing technique. Ezeomedo and Igbokwe (2013) stated that such monitoring techniques based on multispectral satellite data demonstrated potential as a means to detect, identify, and map changes in land use and land cover. Four land cover classes were mapped in this study, namely, built-up areas (BA), open or bare lands (OP), vegetation (VG) and water bodies (WB). Ezeomedo and Igbokwe (2013) adopted a supervised classifications approach using a maximum likelihood classifier. The patterns and extent of land use and cover were then mapped using a change trajectory of post-classification comparison in the study area as well as to determine the magnitude of changes between the years of interest.

Ezeomedo and Igbokwe`s (2013) spatial analysis results shows that the built-up areas have been on an increase and mostly uncontrolled expansion from 8.12% of the study area in 1964 to 41.64% in 2005 and to 67.62% in 2008. The vegetation class, including cultivated and uncultivated agricultural lands showed a steady decline from 79.10% in 1964 to 51.78% in 2005 and a mere 18.74% in 2008. The overall result of change detection shows that as urbanization is increasing, the vegetation is decreasing as depicted. This study concluded that spatial analysis using remote sensing and GIS tools are effective. Ezeomedo and Igbokwe (2013) further concluded that the developed spatial map from these tools can serve as an efficient technical vehicle for spatial analysis and spatial modelling functions, to gain insights into developmental problems, e.g. to evaluate development impacts in the past, and to enhance regional development strategies through facilitating various scenarios. Therefore the study recommended that the government and public agencies concerned in Nigeria should develop policies and strategies to achieve a balanced, coordinated and sustainable development in the urban area and its environs.

3.16.3 Classification of Land Use Land Cover Change detection Using Remotely Sensed Data

Remote sensing imagery has many applications in mapping land use and land cover such as, agriculture, forestry, city planning, and urban growth. A study done by Babykalpana and ThanushKodi (2011) used the remotely sensed data and an image classification method in determining land use and land cover changes. When dealing with digital image analysis, image classification is perhaps the most important and widely used technique. Babykalpana and ThanushKodi (2011) analysed various change detection methods which have been developed nowadays. Some of the most common methods are image differencing, principal component analysis, post-classification comparison, change vector analysis and thematic change analysis.

This study conducted edge detection techniques, image acquisition, image enhancement, segmentation classification, and data modelling processes. However, the pre-processing had to be conducted and included radiometric correction. This corrected the data for sensor irregularities and unwanted sensor or atmospheric noise and converted the data so they accurately represent the reflected radiation measured by the sensor. Distortion, due to sensor-earth geometry variations, was corrected by conducting a geometric correction. Edge detection was performed on the image by the construction of edge detection operators on connected pixels that are on the boundary between two regions (Babykalpana and ThanushKodi, 2011).

Another technique that was employed was image segmentation which is the partition and pick-up of the homogeneous regions of image. The goal of image segmentation is to cluster pixels into silent image regions, i.e. regions corresponding to individual surfaces, objects or natural parts of objects. Image segmentation is a crucial processing procedure for the classifications and feature extraction of high resolution remote sensing image. The segmentation result is able to sway the effect of subsequent processing. The clustering technique was used to determine the natural spectral groupings present in a data set (Babykalpana and ThanushKodi, 2011).

After employing the supervised and unsupervised classification the findings showed that more agricultural lands are converted into residential areas, which reduces the vegetation growth. The industrial areas also showed an increase so that the pollution rate increases. There is a great reduction in the number of trees due to deforestation. Therefore the conclusion was that remote sensing data can be analysed to fix the land cover classification, know how the use of land changes according to time and also performed the temporal analysis. Moreover, analysis can be performed to analysed the supervised and unsupervised classification method successfully (Babykalpana and ThanushKodi, 2011).

3.16.4 Predicting land-cover and land use change in the urban fringe

The study explored the relationships between urban growth and landscape change, and between urban growth and population growth. Lopez et al., (2001) quantified land cover and land use (LCLU) change for the last 35 years since 2001, using rectified aerial photographs and geographic information systems (GIS). Thereafter the LCLU change was projected for the next 20 years using Markov chains and regression analyses. The LCLU change was quantified by interpreting the land cover patterns on sequential black and white panchromatic aerial photographs (1960, 1975 and 1990), corresponding to the city of Morelia and the surrounding urban fringe (nearly 200 km2). Lopez et al., (2001) used the aerial photography and the approximate scales were 1:25,000, 1:50,000 and 1:25,000. Further, the topographic map (1:50,000 scale, 20 contour interval), as well as sequential demographic data were obtained from the census of 1940, 1960, 1970, 1980 and 1990.

The final cartographic products were produced at the coarsest scale. An enhanced and geo-referenced LandSat TM colour composite of 1997, with 30m spatial resolution was used to compare results of prediction with independent data. This research found that urban planning in this type of settlement can be based on models and data which can be easily gathered using widely available aerial photographs or rectified (conventional or digital) and increasingly popular GIS and automated databases with good quality levels. Lopez et al., (2001) stated that Markov chains helped to describe the general tendencies of change, however, prediction capabilities were not strong. The findings show that the most powerful use of the Markov transition matrices seems to be at the descriptive rather than the predictive level. Linear regression between urban and population growth offered a more robust prediction of urban growth. Thus Lopez et al., (2001) suggest that linear regression should be used when projecting growth tendencies of cities in regions with similar characteristics.

3.16.5 Change Detection in Land Use and Land Cover Using Remote Sensing Data and GIS

Opeyemi (2006) conducted a project examining the use of GIS and remote sensing in mapping land use and land cover in Ilorin between 1972 and 2001. This was to detect the changes that occurred between these periods. This study also attempted to project the observed land use and land cover to the next 14 years. LandSat satellite images for three Epochs; 1972, 1986 and 2001 were acquired. Opeyemi (2006) states that on both 2001 and 1986 images there were notable features observed which were not yet constructed as of 1972. The 1986 and 2001 images had the same geo-referencing properties. However, image thinning was applied to the 1972 imagery which had a resolution of 80m using a factor of two to modify its properties and resolution. There were three major software used for this research, namely, ArcView, ArcGIS and Idrisi32.

Opeyemi (2006) developed the classification scheme based on the priori knowledge of the study area and conducted a brief reconnaissance survey with additional information from previous research in the study area. Together, this provided enough information to develop a classification scheme for the study area. The area was calculated in hectares of the resulting land use and land cover types for each study year and subsequently the results were compared. Markov chain and cellular automata were used for analysis in predicting change and for image classification, the maximum likelihood classification was employed. The land consumption rate and absorption coefficient was determined by formulating an equation based on the data acquired. The land consumption rate and land absorption coefficient were introduced to aid in the quantitative assessment of the change as an attempt to project the observed land use and land cover in the next 14 year (Opeyemi, 2006).

This study demonstrated the ability of GIS and remote sensing in capturing spatial-temporal data. Five land use and land cover classes were mapped as they change through time. This work produced results that show a rapid growth in built-up land between 1972 and 1986 while the periods between 1986 and 2001 witnessed a reduction in this class. Forest land showed a steady reduction between 1986 and 2001 and this was predicted to likely be the trend in 2001/2015. The land consumption rate showed a progressive spatial expansion in 1972 and 1986 but showed a drop between 1986 and 2001 and this drop was also anticipated before 2015. Therefore the use of GIS and remote sensing was successful in creating a land use and land cover classification scheme, determining the trend, nature, rate, location and magnitude of land use and land cover change. Further, GIS and remote sensing was used to forecast the future pattern of the land use and land cover in the area using land consumption and the land absorption coefficient.

3.16. 6 Land Use and Land Cover Change Detection Study at Sukinda Valley using Remote Sensing and GIS

The study was undertaken to analyse the land cover and land use change in Sukinda valley between 1975 and 2005 using remote sensing data and GIS by mapping land cover and land use (Majumder, 2011). The data used in this study was the LANDSAT data of three different years (1975, 1992, and 2005), using ERDAS and Quantum GIS software. The aim of the study was to assess the land cover and land use changes in the Sukinda valley in the last three decades which was achievable by creating a land use land cover classification scheme and generating statistical data on land consumption. The Landsat images and topographic data had to be pre-processed before use by conducting a mosaic and geo-referencing the image. Majumder (2011) used ERDAS 8.4 for displaying images and mosaicking and geo-referencing the images and Quantum GIS 1.6.0 for classification by visual interpretation and to create the land cover and land use pattern. A supervised classification method was applied and the result of the work showed that there was a rapid change of quarry and dense forest during the period from 1975 to 2005 (Majumder, 2011).

3.17 Land Use Surveys / Questionnaires

Queensland Health (2007) defines a survey as the gathering and analysis of information about a topic, an area or a group of people. Questionnaire surveys can be an economical and efficient tool for collecting information, attitudes and opinions from many people and for monitoring a project or program's progress. The main benefits of such a method of data collection are that questionnaires are usually relatively quick to complete, are relatively economical and are usually easy to analyse (Bowling, 1997). A questionnaire survey is one of the tools which will be used in this study for collecting information in Adams Rural, to develop an understanding of the area thus developing a model. When a questionnaire survey is designed and administered correctly, the information collected can be a true reflection of opinions held by the group from which you want information (Queensland Health, 2007). However, a high level of knowledge is needed to design and implement a good quality survey. It is not usually possible to survey the whole community of interest; one needs to survey a sample that represents the community. Table 3.2 outlines different methods of sampling people. Queensland Health (2007) states that the sample needs to be representative of the people you really want to talk to so that as little bias as possible occurs. A biased sample is when the results of the survey does not accurately reflect the views of the people from whom the information is needed.

Table 3.2: Showing different methods of taking samples.

Sample type	Definition	How to do it?
1. Random	A random sample is a selection where each person has had the same chance of being selected as all other people.	If lists of all people from which information is wanted are available, number each person and select numbers randomly.
2. Systematic	Survey the people in accordance with a certain of set patterns or criteria.	eg. Survey every fifth person on a list.
3. Convenient	Survey people who can be easily reached.	Survey people who walk past or who visit a show.

Correctly determining the target population is critical. If you do not interview the right kinds of people, you will not successfully meet your goals. According to Queensland Health (2007) all sampling methods are effective as long as potential bias is acknowledged. Therefore, it is important to choose the method that fits best within the time, quality and financial constraints of your project. The first step in any survey is deciding what you want to learn. The goals of the project determine whom you will survey and what you will ask them. If your goals are unclear, the results will probably be unclear (Cochran, 1977).

The next thing to decide is how many people you need to interview. A small, representative sample will usually reflect the group from which it is drawn. The larger the sample, the more precisely it reflects the population. A decision about sample sizes must be based on factors such as: time available, budget and necessary degree of precision (Cochran, 1977). A biased sample will produce biased results. However, totally excluding all bias is almost impossible but if bias is recognized some of the responses can be discounted (Queensland Health, 2007). Sample size is probably the most often asked question about surveys; how many people should be surveyed. Booth (1991) stated that there is no one correct sample size number, as the sample size is a trade-off between what is statistically desirable and cost effective. The statistical aspect is concerned with the sampling error, which is the difference between the values recorded in the sample and what the actual values would have been if the whole survey population had been surveyed. The larger the sample size, the smaller will be the sampling error, the closer the sample approximates the total survey population. This is true, however, only if the sample is unbiased. Bias is often more important than the sample size for statistical accuracy. Hence all measures should be taken to guard against bias (Booth, 1991).

3.17.1 Self-Administered Questionnaire

This is a method of collecting data which is used with paper questionnaires that have been administered in face-to-face interviews; mail surveys or surveys completed by an interviewer over the telephone. This study adopted the scanning questionnaire method where the questionnaire is administered in face-to-face interviews. The advantages of scanning questionnaires are that this can be the fastest method of data entry for paper questionnaires. Scanning is also more accurate than a person who has to read a properly completed questionnaire. However, there are also disadvantages of scanning - one being that this method is best-suited to "check the box" type surveys and bar codes. Scanning programs have various methods to deal with text responses, but all require additional data entry time (Tabachnik and Fidell, 2001; Rietveld and Van Hout, 1993).

3.17.2 Developing a Questionnaire

The intentions of the research must be stated clearly before designing any questionnaire to collect information from people. Many people are cautious and hesitant to answer questions about themselves and to offer their opinions. However, people will probably be more willing to help if the questionnaire intentions are clearly stated. It is advisable that at the top of the questionnaire a brief statement explaining why the information is collected and reassuring each respondent that the information is entirely anonymous (UCSD Student Research and Information, 2013).

Table 3.3: showing the stages in questionnaire development: item generation and scale construction (Jones, 2005: 234)

Questionnaire development	Key issues	Examples of measures
What will the questionnaire Measure?	Knowledge Attitude/beliefs/intention Cognition Emotion Behaviour	The York Angina Beliefs Questionnaire, (Furze et al., 2001) Operationalising the Theory of Planned Behaviour (Conner and Sparks 1995) Illness Perception Questionnaire (Weinman et al., 1996) Anxiety, depression (Spielberger et al., 1983, Goldberg and Williams 1988) Functional Limitations Profile, FLIP(Patrick and Peach 1989)
What types of scale can be used?	Frequency Thurstone Rasch Guttman Mokken Likert type Multiple choice	ICEQ, (Rattray et al., 2004) Nottingham Health Profile, (Hunt et al. 1985) Loneliness scale (De Jong Gierveld and Kamphuis, 1985) FLIP (Patrick and Peach 1989) Edinburgh Feeding Evaluation in Dementia SNSI, (Jones and Johnston 1999) The York Angina Beliefs Questionnaire, (Furze et al., 2001)
How do I generate items for my questionnaire?	Ensure relevance of items? Wording issues Which response format is best? Which types of question are possible? Free text options? Does your measure have subscales? Questionnaire layout	Check research questions, explore literature, experts, target population Follow established guidelines (Oppenheim 1992; Bowling 1997). Discard poor items. Consider and pilot response format (five-point, seven-point, visual analogue scale) In standardized measures most are closed, to allow combination of scores from large numbers of respondents. May have some open, free text responses. Construct items that represent each different hypothesized domain Carefully consider order of items

The wording for survey questions must be brief. Each question should be clearly stated with no misunderstanding about what is being asked. One of the best ways of ensuring that the questions are well worded is to test them by having other people review and test the survey (Kiernan and Ellen, 2004; Taylor, 1998). There are a number of scales and response styles that may be used when developing a questionnaire. These produce different types of data and this will influence the analysis options. As a result, when developing a new measure, it is important to be clear which scale and response format to use (see Table 3.3).

3.17.3 Questionnaire Analysis Tool

The simplest option for analysing survey data is probably to use the analysis tools for data analysis that has already been used to collect the data. Where only basic analysis is required, such as working out the percentage of people to select each option, this is usually the best approach. However, if there is a need to conduct more sophisticated analyses, it is generally necessary to use software specifically designed for the analysis of the questionnaire. There are various specialized types of software used in survey analysis such as:

SPSS – This is a software package used for statistical analysis, and the software name originally stood for Statistical Package for the Social Sciences (SPSS). The most users of this package are market research consultants, internal research departments, statisticians and 'advanced quant' teams. SPSS is difficult to learn, however it is an efficient and flexible creation of crosstabs, has advanced analysis and weighting automation (Market Research, 2015).

The R Project for Statistical Computing – Mostly knows as R software. R is mostly used for environment statistical computing and graphics by statisticians and 'advanced quant' teams. R is poor at creating crosstabs and almost everything has to be done by 'programming' which makes it not user friendly and very slow to use (Market Research, 2015).

Data Cracker – This method is described as having little or no experience in analysing surveys. The creation of complex crosstabs is not flexible. However, it is easy to use and has a predictive modeling that can show which questions relate to each other, and shows you how (Market Research, 2015).

Market Sight - Like SPSS this software is capable of analysing the questionnaire, it can create crosstabs and charts. However, its limitation is that it does not have advanced analysis tools (Market Research, 2015)

This research opted to use the SPSS software based on its availability, capabilities and efficiency.

3.17.4 Questionnaire reliability and validation

According to Jack and Clarke (1998) it is important that the reliability of a questionnaire can be demonstrated. Reliability refers to the repeatability, stability or internal consistency of a questionnaire and a most common method used to demonstrate the reliability is the Cronbach's statistic (Jack and Clarke, 1998). This statistic uses inter-item correlations to determine whether constituent items are measuring the same domain (Bowling 1997, Bryman and Cramer 1997, Jack and Clarke 1998). If the items show good internal consistency, Cronbach's should exceed 0.70 for a developing questionnaire or 0.80 for a more established questionnaire (Bowling, 1997; Bryman and Cramer, 1997). Item-total correlations can also be used to assess internal consistency. If the items are measuring the same underlying concept then each item should correlate with the total score from the questionnaire (Priest et al., 1995). When developing a questionnaire, it is therefore important to include, within the research design, additional established measures with proven validity against which to test the developing questionnaire. Construct validity relates to how well the items in the questionnaire represent the underlying conceptual structure. Factor analysis is one statistical technique that can be used to determine the constructs or domains within the developing measure. This approach can, therefore, contribute to establishing construct validity (Priest et al., 1995; Bowling 1997; Bryman and Cramer 1997).

The validity is necessary to check whether relevant questions about the research topic are being asked and whether sufficient areas are covered. Questionnaire validation also seeks to check whether the obtained information is accurate and consistent. According to Costello and Osborne (2005) factor analysis is assumed to be a more reliable questionnaire evaluation method than the principal component analysis. The factor analysis technique can test the validity of a questionnaire (Bornstedt, 1977; Ratray and Jones, 2007). If a questionnaire is valid one's total score on the twenty items of the questionnaire of interest should represent one's pleasure in writing correctly. Exploratory factor analysis detects the constructs - i.e. factors that underlie a dataset based on the correlations between the variables. The factors that explain the highest proportion of variance in the variables share are expected to represent the underlying constructs. In contrast to the commonly used principal component analysis, factor analysis does not have the presumption that all variance within a dataset is shared (Tabachnik and Fidell, 2001; Rietveld and Van Hout, 1993). The sample size needs to be big enough in order to conduct a reliable factor analysis. The smaller the sample, the bigger the chance that the correlation coefficients between items differ from the correlation coefficients between items in other samples (Costello and Osborne, 2005; Field, 2009; Tabachnik and Fidell, 2001). No matter how well a census or a survey is organized, it is difficult to assure that quality data is collected. It is very important to arrange various data checks before data is distributed to the public.

3.18 Summary

The conceptual discussion on the methods which have been conducted by other researchers are closely related to the study and discussed in this chapter. The chapter outlines spatial analytical techniques which have been previously used for change detection analysis. This section touched on previous research addressing settlement growth, land use and land cover mapping. It also outlined image classification, and accuracy assessment. The enumeration surveys technique and development of a questionnaire survey are also discussed. The next chapter presents a description of the study area.

Chapter 4

Study Area

4.1 Introduction

The study area for this research is Adams Rural. This is a customary region which occupies 29,740 km^2 in the coastal region of KwaZulu-Natal (KZN) and falls under the eThekwini Municipality District. Adams Rural is bordered by two customary regions, namely Umbumbulu and Umgababa. This area is also surrounded by two urban areas, namely Umlazi Township and Amanzimtoti (See Figure 4.1). The region is positioned at 30.0340° S, 30.8150° E on the map. This area is mostly known as Adams Mission. However, Adams Mission is one of the sub-regions of Adams Rural (Isigodi). The name Adams Mission came from the American missionary Dr Newton Adams. Dr Adams first built a mission close to the Umlazi River during the time of war in the area. However, Adams Mission survived Dingane's warrior attacks in 1838. In 1844 Dr Adams moved his mission to the Amanzimtoti Reserve. Therefore the place was named Adams Mission - named in his honour. Dr Adams focused on religious work, education and he also encouraged developments. Although Adams Rural is now filled with residential areas, this region used to support a thriving sugarcane plantation. The choice of Adams Rural as the study area of this research was based on the University of KwaZulu-Natal`s research rules to choose an area in the province of KZN. In addition, the proximity and the accessibility of this area prompted the choice of the area. Furthermore understand the intentions of the eThekwini Municipality on including Adams Rural in their large development plan published in May 2012. Familiarity and the several observed changes in agricultural land use of sugarcane also prompted the choice of Adams Rural as the study area. While sugarcane extraction was known to be the main industry in the upland agriculture of Adams Rural, built-up areas seem to continuously dominate the valley floor. Now Adams Rural encompasses a variety of land uses that range from agriculture, settlement and infrastructure as well as land covers such as water bodies, grassland, mix bush or shrub, forestry, sugarcane and built-up land (Durban Metro Spatial Development Framework, 1998 and SSDP, 2012).

4.2 Adams Rural

Adams Rural has a controlled low density settlement environment, with many sites still under developed. All access is obtained from the tarred Provincial District Road D995 (Sheleni Road) which is classified as an urban district collector. Several schools are located on this road which has good footpaths and traffic calming in the vicinity of the schools. The medium sloping terrain lends itself further to residential development although the area is constrained by deep river valleys on the east side, making the road links very difficult. There is a good network of gravel surfaced local roads. Adams Rural can be classified as an area that has a partial functional environment, that is, the environment does not have full functional attributes to be able to maintain regional ecological functionality (SSDP, 2012).

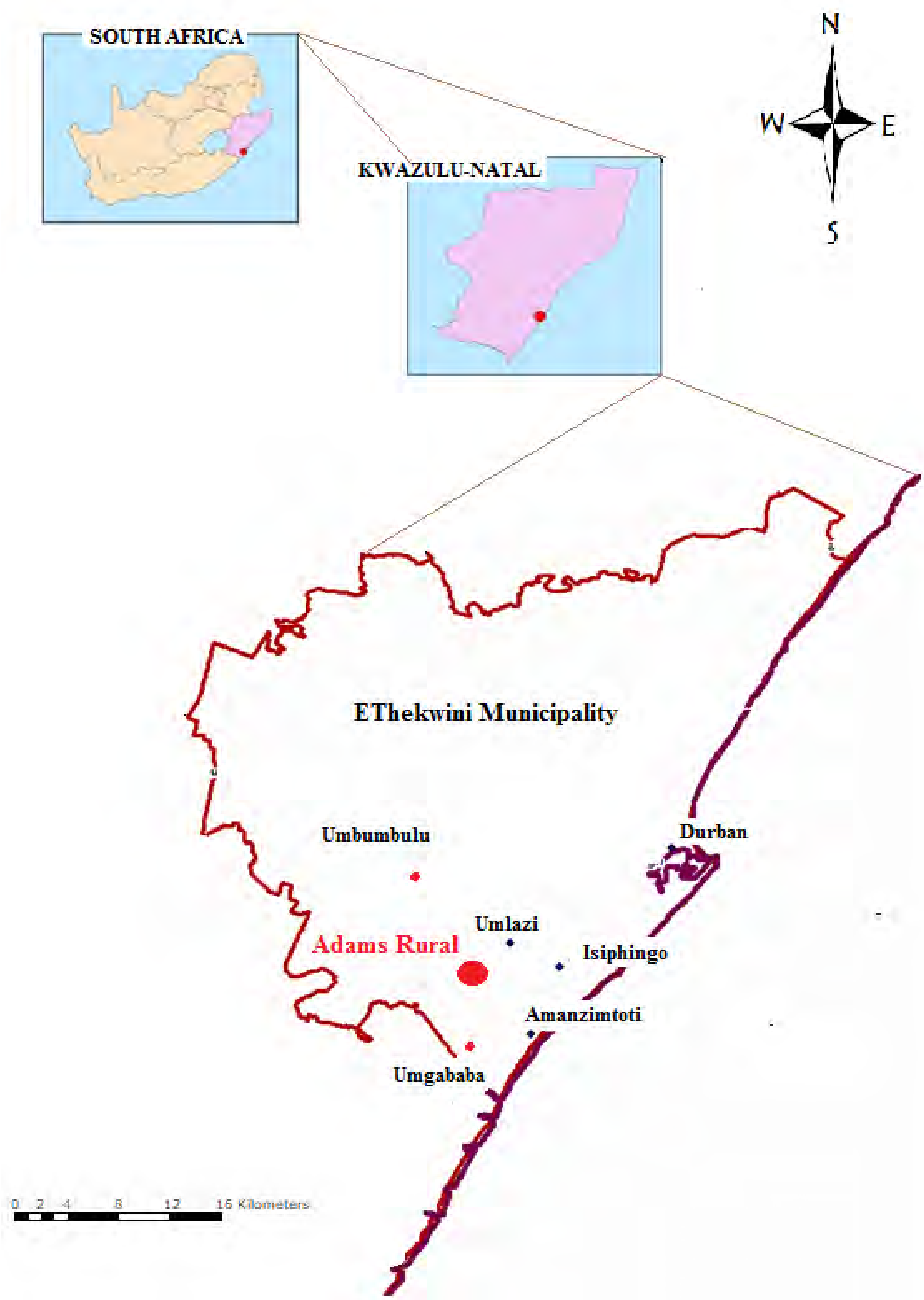


Figure 4.1: Showing the geographic location of the study area

According to the Durban Metro Spatial Development Framework (DMSDF) (1998) partial functional ecosystems comprise of a mix of both natural and built environments and may consist of small to large areas that are of this mix. Adams Rural is not densely populated and there still exists some areas of potential developments. This region consists of a severe topography and is highly degraded with only the high plateaus having ecological value. The study area forms part of the municipal extended areas where no town planning schemes existed before. The study area is composed of traditional areas where land allocation is undertaken by izinduna (Headmans) and local leaders (SSDP, 2012; DMSFF, 1998).

Major challenges in the traditional allocation system defined by SSDP (2012) include:

4.2 (i) Lack of cadastral data.

4.2 (ii) Neither izigodi (sub regions) nor individual households are surveyed.

4.2 (iii) There are no proper checks and balances to prevent corruption and allocation of sites in inappropriate areas.

4.2 (iv) There is no register of all the people who hold land and development rights.

Apart from residential use, there is also agricultural use in these areas as well as social facilities and businesses spread across the region. The KwaZulu-Natal customary region has been a focus for resource-related issues such as producing agricultural products. Recent local debates have been centred around the effects of customary land management on the survival of late successional residential dwelling developments. These and other related topics are mostly addressed in the local workshops, at meetings and during land sale agreements. This research seeks to understand the growth populations and land cover changes currently observed in Adams Rural. The next chapter discusses the research design and methodology.

Chapter 5

Research Design and Methodology

5.1 Introduction

The chapter has two sections. Section A deals with the spatial analysis materials and methodology while section B describes the questionnaire approach. The chapter outlines the approaches used to conduct the research and the data gathering tools used to gather information from the sources. The chapter draws on both secondary and primary data as well as qualitative and quantitative methods. The primary data of the research is in the form of questionnaires which is required to validate assumptions presented in the section on the research background. The images and literature form part of the secondary data required to carry out this research. An overview of the research methodology is outlined in the form of a flowchart and I justify the use of these methods as an alternative to other existing methods. Section also draws on the availability of data, data quality and methods followed to answer the research question and to show that the research objectives have been achieved.

5.2 Section A: Spatial Analysis Materials

5.2.1 Spatial analysis using remote sensing and GIS

In the past when there was no remotely sensed data and computers, one of the methods used to map land use or land cover change was that of tracing paper and topographic sheets (Majumder, 2011). However, this method was limiting and in large areas the method required a lot of effort and time. The conventional ground methods of land use mapping are labour intensive, time consuming and are done less frequently (Opeyemi, 2006; Olorunfemi, 1983; Majumder, 2011). Thus with the advent of GIS and remote sensing techniques, preparing accurate land use and land cover maps and monitoring changes at regular intervals of time is relatively convenient (Majumder, 2011). Additionally, Majumder (2011) stated that multi-temporal analyses using remote sensing and GIS gives a unique perspective of how rural areas evolve. Thus in the rural regions of Adams Rural, remote sensing and GIS can be adequately used as the spatial analysis tools. Remote sensing methods can be employed to classify types of land use in a practical way in Adams Rural. An overview of the research methodology is in the form of a flowchart which outlines the process that was followed when conducting this spatial analysis. (See Figure 5.1).

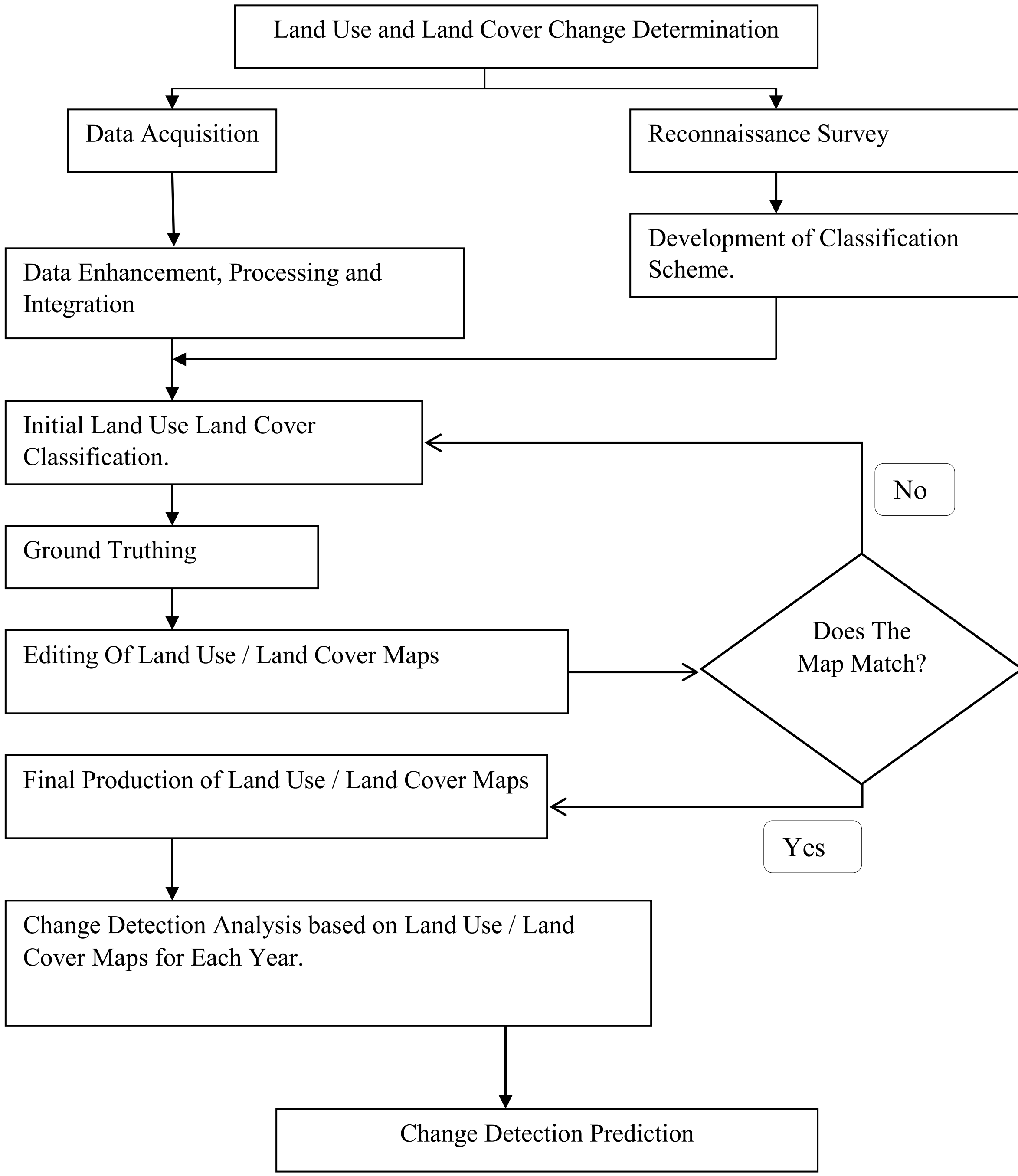


Figure 5.1: Cartographic Model: adopted from Opeyemi (2006:12)

5.2.2 Data selection

Land cover imagery of Adams Rural was an important data layer required in achieving the goals of this research. The land cover maps and imagery were used both as a baseline to document current ecological conditions and as a base for projections of future land cover. This project required good resolution imagery for the study area, which would characterize the wide variety of natural resources, including detailed information about forest condition, agricultural practices and settlement development. The mapping objective for this study was to use orthorectified images to produce a land cover map of Adams Rural that would, to the greatest extent possible, match a list of desired classes for agricultural, forest, bare land and built-up areas.

I. Photogrammetric data

These are orthophoto or orthorectified imagery obtained from eThekwini Municipality for the years 2001, 2004, 2006, 2008, 2010, and 2012, covering Adams Rural. All imagery, whether it is obtained from airborne or space-based sensors, has inherent distortion. There are distortions caused by the angle between the camera or sensor and the ground, distortions from the movement of the camera through the air or space, and distortions created from variations in terrain. The eThekwini municipality provided images which have already been orthorectified. Therefore these images have been corrected for these distortions. Thus the pixel and line locations in imagery are mapped to real world positions on the earth's surface. This results in a planimetrically correct image map (Diallo et al., 2009; Adeniyi and Omojola, 1999; Ololade et al., 2008). Therefore the orthorectified imagery is not a simple picture but a valuable source of information from which information can be extracted. These images have a spatial resolution of 30*30cm. Orthorectified images were chosen based on their accessibility and availability from the source and it is rather simpler to categorise classes on the orthophoto imagery. Additionally, in the year 2001 the growth of built-up areas was noticed after investigating orthophotos. The six date chosen represent the near full progression of phenological development of the major settlements in the Adams Rural area, which is critical for the accurate classification of agricultural land cover types. The images were of good quality, and only the 2006 and 2008 images contained clouds confined to small areas in the north east region.

II. Topographic Maps

Topographic map are widely used by analysts in the field of land use and land cover mapping (Diallo. et al., 2009; Adeniyi and Omojola, 1999; Ololade et al., 2008). Thus this study adopted the concept of using theses maps for image analysis and validation. These are 1:50 000 maps acquired from the National Geo-Spatial Information in Cape Town. These Topographical maps are the largest maps providing full coverage of the area. They accurately depict the location of natural and man-made features by means of symbols and colour, and elevation by means of spot-heights and contours (20m interval). Additional information added are place names, boundaries, magnetic data, etc. These maps contain essential information for planning and decision making but also have many other uses

III. Shape Files

These are geo-referenced digital spatial layers of traditional boundaries obtained from the eThekwini Municipality. The shape files were used in ArcGIS for creating a complete view of Adams Rural.

IV. Historical Images

These are images acquired in the early 90s and they were used to reconstruct and study the history of Adams Rural. A comparison of the land used in these images was made with the latest images and change detection was validated. The images were obtained from the National Geo-spatial Information (NGI) in Cape Town. These are Orthorectified images which were only used as a visual change detection tool for the purpose of this study.

5.3 Technique and software

Shape files and multi-temporal data consisting of topographical maps, orthophoto images and historical images were used and processed. This was conducted using spatial analysis tools of resampling, geo-referencing, classification and post-classification overlays, to map the patterns and extent of land use and land cover in the study area as well as determining the magnitude of changes between the years of interest, 2001, 2004, 2006, 2008, 2010 and 2012 respectively (Ezeomedo and Igbokwe, 2013). The spatial analysis tools used were ArcGIS 10.1 and ERDAS 8.4. ArcGIS 10.1 was used for displaying images, creating a complete set of the study area and geo-referencing validation of the images. ERDAS 8.4 was used for mosaicking, creating signature, image classification and to create the land cover and land use patterns.

Land cover and land use change analyses and projections provide a tool to assess ecosystem change and its environmental implications at various temporal and spatial scales. There are a number of detection techniques but the most common approach is the simple technique of post classification comparison (Blaschke, 2004). Image differencing is probably the most widely applied change detection algorithm for a variety of geographical environments (Singh, 1989). It involves subtracting one date of imagery from a second date that has been precisely registered to the first. The image differencing technique implemented in this study, was motivated by Coppin and Bauer`s (1996) research, which showed that image differencing performs generally better than other methods of change detection.

A post-classification comparison, which is the most straight forward technique, was implemented in this study. The land cover maps for the years of interest were first simplified into four classes: built up area, bare, forestry and agriculture. The post-classification comparison was then applied by differentiating the corresponding classified maps to generate change maps. The change map of images is generated as a table

(Fan et al., 2007). The result of the detection change entirely depended on the accuracies of each individual classification. Image classification and post-classification techniques are, therefore, iterative and require further refinement to produce more reliable and accurate change detection results (Fan et al., 2007).

5.4 Pre-processing

The pre-processing function involves those operations that are normally required prior to the main data analysis and extraction of information. The eThekwini municipality provided images which were already ortho-rectified. However, the images were provided in the form of tiles (separate dataset) therefore there was a need for pre-processing these images. Firstly, the images were mosaicked, georeferenced and clipped to the extent of the study area.

5.4.1: Mosaicking raster datasets:

The eThekwini municipality breaks the images into tiles for better handling and faster processing on their database. Therefore, it was not possible to work with them in that form. Thus the images were joined together to give a complete view of the study area. The method used to combine the images was the mosaicking process, using ERDAS 8.4. The process of mosaicking combined these separate datasets into a single seamless raster dataset. The colour correction was applied to the mosaicking process for the raster dataset to appear as a single image after the mosaicking. The image dodging option was used as it applies and algorithm which correct the radiometric irregularities such as hot spot.

5.4.2: Spatial Reference:

Some of the datasets obtained from the eThekwini Municipality had no spatial reference. Therefore the datasets were referenced using haarterbeesteok94 as the datum as the spatial reference in ArcGIS. This system was used because it the official geodetic datum for South Africa. The datum was implemented in 1999 when it replaced the Cape Datum. Haartebeesteok94 uses WGS84 as the reference ellipsoid. Moreover the shape files boundaries defining the study area are on this system.

5.4.3: Clipping the Image:

The clipping tool in ArcGIS was utilised to extract a portion of a raster dataset which was based on a traditional boundary shape file. A set of six (2001, 2004, 2006, 2008, 2010 and 2012) ready to use imagery were produced which covered the region of Adams Rural.

Because the study intended to analyse changes in Adams Rural vegetation indices among the five different imagery dates to identify land cover types, geo-registration of the imagery had to be tested and confirmed. Geo-registration confirmation was accomplished in two steps: Firstly by assessing if the 2001, 2004, 2006, 2008, 2010 and 2012 imagery consisted of the same registration using ArcGIS. This was a rather simple task as all images were uploaded in the software by randomly selecting numerous points on one image and comparing them with the topographic map and secondly these comparisons of the randomly selected points were tabled against the topographic map points and a relative accuracy was determined to test the confidence of the comparison results. The root mean square error was also determined for accuracy assessment. There was an option of ground point's measurement comparisons but since the topographic maps were available, the cost and time implications were limited.

5.5 Image Classification

Loveland et al., (2002) suggested factors which require consideration in performing the image classification which is discussed in the works of Chen et al., 2001; Tappan and Cushing, 2004. Hence this study reflected on the types of data used, land-cover and land-use information, determination of a suitable classification approach, post-classification processing, and accuracy assessment. The image classification procedure started with the pre-classification requirements. This study noted that image classification applies to both pre-classification and post-classification change detection approaches and can be performed using either supervised or unsupervised approaches. In order to improve the classification accuracy, the selection of an appropriate classification method was required. This enabled analysts to detect changes successfully. In various empirical studies noted in the literature, different classification methods are discussed (Lu and Weng 2007; Campbell, 2007; Mather, 2001; Jensen, 2005). Hence scholarship on supervised classification has shown to produce better and reliable results. Therefore this study has adopted the supervised classification approach. The steps followed for analysis are: (a) digitization of different classes using the polygon tool (b) displaying all the different classes in the same layer and (c) calculating the area of each class. The data of six years was analysed and changes in land use pattern was detected by creating a land use table which featured the area of different classes (Majumder, 2011).

5.5.1 Development of Classification Scheme

The mapping approach in this project involved stratifying the Adams Rural area into four broad cover types: forest, built-up areas, agriculture, and bare-land. The orthophotos were used to reference an initial classification scheme (land cover classes) of land cover types within the Adams Rural region. The knowledge gained from the site visits was used to develop an interpretation technique, which employed four separate land cover types based on visual interpretation of the site and image analysis. The classification scheme which gives a broad classification of the land use and land cover of the study area is shown in Table 5.1.

Table 5.1: Shows the land cover classes sample of Adams Rural.

Class no.	Class Name	Class Description
1	Built-Up	Residential buildings and manmade structures/ Tar Roads
2	Agriculture	Sugarcane plantation / Grass Land
3	Bare Land	Undeveloped / Gravel Road/ Grazed Land
4	Forest	Forest of mixed trees types / Bushes / Shrubs

5.5.2 Training Data

Conducting supervised classification requires the training of the system on what the pixels on the image represent. Therefore this process was conducted in ERDAS 8.4 under signature editor tool which allows defining of the training site using polygon tools. A minimum of at least 20 training areas were defined for each class across the image and the mean digital values of the training areas were determined. All the samples were carefully obtained to acquire the best training data, defining each class and for good accuracies. Thus the research used a sufficient number of training samples as they are critical for image classification. The training samples were collected from ortho-rectified images. The influence of single pixel seed and polygon collection methods on the classification results were closely analyzed and the polygon method was applied. The selection of the training sample was not difficult since the landscape of Adams Rural is not complex and very heterogeneous.

5.5.3 Change Detection

The study draws on the classification technique to detect and quantify the magnitude of change in land cover and produce change imagery. The post-classification technique is the most commonly used technique employed to detect changes in land, and requires the comparison of independently produced classified images of different epochs. Thus this technique was expected to work adequately in this research. The land cover maps for the years 2001, 2004, 2006, 2008, 2010 and 2010 were first simplified into four classes: built up area, bare land, agriculture and forestry. The post-classification comparison was then applied by differentiating the corresponding classified maps to generate change maps. The image differencing was performed and the change map of images was generated as a table which featured areas of different classes (Majumder, 2011). This table compares the information contained in images taken on different dates and representing different classes, to analyse change. Cross-tabulation showed which classes have changed or remained the same. A new imagery was also created showing all changed and unchanged classes using ArcGIS. The creation of land cover maps was done through the vectorisation of land cover classes of concern. These maps were required for analyses of land cover and land use change of Adams Rural.

5.5.4 Method of analysis

The following methods of data analysis were adopted in this study:

- Maximum Likelihood Classifier was used to carry out the classification.
- The surface areas of land use type in an area were calculated in hectares for each study year and subsequently compared.
- An Image Overlay Operations was used.
- A land change rate was determined.

After the training data was developed, the maximum likelihood classification was then applied. The obtained surface areas were tabled in hectares and the percentage change for each epoch (2001-2004, 2004-2006, 2006-2008, 2008-2010 and 2010 -2012) measured against each land use and land cover type calculated. To determine the trend of change, a percentage change was calculated by dividing observed change by the sum of changes multiplied by 100 (Opeyemi, 2006).

$P_c = (O_c / S_c) * 100$ ……………………………………………….eq. 3.1

Where: P_c= - Percentage change

O_c - Observed change

S_c - Sum of change

5.6 Error analysis and the validation of results

According to Anderson et al., (1976) land use and land cover data are required for planning and management purposes and the accuracy of analysis at the generalized first and second levels is acceptable when the interpreter makes the correct interpretation 85 to 90 percent of the time. For regulation of land use activities or for tax assessment purposes, for example, greater accuracy usually will be required. Thus, for the purpose of this study, the error analysis based on the 85 to 90 percent accuracy assessment of the classified images shall suffice.

Three standard criteria were used to assess the accuracy of the classifications:

(1) The user accuracy was defined as the proportion of the correctly classified pixels in a class to the total pixels that were classified in that class. It indicated the probability that a classified pixel actually represents that category in reality.

(2) The overall accuracy was defined as the total number of correctly classified pixels divided by the total number of reference pixels (total number of sample points) (Rogan et al., 2002).

(3) Kappa coefficient was defined as a statistical measure of accuracy that ranges between 0 and 1; it measures how much better the classification is, compared to randomly assigning class values to each pixel. For example, a Kappa of 0.76 means the classification accuracy is 76% greater than chance (Jensen, 1996).

The error matrix-based accuracy assessment method is the most common and valuable method for the evaluation of change detection results. Therefore, the error matrix and Kappa analyses were used to assess change accuracy. Kappa analysis is a discrete multivariate technique used in accuracy assessments (Congalton and Mead, 1983; Jensen, 1996).

5.7 Accuracy assessment

Performing a qualitative assessment of the post-classification accuracy is important, especially after using photogrammetric data in producing classified land use and land cover maps. Moreover, the assessment is an important procedure in classification and change detection analysis. Reference data was compared to the classified data; this was represented as an error matrix, whereby columns represent the reference data, while classified data is represented in rows (Jensen, 1996). In the error matrix, the sum of diagonal samples was divided by the total number of samples, to obtain the assessment accuracy (Jensen, 1996). Thereafter, a visual inspection was practiced. There is an assumption from the literature that the difference between image classifications result and reference data is classification errors. This was analysed and discussed in the discussion section.

5.8 Accuracy assessment of the created seamless dataset of Adams Rural

The mosaicking process successfully merged the images obtained from eThekwini Municipality to a seamless dataset. The resultant images from pre-processing were then validated by using the topographic maps to make a comparison of randomly selected points on the map. The general idea is the comparison of the 2D position from measured image points in the pre-processed rectified image data with the coordinates of the topographic map. These coordinates provide a reference in assessing and validating the imagery. Basically, this process was conducted in order to test whether the seamless imagery has been geo-referenced and was not affected by the pre-processing of imagery. The points compared were randomly selected points at the T-Junctions and cross roads on both the topographic map and the preprocessed image (Figure 5.2 and Figure 5.3). The differences between the 2001 topographic map versus the pre-processed image are shown and briefly discussed in chapter six, and the results for 2004, 2006, 2008, 2010 and 2012 are shown in Appendix G. The differences obtained had an average of five seconds in both X and Y coordinates. This confirmed that the imagery was well geo-referenced. Singh (2013) also obtained geo-referenced multispectral aerial imagery, but from the Chief Directorate: National Geospatial Information (CD: NGI). However, the imagery was not orthorectified. Pillay (2009) geo-referenced the 1991 and 2006 LandSat imagery and used 2001 imagery as the base map. Pillay (2009) used a minimum of four ground control points, mainly river bends and junctions for geo-referencing the images.

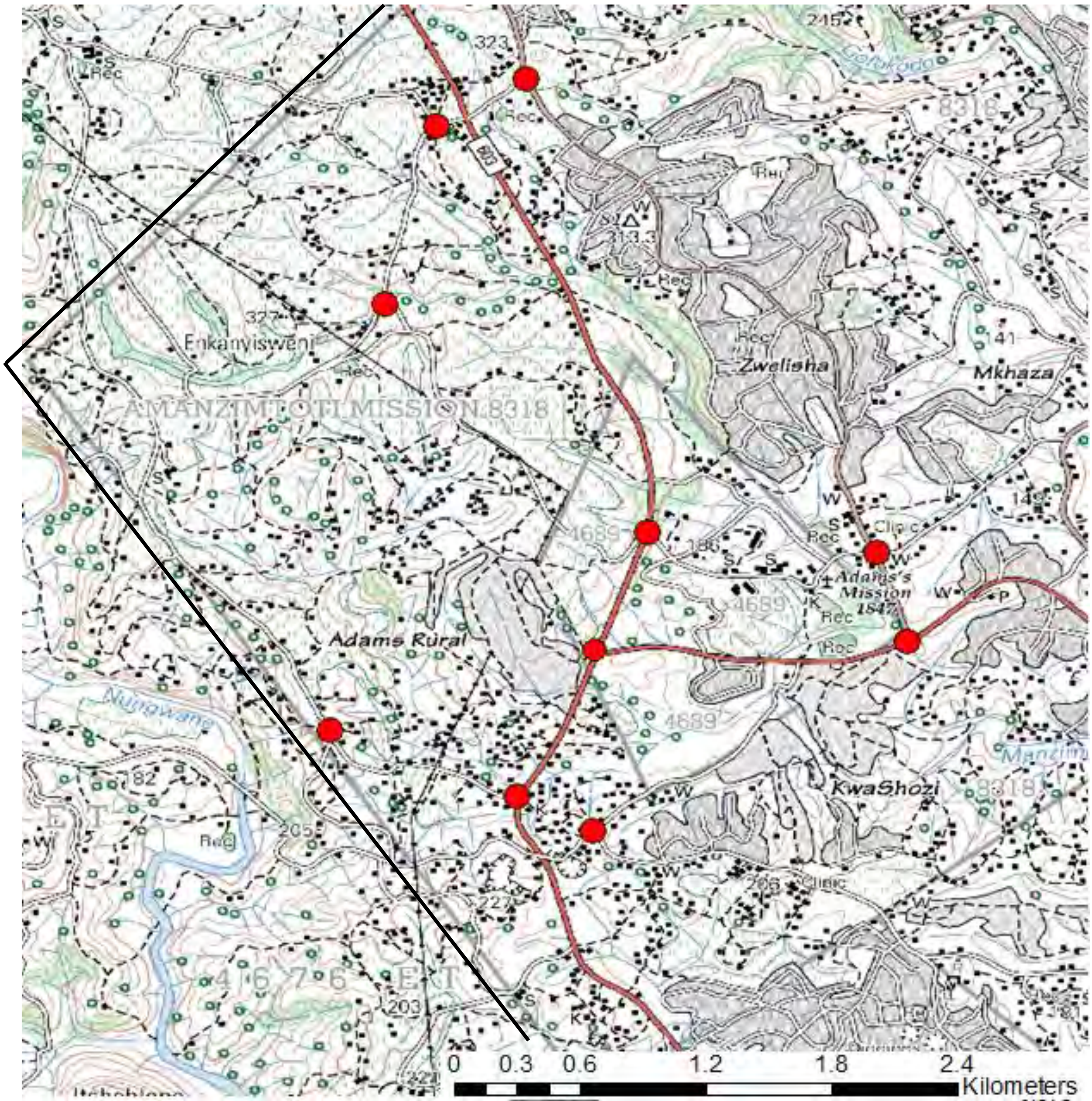


Figure 5.2: Zoomed Topographic Map showing randomly selected points. (Source: CD: NGI, 2012)

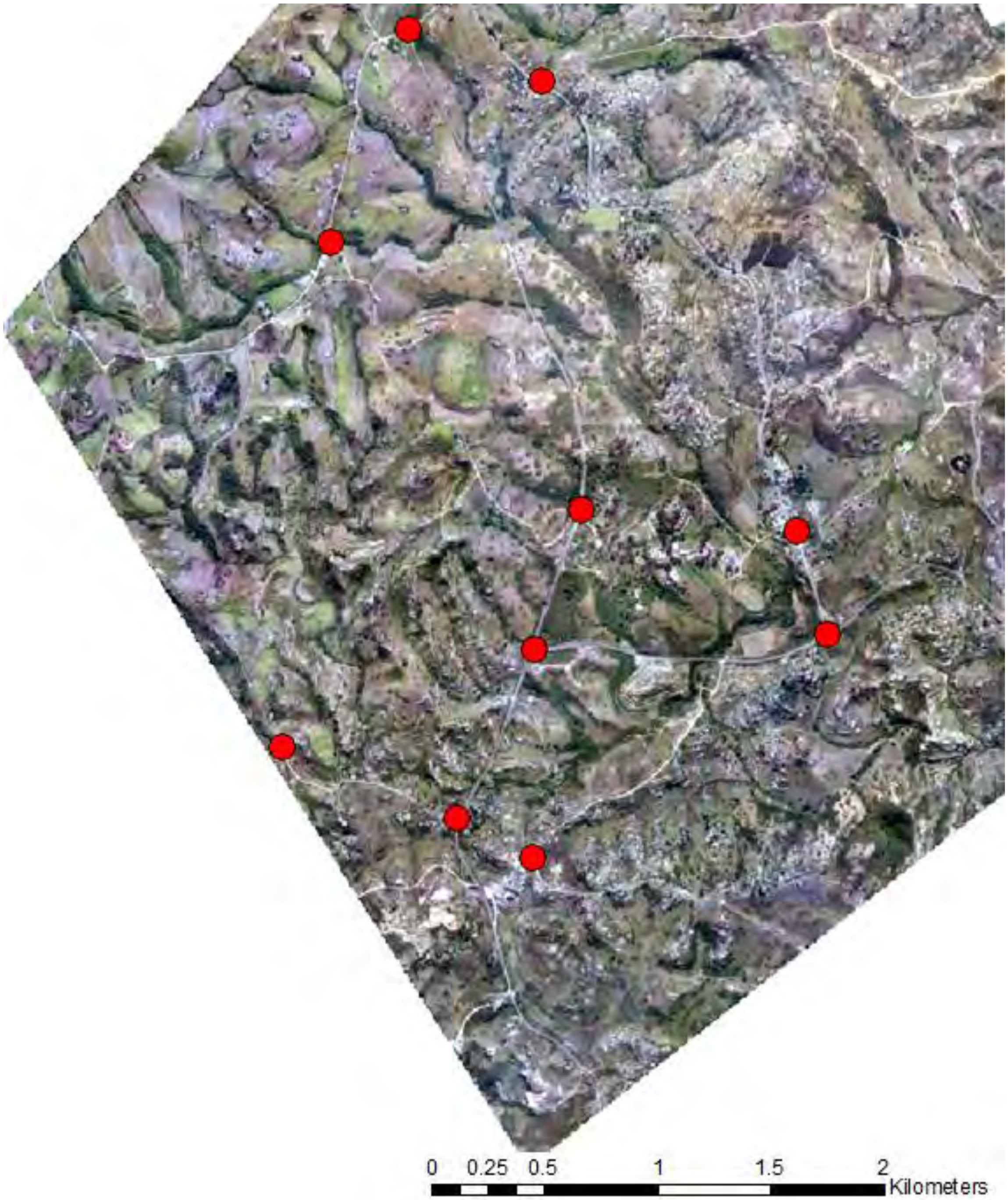


Figure 5.3: Zoomed pre-processed orthophoto showing randomly selected points.

Section B - Questionnaire

5.10 Introduction

The qualitative research design was chosen for this part of study because it is time-efficient, it coincided with the one week time frame of data collection and is cost effective (Neumann, 2008). The questionnaire was conducted using a cross-sectional design, whereby the participants were accessed once by the researcher. Hence the advantages of the cross-sectional design are that it is cost effective and time efficient (Mendenhall, Beaver and Beaver, 2009). Probability (random) sampling means that the researcher did not have information about any specific member within the population who could be selected. In this way bias on the part of participants would be limited. To obtain the information outlined in the statement of objectives, the method of data collection needed to be considered. The point that needed to be considered was the availability of information. If the information was not available from these sources, then the most appropriate form of data collection had to be decided upon.

The convenient sampling technique was used because the participants selected were easily accessible and in close proximity to the researcher therefore the exercise was cost effective and time-efficient. The questionnaire was administered to one hundred people. However, only 88 questionnaires were answered and collected and the remaining questionnaires were lost by the participants and some did not complete them. There were questionnaires left home for the respondents to complete and some were completed in the presence of the researcher.

5.11 Development of Questions

The intentions of the research were clearly stated before the questionnaire was designed. The questionnaire included the reasons for the participants` decisions to relocate to Adams Rural as well as the resulting factors emanating from their decisions to relocate. Moreover, the differences they identified with regard to residing in a customary region as opposed to an urban area. There are two different types of questions that could have been used to collect information, they are structured and non-structured questions. The structured questions are those which contain fixed responses and the non-structured are open-ended questions. It was important to understand when and how to use these questions when developing the questionnaire. The questionnaire was designed to be easily understandable and to take less time. Structured questions make data collection and analysis much simpler and they take less time to answer (Tabachnik and Fidell, 2001). Therefore structured questions were best suited for this research. However, there were some questions which were not suitable to be structured as they needed the participants to respond at length. Therefore those types of questions were open ended and allowed the participants to reflect and answer in accordance with their experiences. In this research, it was noted that there are people who were cautious and hesitant to answer questions. Therefore, the first page of the questionnaire contained a brief statement explaining why the information was necessary, and included very general and biographic questions that are not intrusive. The participants were reassured that the information is anonymous and would remain confidential.

5.12 Sampling Method

The sample design of surveys focus on selecting a sample from a list of the survey population, for example, telephone surveys which sample from telephone directories. However, no such list exists for the growing population of Adams Rural. Instead, the sample design is based on availability, types of houses and locations. The sample was selected by choosing 35 survey days and divided evenly between seven survey sites, so that five days are spent surveying at each site. The people who were interviewed during these days formed the sample. Therefore, rather than only randomly selecting people, the sample is also based on a random selection of survey days at survey locations. A probability sampling method was conducted which allowed everyone a chance of being selected for the study (Kish, 1965; Gardner, 1978).

5.13 Data collection procedure

The community leader (headman) received a letter notifying him of the aims, nature and significance of the proposed study. Once permission was granted, the researcher then requested the headman to further explain the study to the community in one of the community meetings and to emphasise that participation is voluntary. The scanning questionnaire method (self-administered) was adopted and the questionnaire was administered in person to the participants. The advantage of the scanning questionnaire method is that it is a faster method of data entry for paper questionnaires. Scanning is also more accurate than having someone read and properly complete a questionnaire in time (Tabachnik and Fidell, 2001; Rietveld and Van Hout, 1993).

House visits were done and the participants were issued a questionnaire with a declaration stating that they are participating freely and voluntarily. The presence of the analyst helped to clarify any questions the participants had. However, some questionnaires were left with some participants, and the analyst had to go back for them. The houses that were targeted are those which appeared to be built recently and the orthophoto confirmed that they were built in the last 10 years. The reason being that these are the properties where land use change would be visible on the maps and this would allow for some of the objectives to be realised.

5.14 Questionnaire Analysis and Validation

The simplest option for analysing survey data was to use the questionnaire analysis tool. Statistical Package for the Social Sciences (SPSS) is a computer application that supports the statistical analysis of data. This software allows for in-depth data access and preparation, analytical reporting, graphics and modelling (Landau and Everett, 2004). The results of the community questionnaires were presented and analysed using SPSS. SPSS is efficient and flexible in the creation of crosstabs and has advanced analysis and weighting automation (Market Research, 2015). Jack and Clarke (1998) stressed the importance of the reliability of a questionnaire. The SPSS tests for reliability using the inter-item correlations to determine whether constituent items are measuring the same domain (Bowling 1997; Bryman and Cramer 1997; Jack and Clarke, 1998). SPSS consists of tools which are developed for testing the reliability of the questionnaire.

5.15 Model Development

The model estimating the future of land patterns was developed through a land use survey method.

5.15.1 Land use Survey Method

A land use survey was conducted to establish the existing and prior land use in the Adams Rural area. The objective of the survey was to determine whether prior land use in the Adams Rural area was for agricultural purposes. The area comprised of small holdings. The survey provided a preliminary assessment for the driving forces of settlement growth in Adams Rural. The questionnaires administered to the community and the stakeholders were also used, to evaluate the significance of probable driving forces of land use change, which was structured as site-specific, proximity and neighbourhood characteristics. The information gathered, combined with results from change detection was used to develop a basic Hierarchical Settlements Development model in Adams Rural.

5.15.2 Data table Simulation

Using the change detection results, the annual growth rate of the settlements was determined. The annual growth rate was determined by taking the differences of a land use class surface area in 2012 and 2001 obtained from the classified images. The obtained difference was then divided by the number of years from 2001 to 2012. That gave a change rate per year, however, the prediction was in multiples of two years. Thus the change rate was multiplied by two and the resultant value was applied to the 2012 settlement coverage area. The value obtained estimated the 2014 settlement coverage area and the data tables were created up to 2022 in multiples of two years. The aim was to check the simulated against the "real" data. This presented the only opportunity to validate the simulation trend. The table is further validated by the questionnaire responses and strengthened with the Hierarchical Data Model.

5.16 Summary

The chapter described both secondary and primary data used as well as qualitative and quantitative methods undertaken. The chapter discussed different methodological approaches that were implemented in the study. The methods and data used are presented in detail. Further a development of the questionnaire and the calculation of the change rates are explained. The next chapter presents the findings, analysis and discussion of data.

Chapter 6

Result and Analysis

6.1 Introduction

This chapter presents and discusses the findings of the study. The results are presented in the form of tables, graphs and maps. The chapter commences with the examination of the pre-processed imagery, and the presentation of training data and quality evaluation. This provides an indication as to whether the classification results are reliable and whether they can be used to draw conclusions. The presentation of image classification results follows and the questionnaire findings are also presented and discussed. Finally, the conceptual model based on questionnaire responses, post-classification and the literature review is presented and explained.

6.2 Pre-processing results

ERDAS software was used to create seamless images for the coverage of the years 2001, 2004, 2006, 2008, 2010 and 2012 by mosaicking individual images making up the study area. Thereafter, ArcGIS was used to extract a portion of the mosaicked raster dataset using a geographically referenced Adams Rural traditional boundary feature so as to obtain a seamless image of the study area. Tiled images were joined after being mosaicked, registered in a reference coordinate system and clipped creating a seamless layer of the study area for each of the years. Figure 6.1 shows the resultant clipped, geo-referenced and mosaicked orthorectified imagery of the study area for 2001 (Resultant images for 2004, 2006, 2008, 2010 and 2012 are in Appendix A). After the datasets obtained from the eThekwini Municipality were pre-processed, a spatial reference was defined. The datasets were referenced using haarterbeesteok94 as the datum and the World Geodetic System (WGS) 84 as the spatial reference. Topographic maps obtained from NGI were used to test if the pre-processed images were correctly referenced. This was done by using the coordinates of the published Trigonometric (TRIG beacons compared with the measured TRIGS beacons identified in the pre-processed image (see Table 6.1). Furthermore, 10 points were randomly selected in the image and on the topographic map and the coordinates of these points were compared (see Table 6.2).

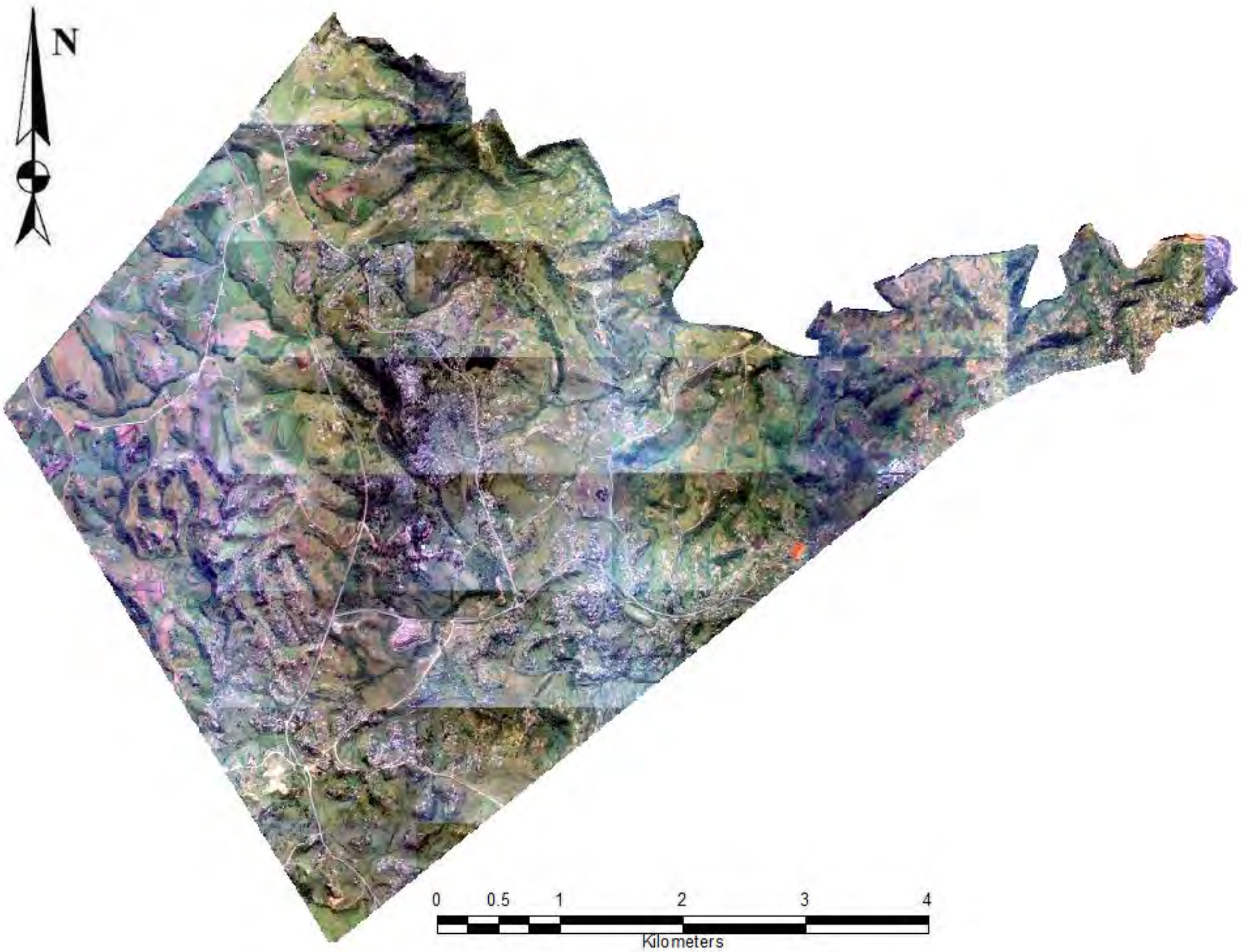


Figure 6.1: Orthorectified image of 2001

The geographic referencing of these images as well as the TRIGS of the images compared well resulting in a difference of less than 0.5m (see Table 6.1). When using the randomly selected points on the image and on the Topographic maps an average of less than 2m meters is obtained on both X and Y (see Table 6.2). These differences are caused by the human error when reading the coordinate values on both maps and especially on the images. The results for 2006, 2008, 2010 and 2012 maps and image comparisons are given in Appendix G. According to the Chief Directorate: National Geo-Spatial Information (CD:NGI , 2010), the horizontal positional accuracy of all coordinated points, which include trigonometrical beacons, gratitule intersections and grid lines depicted on the map, shall not exceed 0.8 meters on the digital orthophoto map, at the 95% confidence level. This study obtained a maximum of 0.35 meters (see Table 6.1) which is within the standards of the CD: NGI (2010) of 0.8 meters. This was achieved by comparing published coordinates of 4 trigonometrical beacons (Pine 21, Pine 28 New, KwaMakhutha and

Pine 22 – Nevad with the measured coordinates on the image (see Table 6.1). This gives confidence on the accuracy of the pre-processed data. The last two columns in Table 6.1 and 6.2 show an absolute accuracy result which was determined to test if all features depicted are correctly classified at a 95% confidence level as stated by CD: NGI (2010).

Table 6.1: Comparison between published Trig coordinates and measured Trig coordinates on the 2001 image.

Name	**Trigs**		**Differences (m)**			**Image**		**Absolute Accuracy (%)**	
	Y	X	Dy	Dx	DS	Y	X	Y	X
Pine 21	18212.67	3321513.63	0.04	-0.34	0.34	18212.71	3321513.29	**100.00**	**100.00**
Pine 28 New	16656.69	3325976.48	0.12	-0.33	0.35	16656.81	3325976.15	**100.00**	**100.00**
Kwa-Makhutha	14600.54	3323654.44	0.01	-0.21	0.21	14600.55	3323654.23	**100.00**	**100.00**
Pine 22 – Nevada	14284.44	3320344.22	0.21	-0.22	0.30	14284.65	3320344.00	**100.00**	**100.00**

Table 6.2: Comparison between random selected map co-ordinates and image coordinates for 2001

Name	**Image**		**Differences (m)**			**Map**		**Relative Accuracy (%)**	
	Y	X	Dy	Dx	DS	Y	X	Y	X
1	19029.99	3320897.30	-0.98	0.22	1.01	19029.00	3320897.52	**100.01**	**100.00**
2	18737.13	3320670.42	-1.01	-0.70	1.23	18736.12	3320669.72	**100.01**	**100.00**
3	19652.11	3322319.32	-0.15	0.76	0.78	19651.96	3322320.09	**100.00**	**100.00**
4	18380.80	3324038.63	1.75	0.99	2.01	18382.55	3324039.62	**99.99**	**100.00**
5	18651.46	3325232.27	-0.50	-0.98	1.10	18650.96	3325231.29	**100.00**	**100.00**
6	18374.23	3325070.22	-2.74	2.21	3.52	18371.48	3325072.43	**100.01**	**100.00**
7	17411.16	3324085.56	1.70	1.39	2.20	17412.86	3324086.95	**99.99**	**100.00**
8	16882.26	3323964.40	-0.25	-2.98	2.99	16882.01	3323961.43	**100.00**	**100.00**
9	15987.20	3323862.33	0.47	-2.89	2.93	15987.68	3323859.44	**100.00**	**100.00**
10	17031.44	3323462.27	1.38	-0.13	1.39	17032.82	3323462.14	**99.99**	**100.00**

Absolute accuracy was calculated by using equation 6.1.

$$A = \frac{Av-(Av-Mv)}{Av} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq 6.1}$$

Where: A - Absolute Accuracy, Av - Actual value, Mv – Measurement value

The published trigonometric beacon coordinates are the actual values and the measured values are the coordinates of corresponding points on the created orthophoto map of the study area. Table 6.1 shows that the obtained absolute accuracies are above 95%, which is required by CD: NGI. This means that the created seamless data set can be confidently used to draw conclusions based on the obtained results. CD: NGI (2010) further states that the positional accuracy of all well-defined points of detail on the map shall not exceed five meters in relation to the national control survey network. Hence an average of less than 2 metres was obtained. Moreover, the positional accuracy was further tested using a Root Mean Square Error (RMSE). A minimum of four known points was required to conduct this test in ArcGIS. However, 10 well-defined points were selected for an overall positional accuracy test of the image. Thus 10 known points from the topographic map were compared with measured points on the pre-processed orthophoto map. Figure 6.2 shows the results of the RMSE calculated in ArcGIS for the 2001 image. The 1.03394 meter error was obtained which is less than five meters required by the CD: NGI when conducting an accuracy assessment on digital copies. Table 6.3 shows the result for 2004, 2006, 2008, 2010 and 2012. Therefore, based on these results, the images created are shown to have good accuracies, which give confidence for their use in image classification.

Link	X Source	Y Source	X Map	Y Map	Residual
1	-19016.753942	-3320899.088...	-19029.003635	-3320897.518...	0.30680
2	-18723.990968	-3320671.264...	-18736.121810	-3320669.721...	0.08875
3	-16875.023921	-3323970.231...	-16882.010684	-3323961.426...	2.12557
4	-15983.237429	-3323871.246...	-15987.675110	-3323859.440...	0.93656
5	-18374.544138	-3324051.111...	-18382.545779	-3324039.616...	1.40367
6	-17406.019836	-3324098.028...	-17412.858993	-3324086.947...	0.29924
7	-18364.206947	-3325086.162...	-18371.480385	-3325072.426...	1.02071
8	-18643.465822	-3325242.800...	-18650.960253	-3325231.289...	1.43797
9	-17026.015147	-3323471.713...	-17032.820719	-3323462.141...	0.15365
10	-19698.647633	-3322373.090...	-19710.509512	-3322367.914...	0.00031

Auto Adjust   Transformation: 1st Order Polynomial (A   Total RMS Error: 1.03394

Figure 6.2: The Root Mean Square (RMS) of the created 2001 image**.**

Table 6.3: The Root Mean Square Error (RMSE) for the years 2004, 2006, 2008, 2010 and 2012.

Year	RMS Error
2004	**1.48903**
2006	**1.39780**
2008	**1.68189**
2010	**2.47909**
2012	**1.21879**

6.3 Training Data Refinement and Quality Evaluation

The correctness of the training data sets was determined by performing accuracy assessments and presenting the results in an error matrix. The signatures were created by using the polygon and the growth methods. These signatures were then evaluated by the signature separability method (see Table 6.4) and error matrix tabulation. The evaluation gave an idea of what the results of the classifier, based on the signatures created would yield. It is very important to note that the training site was done repeatedly to obtain the best possible results.

Table 6.4: Separability of the classes using Euclidean Distances, 2001.

Separability Listing								
			Class Pairs:					
Bands	**Ave Min**		**1:2**	**1:3**	**1: 4**	**2: 3**	**2: 4**	**3: 4**
1 2 3	114	30	42	156	56	190	30	210

Legend: 1 = Agriculture; 2 = Bare Land; 3 = Forest; 4= Built-Up Areas

The 2001 class pixel separability using Euclidean distances separated the class centers as shown in Table 6.4. The minimum value of 30 units resulted from class two against class four which is the distinct value separating these two classes. Therefore, the classifier is expected to have the most pixel confusion between Bare Land and Built-Up Area. The classes will have confusion on Band 1, shown by the yellow circle in Figure 6.3. This is due to the pixel of these classes containing pixel values near each other on the 2001 image. High pixel confusion is also expected from agriculture against bare land as they have a separability Euclidean distance of 42 units. This is also seen in Figure 6.3 which also proves the concept of bare land and agriculture classes containing pixels which are close to each other.

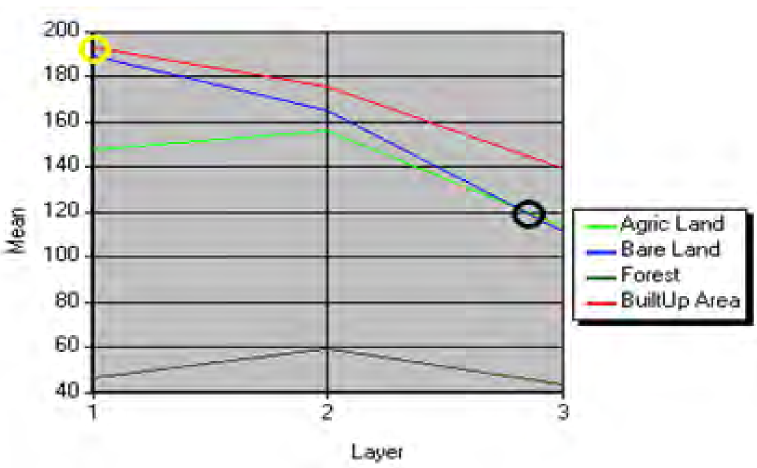


Figure 6.3: Line graph representing the signature mean plot of 2001.

The classifier confuses these classes mostly on Band 3 shown by the black circle in Figure 6.3. Figures 6.4 and 6.5 further demonstrate how these classes are near each other in B and 1 and Band 3. [See Appendix G for Histograms of other images]

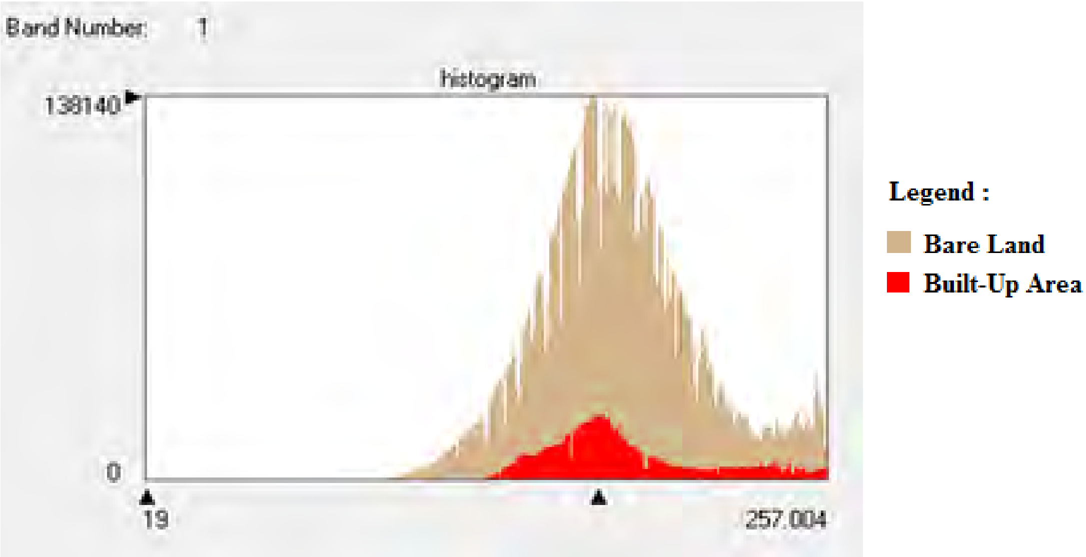


Figure 6.4: Pixel confusion histogram of Bare Land and Built-Up classes on Band 1 in 2001.

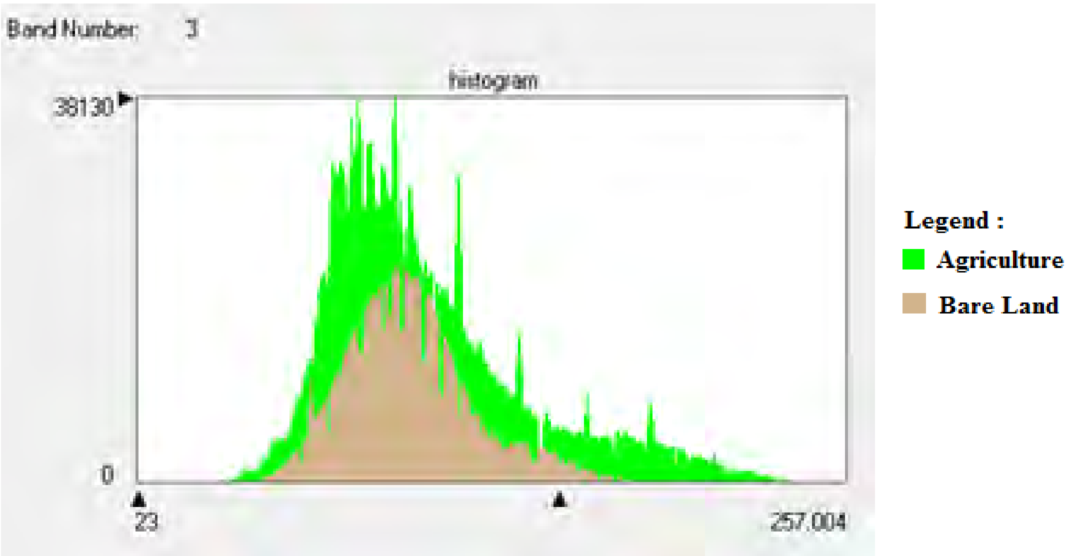


Figure 6.5: Pixel confusion histogram of Bare Land and Agriculture classes on Band 3 in 2001.

The forest class contains pixels which are not very close to any other classes. Figure 6.6 shows that in all the bands there is a little pixel confusion of forest with other classes. However the agriculture, bare land and built-up areas classes contain pixels which are near to each other, thus there is a high probability that the pixels of these classes will be misclassified. The contingency matrix in Table 6.5 shows a 17.43 % pixel confusion of agriculture classified as built-up area and 20.37 % of built-up areas were classified as agricultural land. The contingency matrix which shows how the confusion of pixels performed in images for 2004, 2006, 2008, 2010 and 2012 are found in Appendix B to E. The evaluation of signature results was proven to be true by the contingency matrix (see Table 6.5).

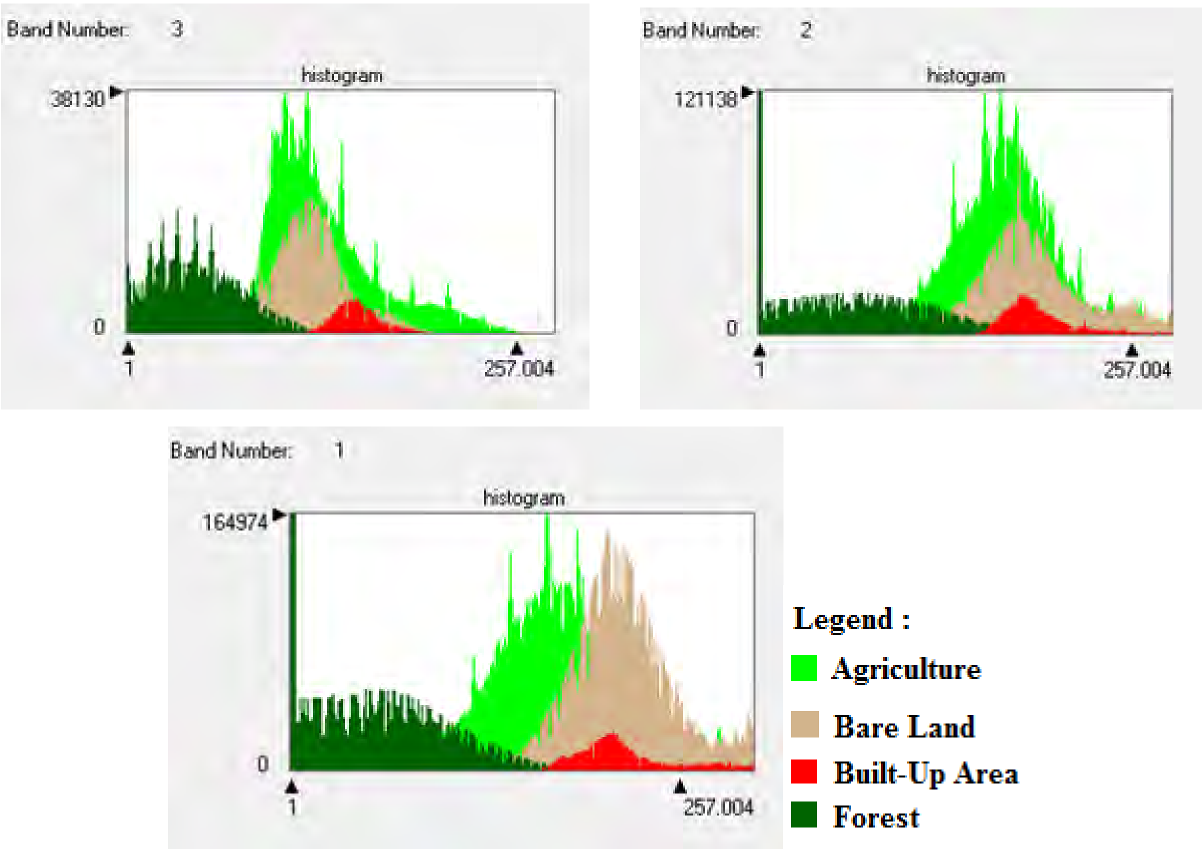


Figure 6.6: Pixel confusion histogram of all 4 classes on Band 1, Band 2 and Band 3 in 2001.

Table 6.5: Contingency Matrix

	Reference Data			
Classified Data	**Agriculture (%)**	**Bare Land (%)**	**Forest (%)**	**Built-up Areas (%)**
Agriculture	69.24	8.27	7.45	20.37
Bare Land	6.10	82.01	1.84	8.01
Forest	7.24	0.11	90.68	0.41
Built-up Areas	17.43	9.61	0.03	71.21
Total	**100**	**100**	**100**	**100**

Table 6.5 shows a measure for the overall classification accuracy can be derived from this table by counting how many pixels were classified the same in the classified image and on the ground and dividing this by the total number of pixels. This also shows how many pixels were misclassified to an incorrect land use class.

6.4 Post-Classification Accuracy Assessment

The accuracy assessment of the classifier is presented in Table 6.6. A minimum of 60 points was randomly created in the 2001 image to evaluate the correctness of the classified image. The assessment of the 2001 image yielded an accuracy of 94.74 % and overall kappa statistics of 0.9205 shown in Table 6.7. The Kappa compares the similarity between the accuracies obtained from training data to that based on the classified image. Therefore, the training data and classified image comparisons were good.

Table 6.6: Error Matrix for the classification of the orthorectified image for 2001.

Reference Data									
		Agriculture	Forest	Built Up Areas	Bare Land	Total Classified	Number Correct	User Accuracy	Producer Accuracy
Classification Data	Agriculture	23	2	0	0	24	23	95.83%	92.00 %
	Forest	1	10	0	0	11	10	83.33 %	90.91 %
	Built-up Areas	0	0	2	0	2	2	100 %	100 %
	Bare Land	0	0	0	19	19	19	100 %	100 %
	Reference Total	24	12	2	19				

Overall Accuracy (OA) = ((23+10+2+19)/ 57) x 100 = **94.74%**

Table 6.7: Shows conditional kappa values for each class of the 2001 image classification.

KAPPA (K^) STATISTICS (Conditional Kappa for each Category)	
Class Name	**Kappa**
Agriculture	0.8618
Forest	0.8848
Built Up Areas	1.0000
Bare Land	1.0000

Overall Kappa Statistics = 0.9205

The 94.74 % accuracy assessment and a kappa value of 0.9205 showed that the classification of the 2001 images were good. Therefore the classified images are reliable when conducting the process of change detection analysis. The classification of each of the images yielded observable pixel clusters which presented the spatial features on the ground (see Figure 6.7). Noticeable pixel confusion can be seen on the land use classification map in Figure 6.7.

The confusion occurred mostly in the western area of the classified image, where it confuses bare land with built-up area. This was expected as these two classes had 30-units separability. Pixel confusion was also expected between agricultural land and forest as they have a small separability that is a Euclidean distance of 42 units. The training sample was conducted over and over again until the least pixel confusion was obtained, thus obtaining a classified image that reflected the orthorectified image Figure 6.7 (see Appendix B, C, D, E and F). Overall, the classified images did reflect spatial features on the ground at most. This was confirmed by conducting a visual assessment, overlaying the classified over an orthorectified image and using a swipe tool on the Erdas software.

The same process was done for the images of 2004, 2006, 2008, 2010 and 2012. These images also yielded good overall accuracy assessments: 2004 = 82.42%, 2006 = 94.37%, 2008= 92.45%, 2010 = 97.30% and 2012 = 95.86%. The figures and table showing the results obtained are given in Appendix B, C, D, E and F. Using the six sets of classified images produced, change was detected between the following periods: 2001-2004, 2004-2006, 2006-2008, 2008-2010 and 2010-2012. Built-up-area change detection maps were then produced (see Figure 6.8).The expansions and losses, net changes, and contributors to net change experienced by the various land cover types were quantified and examined.

6.5 Post Classification Land Use Change

Tables 6.8 and 6.9 and Figure 6.8 indicate the land use change of built up areas from 2001 to 2004 in Adams Rural. Quantification of spatial coverage of each of the land cover and land use categories on the classified images showed a steady increase in built-up areas between 2001 and 2012 (see Table 6.8). The increase was largest between 2001 and 2004 with a 63ha spatial coverage (see Table 6.9). Agriculture (sugarcane) shows an inconsistent change with the largest loss being between 2001 and 2004, the same period when the increase in built-up areas was the largest (see Table 6.9). However, it is also important to note that during this period there was a high gain in bare land spatial coverage. This gain was a result of sugarcane plantations being harvested during the period when the image was taken. Thus the classifier classified these harvested areas as bare land. This does not contradict the finding that a portion of sugarcane plantation has been converted to residential land use in Adams Rural, which is observable from the images.

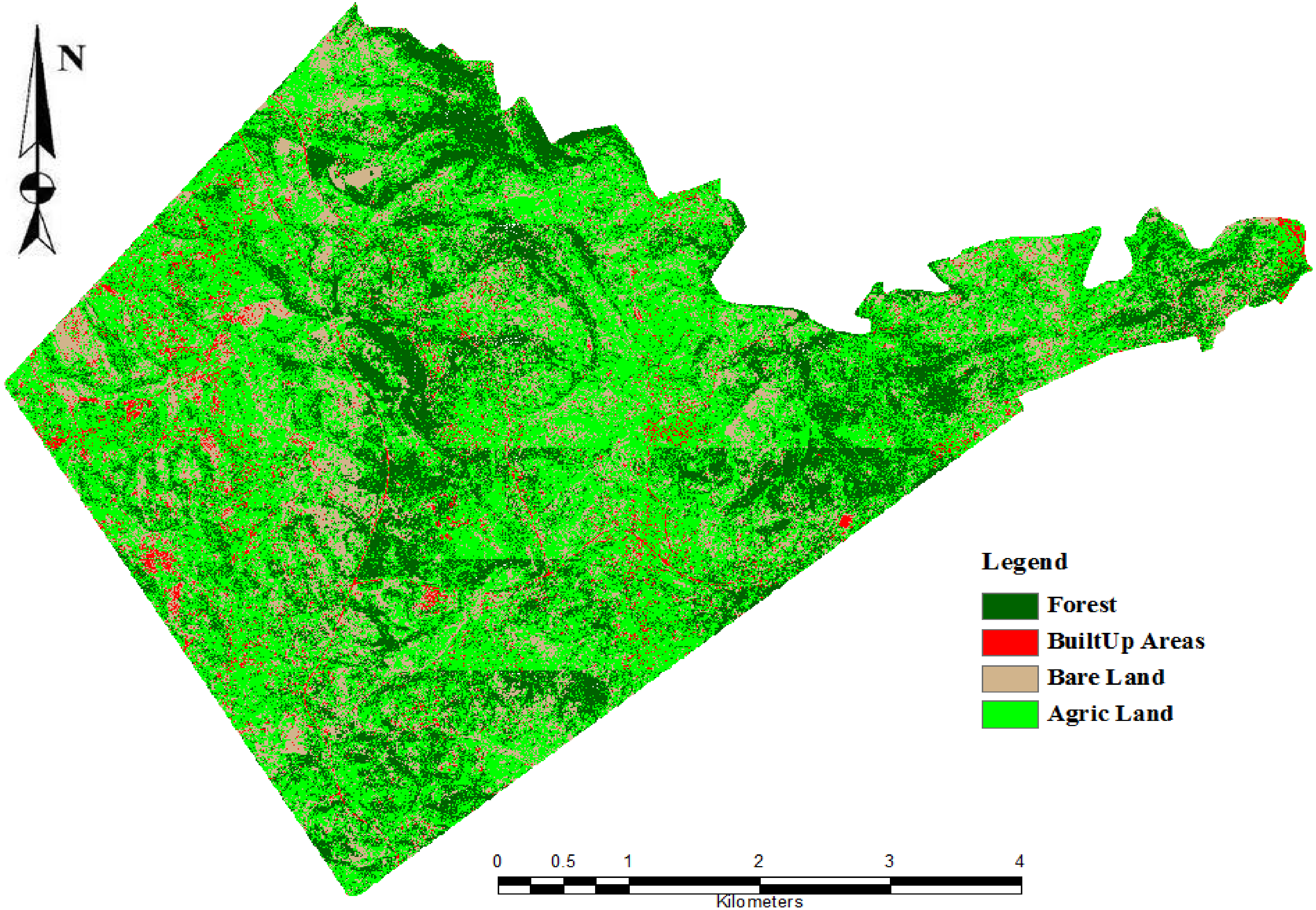


Figure 6.7: Land Use Classification Map of Adams Rural for 2001

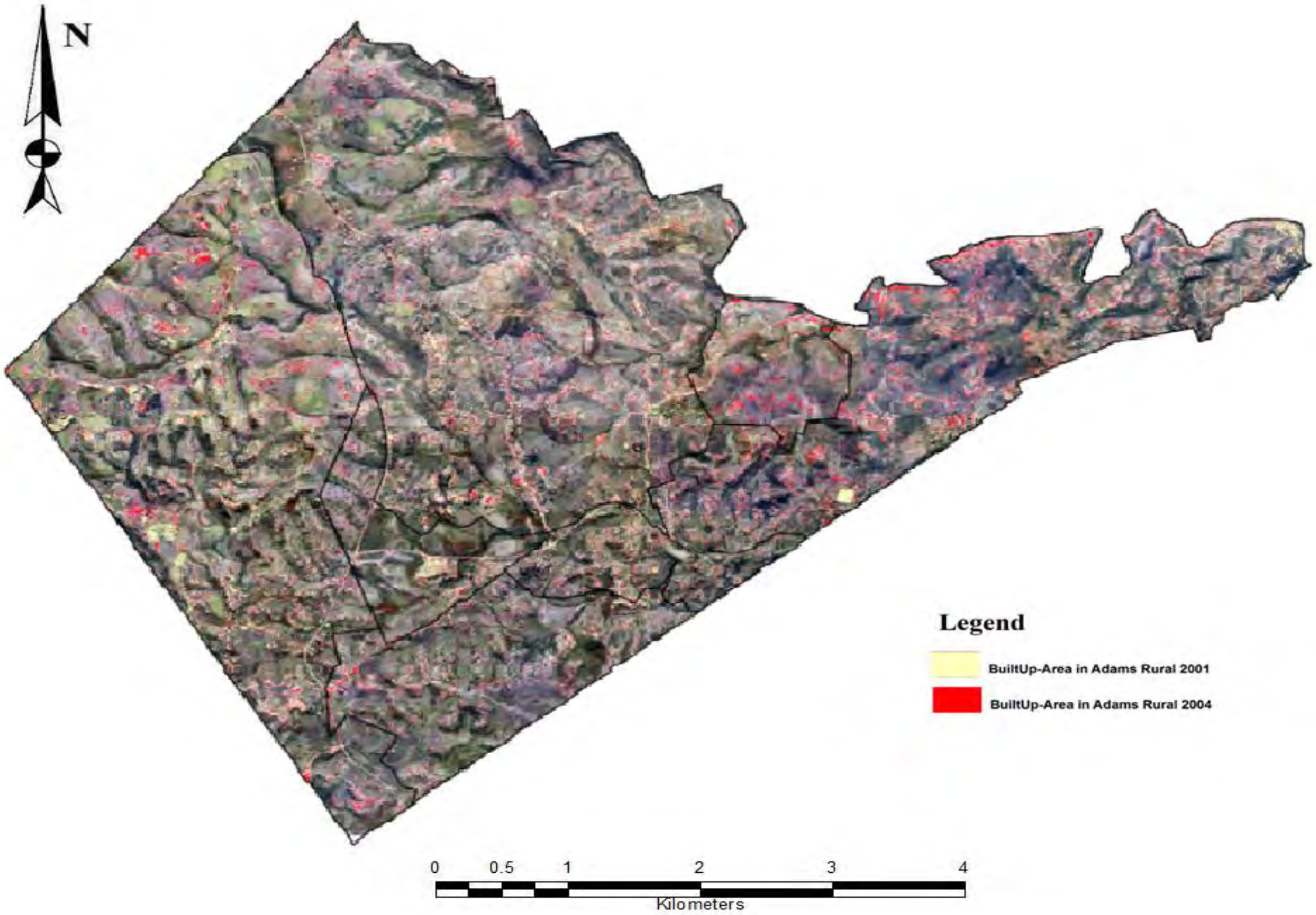


Figure 6.8: Land Use Change Map of Adams Rural in Adams Rural of 2001-2004

Table 6.8: Classified Land cover and land use for 2001, 2004, 2006, 2008, 2010 and 2012.

Class Name	2001	2004	2006	2008	2010	2012
Bare land	572	1365	1188	1412	593	766
Forest	830	865	602	702	849	965
Built-up Area	120	182	193	231	243	253
Agriculture	1634	744	1172	811	1490	1173

Table 6.9: Change in land Cover/Land Use between years: 2001-2004, 2004-2006, 2006-2008, 2008-2010, 2010-2012 (Area in Ha).

Class Name	2001 -2004	2004-2006	2006-2008	2008-2010	2010-2012
Bare land	793	-177	224	-819	173
Forest	35	-263	100	147	116
Built-up Area	63	11	38	12	10
Agriculture	-889	428	-361	679	-317

Other land cover categories exhibited inconsistent fluctuations between various land category pairs over the same period of study as shown in Figure 6.9. The images were not taken at the exact seasonal date (The source stated that the images are normally taken from February to April yearly) which is probably oone of the reasons for the fluctuation in the pixel reflectance.

The pixel reflectance is not the same for all images, which adds to the fluctuation of the spatial coverage of the classes. In the 2004, 2006 and 2008 images there is an observable increase in bare soil coverage in areas previously occupied by sugarcane plantations (see Appendix A, C and D). Figure 6.9 shows that all land use categories experienced a noticeable gain and loss during the period of 2001 to 2012. However, the built-up area had a steady increase during this period. The classification process is subjective as established in the literature therefore misclassification of spatial data was expected and experienced in this study.

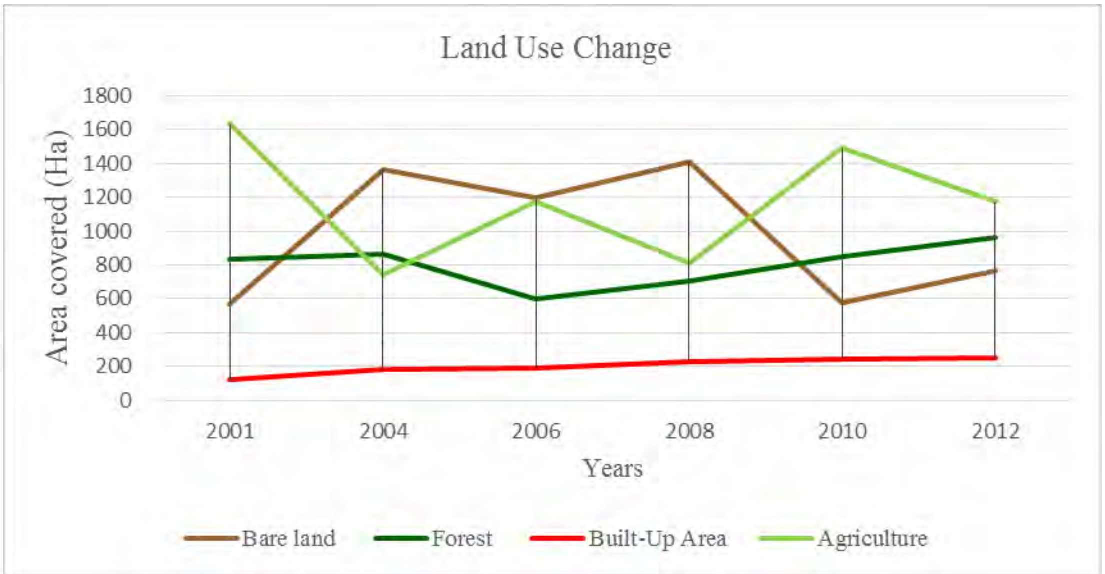


Figure 6.9: Graphical presentation of land use change from classified images

The misclassification of pixels has an impact on the gains and losses of the land use categories shown in Figure 6.9. There is a noticeable relationship in Figure 6.9 between bare land and agriculture. Whenever bare land increases agriculture decreases and this is due to the harvesting of plantation sugarcane. Whenever there is the harvesting of sugarcane, the classifier classifies that harvested portion as bare land. This is experienced in images of 2004 and 2008 which results in a loss of agriculture. However, apart from the permanent loss of agriculture due to built-up areas, seemingly there is also a 'temporal' loss of agriculture due to harvesting, which is important to note in the analysis of this study. The classification maps in Figure 6.10 are compared to determine the growth of settlements in all five epochs. The equation 4.4 was used to calculate the percent change in the built-up area.

$$\text{Percentage Change} = \frac{\textit{Year later Coverage} - \textit{Year earliar Coverage}}{\textit{Year earlier Coverage}} \text{.............................. Eq 6.2}$$

Table 6.10: Percent change of built-up area in Adams Rural.

Class Name	2001 -2004	2004-2006	2006-2008	2008-2010	2010-2012
Built-up Area	**53 %**	**6 %**	**20 %**	**5 %**	**4 %**

Table 6.10 shows a high 53% increase in built up during the period of 2011-2004 and a 20% increase in 2006-2008. This is due more people accessing Adams Rural for residential purposes during these periods.

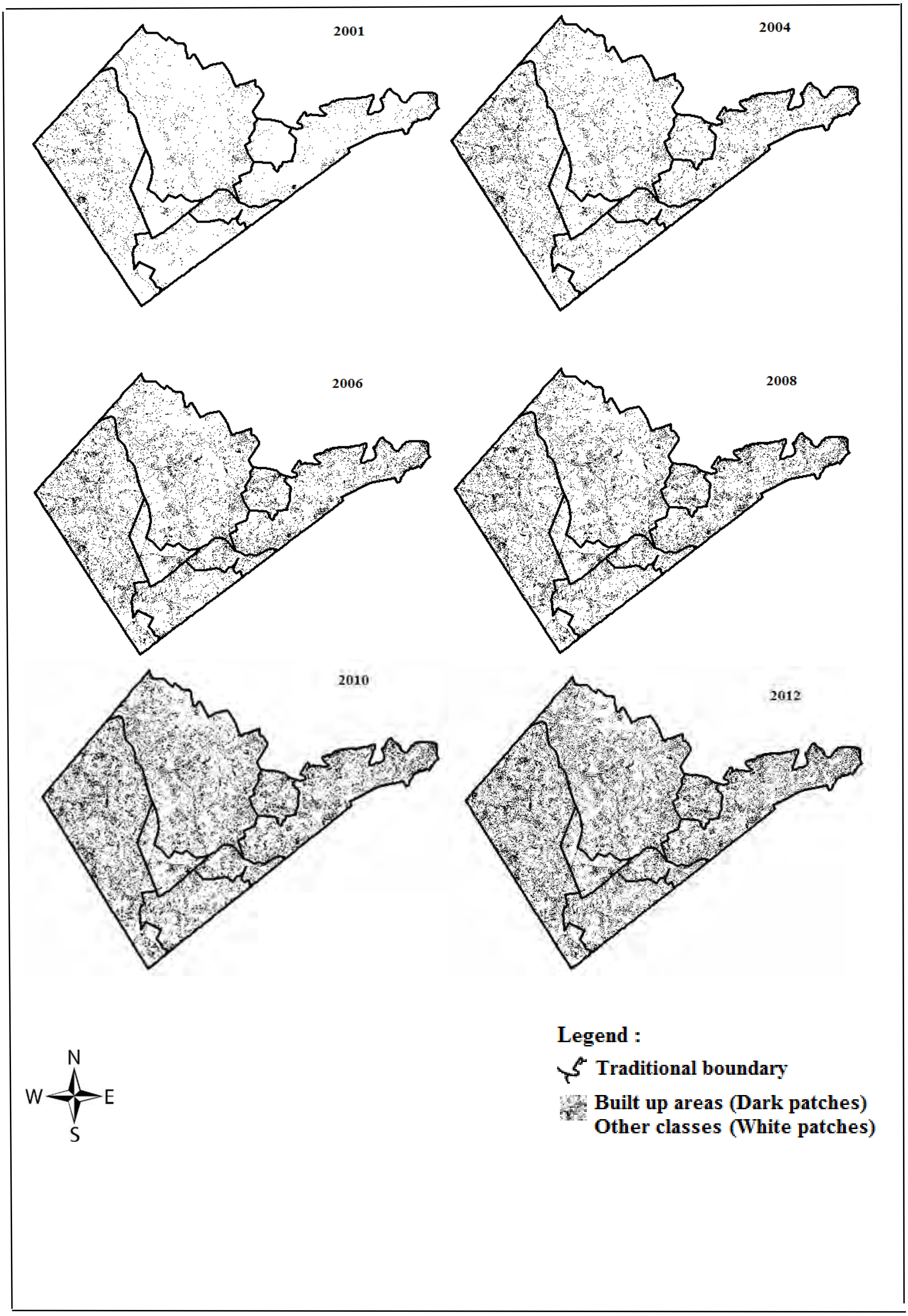


Figure 6.10: Series of Land cover maps of built-up class in Adams Rural.

Therefore the result depicts that by 2012 the built-up area will have expanded up to 111%.This result is obtained by using equation 6.2 [120ha (2001) -253ha (2012) / 120ha (2001)]. This is also confirmed by the visual analysis of image comparison in Figure 6.11 and 6.12. The 2012 images in Figure 6.11 contain spatial coverage of built-up areas that are twice as much as the 2001 images. Figure 6.11 and 6.12 visually confirm that there has been a huge increase in built-up areas in the zoomed portion of Adams Rural. Thus these images highlight changes in Adams Rural in the form of settlement growth. The construction of new roads and settlements can be clearly observed from Figures 6.11 and 6.12. It can be observed that the settlement expansion is close to the main roads (Figure 6.14). The classified images in Figure 6.13 and 6.14 show that the classified images are the reflectance of the orthophoto images, thus the spatial coverage measured from these classified images are reliable. However, in Figure 6.13 it can be observed that there are pixels classified as a built-up area, but when comparing this image with Figure 6.11 they should have been classified as bare land. This is one of the observable pixel confusions.

However the image in Figure 6.13 and all other classified images are the best that could be obtained from the training sites, which was done over and over again and gave repetitive results which were then accepted. Zoomed orthorectified and classified images of the years 2004, 2006, 2008 and 2010 can be seen in Appendix F. The 1974 and 1983 images in figures 6.15 and 6.16 are compared to see if the current increase in settlements in Adams Rural is not a new phenomenon. The images show that little change has occurred during this 11 year period. A noticeable change in these images is the trees (or forest) which seems to have been removed from the plantation of sugar cane. These can be can be seen as dark spots on the 1974 image. A period of nine years of image comparison was also done on the 1983 and 1992 images (Figure 6.16 and 6.17). Little change in the area was visible during this nine year period.

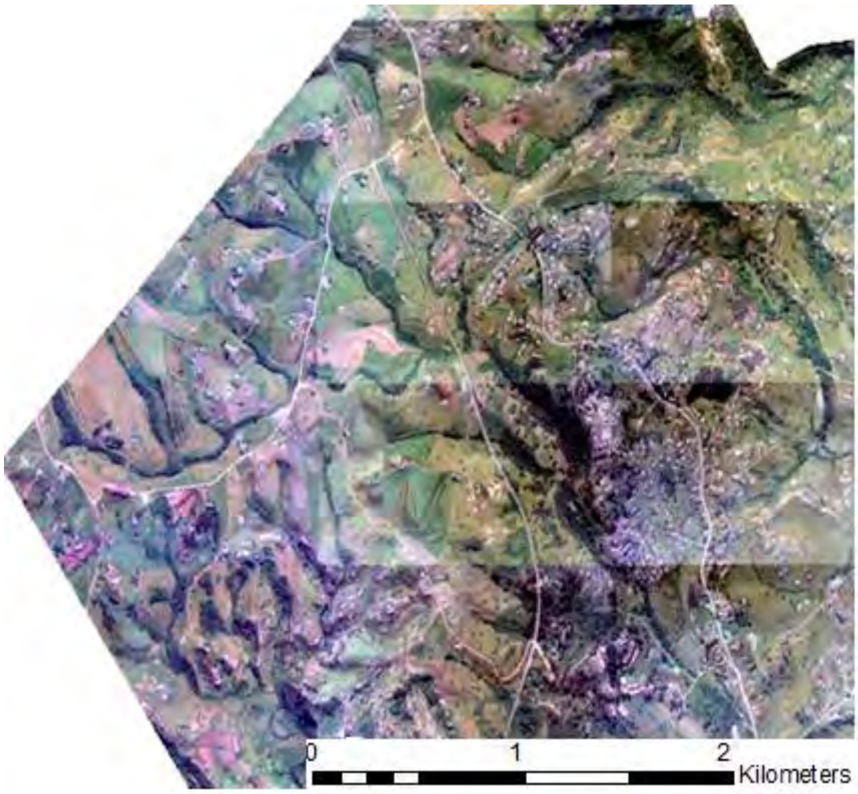


Figure 6.11: 2001 Orthorectified showing a close view of Adams Rural.

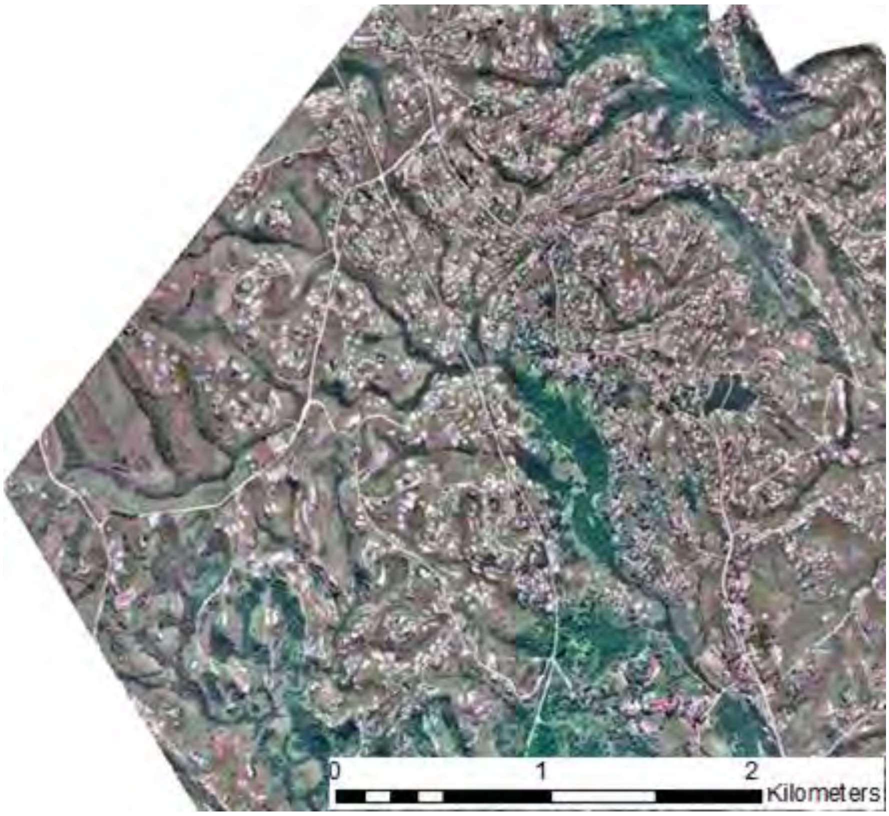


Figure 6.12: 2012 Orthorectified image showing a close view of Adams Rural.

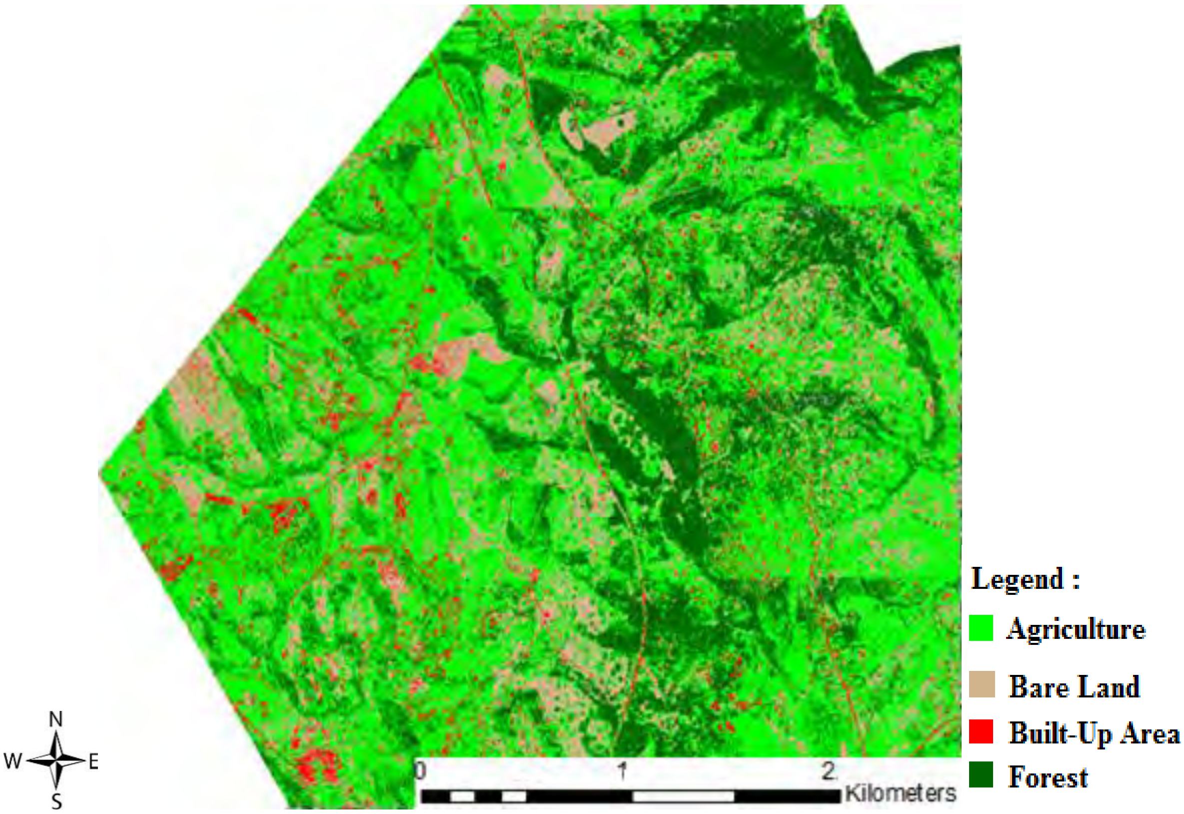


Figure 6.13: 2001 Classified image showing a close view of Adams Rural.

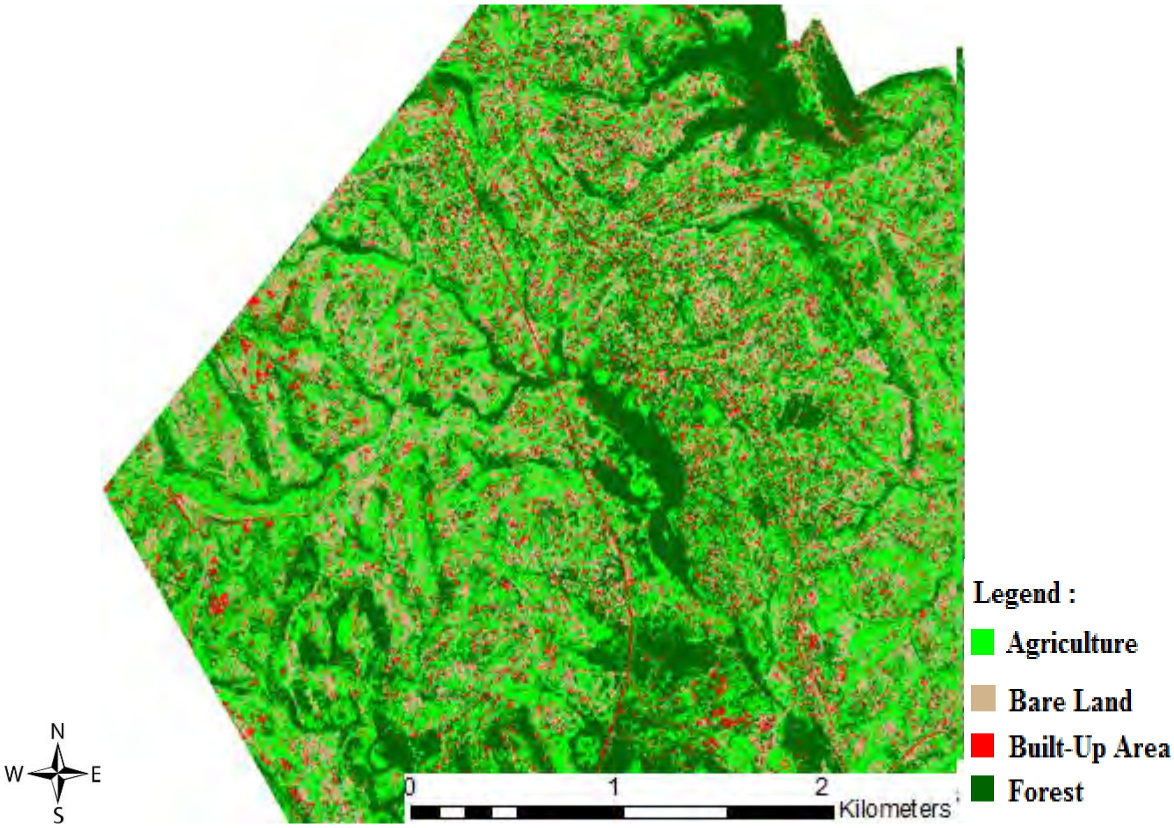


Figure 6.14: 2012 Classified image showing a close view of Adams Rural.

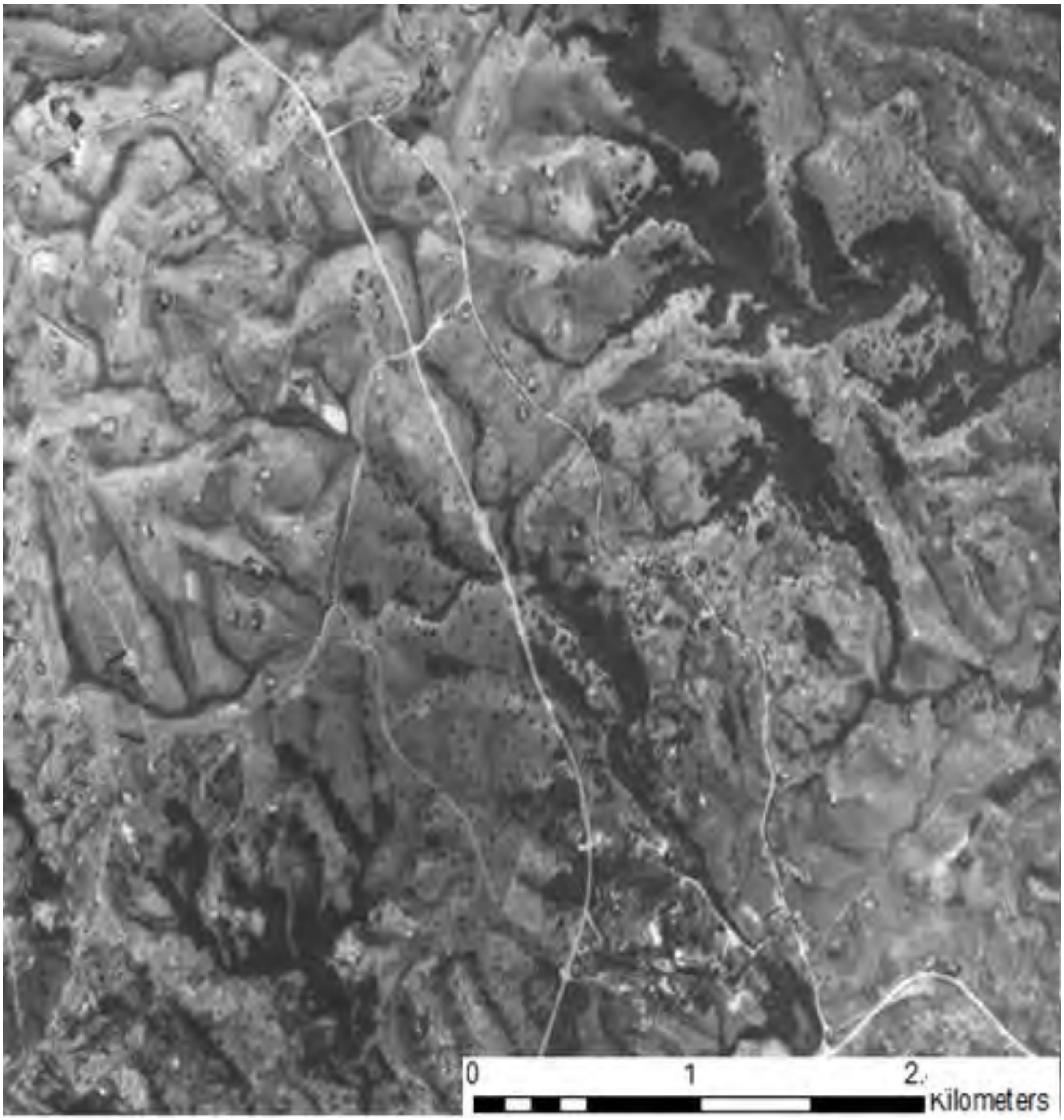


Figure 6.15: Showing 1974 Historical image of Adams Rural.

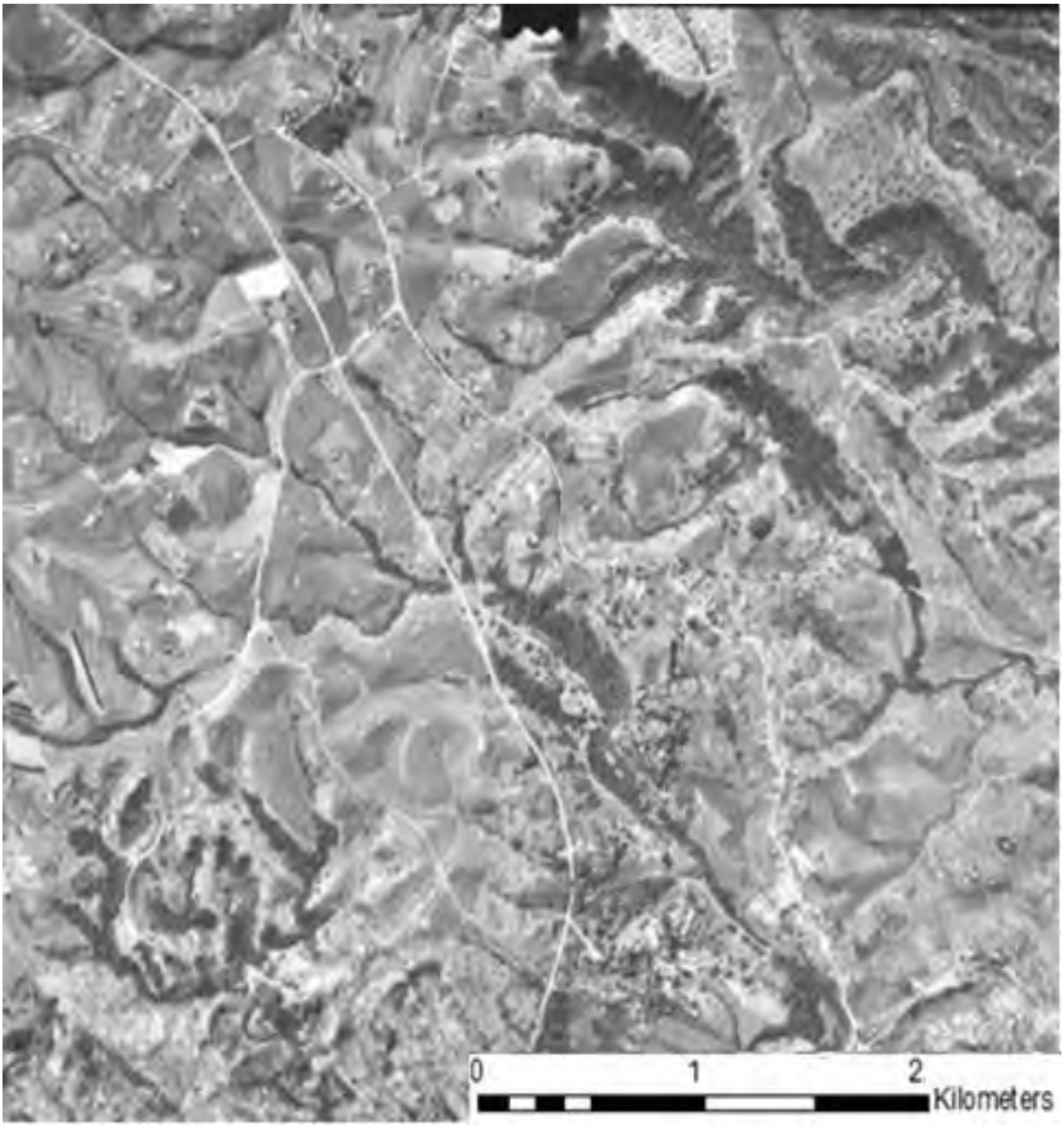


Figure 6.16: Showing 1983 Historical image of Adams Rural.

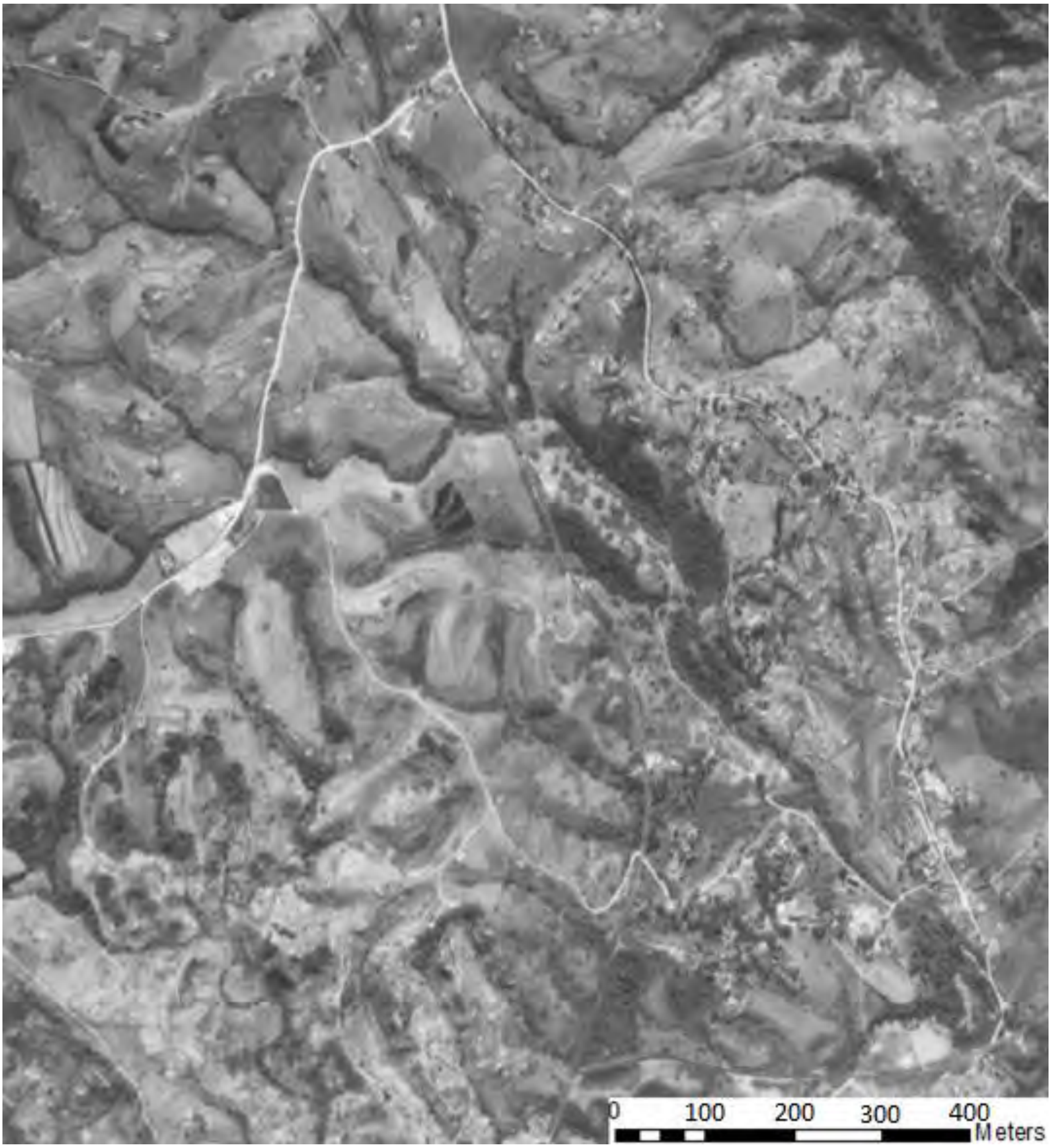


Figure 6.17: Zoomed 1992 Historical image of Adams Rural.

6.6 Analysis of Questionnaire Responses

6.6.1 Socio-demographic characteristics of research participants

A Statistical Package for the Social Sciences (SPSS) and Microsoft excel were used to analyzing analyse the questionnaire. Table 6.11 shows the characteristics of the sample in the study. All the participants were Black South Africans, and are living in Adams Rural throughout the year.

Table 6.11: Socio-demographic information of the participants (n = 88)

Characteristics	**N**	**%**
Gender		
Male	46	52.3
Female	42	47.7
Age (Mean =40.44, SD =2.59) Range: 25– 66		
Home Language		
Zulu	69	78.4
Xhosa	19	21.6
Type of school attended		
Rural School	47	53.4
Township School	38	43.2
Missionary School	2	2.3
No matric	1	1.1
Source of Income		
Working	73	83.0
Self-employed	9	10.2
Retired	6	6.8
Length of stay in Adams Rural (Mean = 7.41, SD = 7.969) Range: 1 – 55 years		
Living in Adams Rural throughout the year	88	100
Knowledge about Adams Rural		
Word of mouth	78	88.6
In passing	4	4.5
Not Applicable	6	6.8
Do your ancestors come from *Adams Rural*		
Yes	9	10.2
No	79	89.8

The average number of years the participants have lived in the area is approximately seven years. Of the 88 participants, the mean age was 40.44 years (Standard Deviation (SD) = 10.79, range = 25–66). The majority were males (n = 46, 52.3%) and there were 42 females. Approximately 99% of the participants had some form of education (up to matric level), and a higher number of the participants (93%) had either formal employment at an organization or they are self-employed. The participants interviewed were either Zulu (78%) or Xhosa (22%) speakers. Over half (52%) of the respondents were under 40 years of age. The results as presented in Table 1 also show that about 10% of the participants` ancestors are originally from Adams Rural, and an equally high number of participants (88.6%) indicated that they came to know about Adams Rural from others (word of mouth). The questionnaire results show that a majority of the people (53%) went to rural area schools, implying that before they stayed in urban areas these individuals once lived in rural areas. Therefore, these people are familiar with the lifestyle of rural areas, which made relocating to Adams Rural easier.

6.6.2 Land Acquisition in Adams Rural

The results as shown in Figures 6.18-6.20 indicate that some of the people living in Adams Rural had acquired the land from the King (Induna), that is, 37.5% or from other residents (60.2%). This therefore means that Adams Rural settlement expansion was not a result of land invasion nor the extension of an urban area as Adams Rural is periphery to an urban area. Rather, people are accessing this region through the traditional custom of customary land allocation.

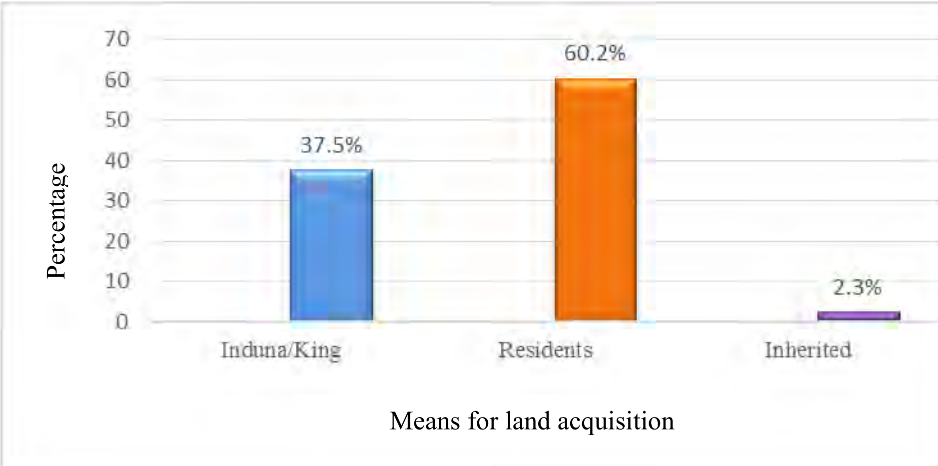


Figure 6.18: Land acquisition in Adams Rural.

The assumption made at the beginning of this study, that the growth of settlements is due to people relocating from urban areas to Adams Rural is supported by Figure 6.19. When asked if they are from a rural or urban area, the majority of the participants in the study area indicated that they are from urban areas. This is confirmed by data in Figure 6.19, which shows that the majority (85.2%) of the people interviewed are from urban areas.

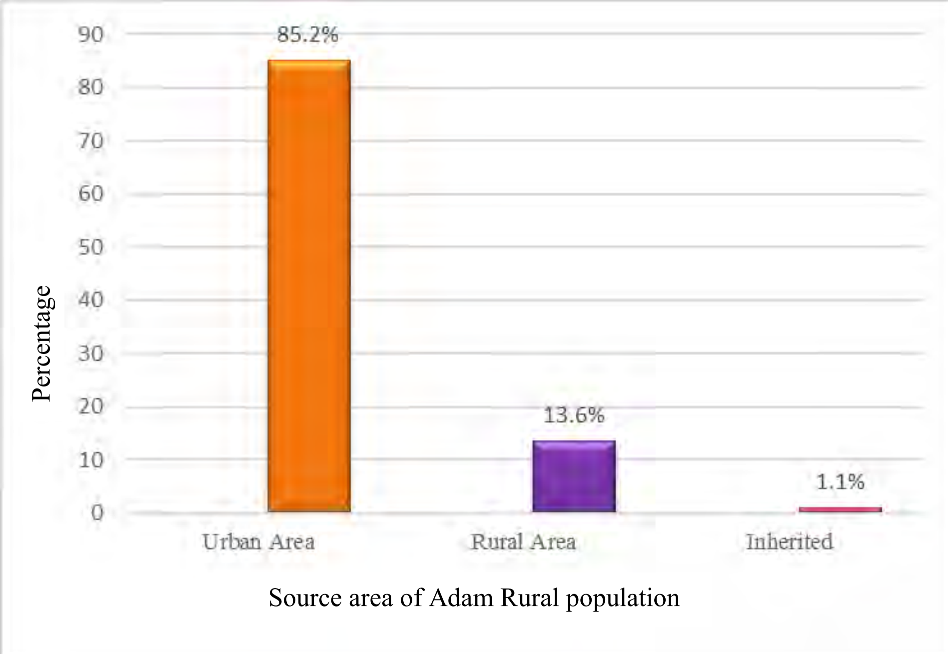


Figure 6.19: Area of residence prior to moving to Adams Rural.

For the participants who are from urban areas, over 71% had full ownership of their houses, about 12.5% were renting and just over 10% were either staying with their siblings or parents (see figure 6.20). Five point seven percent originated from Adams Rural therefore this was not applicable to them.

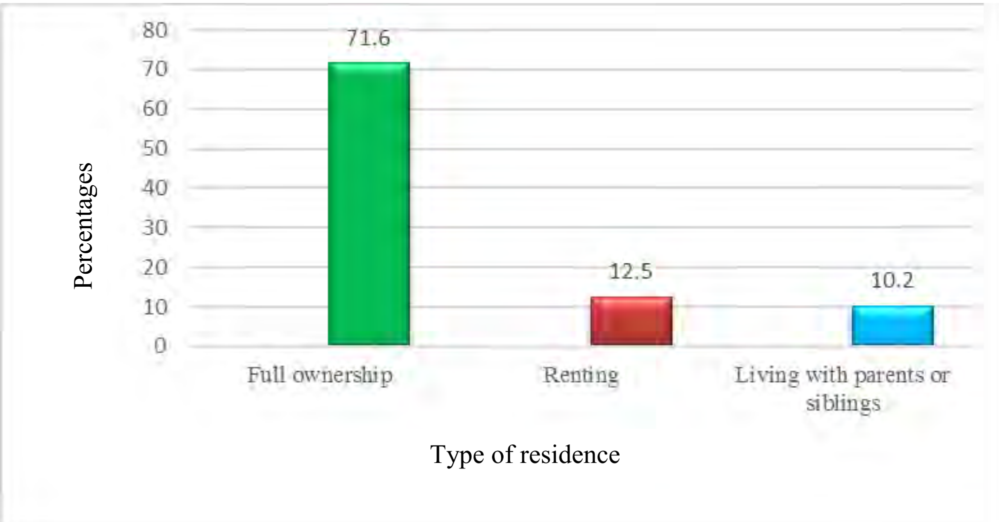


Figure 6.20: Type of residence for urban dwellers before relocating to Adams Rural.

The results from the study also showed that approximately 82% of the participants who completed the questionnaires had full ownership of their current land, with the remaining 18% not sure whether they have full ownership or otherwise. This result is illustrated in Figure 6.21

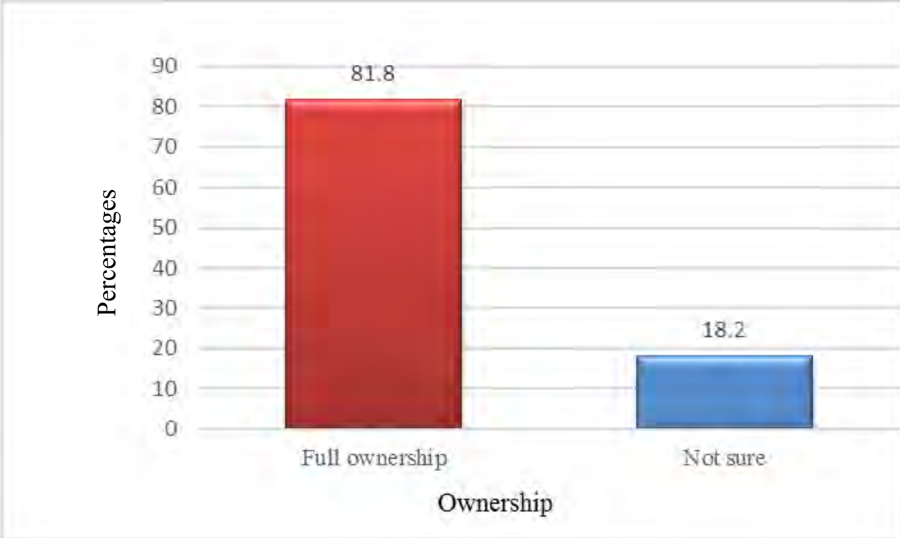


Figure 6.21: Ownership of land at Adams Rural.

When asked the reasons for relocating to Adams Rural, the respondents gave several responses, with some being common. Over 87% indicated that the low cost of living and the fact that there were neither rates nor bonds attached to their land was the reason for relocating. This was evidently the most common reason for relocating. While 42% attributed the idea of having bigger spaces and houses, the same number of people (42%) indicated the fact that the area is developing as the main reason for relocating. Approximately a third (30%) said that they relocated because Adams Rural was not too far away from the city (see figure 6.22).

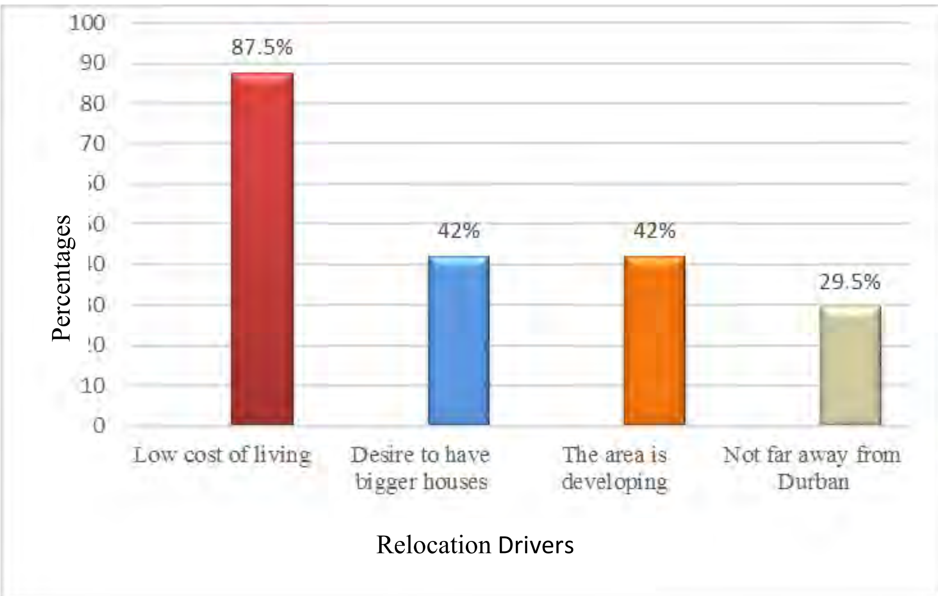


Figure 6.22: Reasons for relocating to Adams Rural

6.6.3 Land Use in Adams Rural

The participants in the study were asked if they knew what the land was used for prior to their acquisition. The results as shown in figure 4.23 illustrate that almost all the participants (98.9%) said that the land acquired was previously used for agricultural purposes (sugarcane plantation) with the remaining 1.1% having been used for residential purposes. Upon acquisition, however, the use of land acquired by people living in urban areas change drastically and this is evident since over 93% are now using the land for residential purpose, with only 6.8% of the land being retained for agricultural use (Figure 6.23). These finding support the change detection results that the major land use in the area affected by residential settlements, is agricultural use, as people have not continued with sugarcane plantations, but rather they have chosen to build residential houses.

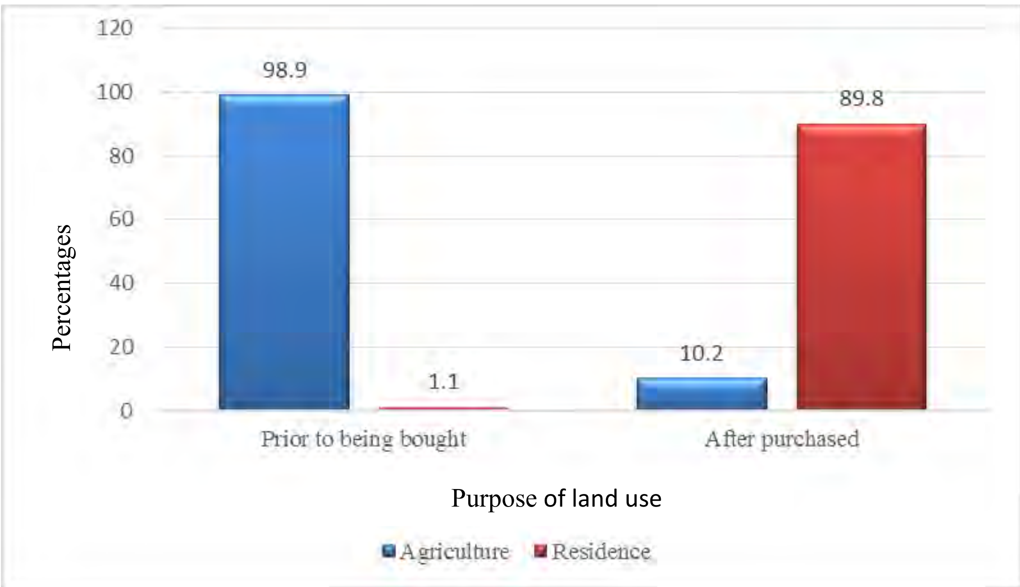


Figure 6.23: Purpose of land use in Adams Rural.

Participants were also asked about their future plans for their land acquired in Adams Rural. The majority (88.7%) of them indicated that they would like to extend their houses, have gardens around it and to reside with their families. Others indicated that they would also like to use it for business or to sell the remaining piece of land (10.2%) while others indicated that would continue using it for plantation (1.1%). This information is illustrated in Figure 6.24.

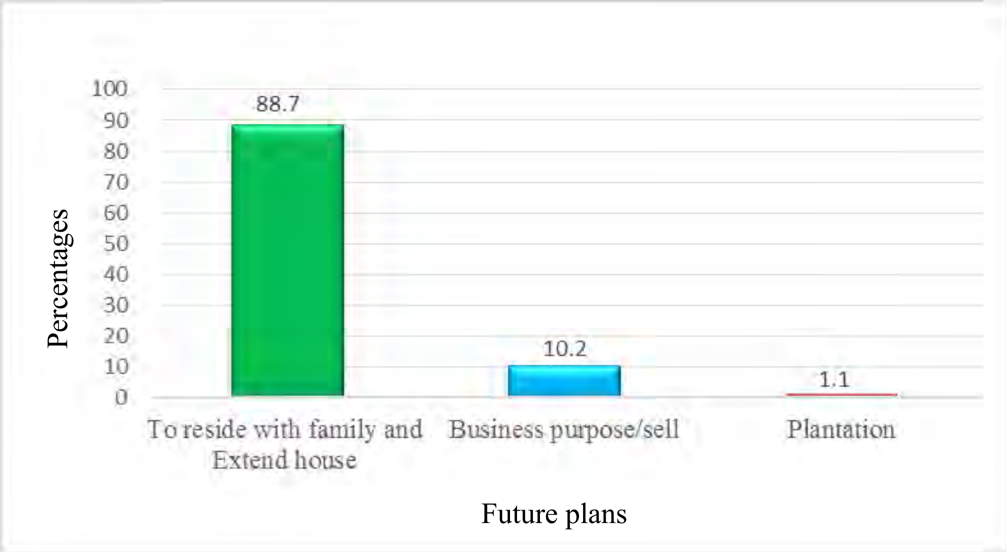


Figure 6.24: Future plans for land owned in Adams Rural

6.6.4 Cross tabulation of Results

Land in customary tenure is owned by indigenous communities and managed in accordance with their customs, as opposed to statutory tenure. Therefore SPSS was used to conduct a cross tabulation of the relationship between urban areas and Adams Rural migrant land ownership. The results in table 6.12 show that the majority of people (50) who previously resided under full ownership in urban areas, are living under the perception of full ownership in Adams Rural. There are 13 people who previously had full ownership, but stated that they are not certain of their current land ownership status in Adams Rural.

Table 6.12: Cross tabulation table of previous land ownership vs current ownership.

		What type of ownership do you have in Adams Rural ?		
		1. Full Ownership	2. Not Sure	**Total**
What type of ownership were you residing under in urban areas ?	1. Full Ownership	50	13	**63**
	2. Renting	11	0	**11**
	3. Living with parents	6	3	**9**
	4. Originated from Adams rural	5	0	**5**
	Total	**72**	**16**	**88**

It appears that the people, who were renting in urban areas and then relocated to customary areas, with the intention of owning a property, have full ownership in their current residences (Adams Rural). Of the respondents who previously lived with their parents, six of them believed that they possess full ownership while three were not certain of their land ownership status. Five out of the 88 respondents originated from Adams Rural and they also stated that they possess full ownership. This therefore shows that land is the most important assets in these people's lives, and many of them want to own property, even in regions where customary tenure is still being practiced. However, the participants do understand that the chiefs and headmen govern land affairs in Adams Rural. The participants also seemed to understand their limitations in customary land. However, the idea of full ownership is still desired by many in the area. Therefore a chi square was conducted to test the set hypothesis that people who had full ownership in urban areas believe that they have full ownership in Adams Rural, a customary region.

Chi Square Test

A chi square test was conducted using SPSS to test the significance of land ownership. A chi square test is a test for independence or it can be thought of as a correlation co-efficient test for an association. Chi square tells if the association is significant but does not tell how strong it is. Phi and Crammer's v, were used to test if there is a relationship between two variables depending on the size of the matrix. Thus, the chi square test was conducted for ownership in urban areas and in Adams Rural for the migrants. Table 6.13 shows the cross tabulation results of the observed count and the expected count. Evidently the observed count is different from the expected count. Therefore, the chi square test helps to determine if these counts are different enough for the test or the association to be significant (Landau and Everitt, 2004).

Table 6.13: cross tabulation table of previous land ownership vs current ownership with expected counts.

			What kind of ownership do you have on your land ?		
			Full Ownership	Not Sure	Total
If Urban Area, what type of ownership were you residing under ?	Full owenership	Count	50	13	63
		Expected Count	51.5	11.5	63.0
	Renting	Count	11	0	11
		Expected Count	9.0	2.0	11.0
	With Parents or Siblings.	Count	6	3	9
		Expected Count	7.4	1.6	9.0
	Originated from Adams Rural	Count	5	0	5
		Expected Count	4.1	.9	5.0
Total		Count	72	16	88
		Expected Count	72.0	16.0	88.0

Table 6.14 shows the percentage of cells that were expected to have counts less than five. This is important because it is an assumption made by the chi square test. The percentage of the crosstab results should not be greater than 20%, however, in this case it is 50%. This means that the assumption has been violated, therefore a different cause of action was taken as the percentage was more than 20% (Landau and Everitt, 2004).

Table 6.14: Chi- Square cross tabulation test. (Urban and Customary ownership)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.199[a]	3	.158
Likelihood Ratio	7.847	3	.049
Linear-by-Linear Association	.564	1	.453
N of Valid Cases	88		

a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .91.

This means that the Pearson chi-squares values will not be used, but a likelihood ratio is used, and compared to the standard level of significance of 0.05. Therefore the obtained likelihood ratio result value should be equal or less than 0.05 for the variables (urban and rural ownership) to be deemed significant (Landau and Everitt, 2004). Table 6.15 shows that the likelihood ratio is 0.049, which means that there is an association and the association for the cross tabulation is significant. Therefore, there is a relationship in ownership status previously possessed in urban areas and currently possessed in Adams Rural. In essence, current ownership status is dependent on the previous ownership. Those who had full ownership in urban areas wanted to continue with that status and those who have been renting or living with parents want to have full ownership of land. Thus the set hypothesis was tested to be true.

Table 6.16: Chi – Square cross tabulation test (Gender and Ownership)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.040[a]	1	.841		
Continuity Correction[b]	.000	1	1.000		
Likelihood Ratio	.040	1	.841		
Fisher's Exact Test				1.000	.529
Linear-by-Linear Association	.040	1	.841		
N of Valid Cases	88				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.64.

b. Computed only for a 2x2 table

The ownership in Adams Rural was further cross tabulated with gender. Table 6.16 shows that there is an approximate level of ownership perception between males and female migrants in Adams Rural. In this case, the set hypothesis is that land ownership is not specific to one gender. This means that both men and women want to have full ownership.When testing for a level of significance between these two variables, Table 6.16 shows that there is no level of significance. The cross tabulation of gender and ownership in Adams Rural is therefore violated. Even though the percentage shown in

Table 6.16 is zero cells (0%) e expected counts less than five , but this works for a three by three matrix (Landau and Everitt, 2004).

Therefore the Pearson chi-square value was not used to test for association, but a Fisher's exact test value is used. When comparing the significant value of the Fisher's exact test (1.000) (Table 6.16), with the standard significant test of 0.05 the results show that there is no significance in gender association with ownership status in Adams Rural. Thus the participants` land ownership status is completely independent of their gender. This therefore means that both men and women in Adams Rural want to have some form of land ownership. Therefore the set hypothesis is tested to be true.

6.6.5 Land management in Adams Rural

A formal interview was held with the Adams Rural headman, to better understand the management of land in the area. A copy of the questions and responses can be seen in Appendix J. As stated in chapter 4, Adams Rural is a rural area, under the Ingonyama Trust Board where traditional customs are still practiced. There is no alienation of land and customary tenure still exists. When the headman was asked about the availability of land for the public to access, it was discovered that the land is available to anyone. Anyone above the age of 21 years is allowed to obtain land in Adams Rural (Customary Land). However, only land that is available and not being occupied by anyone will be offered by the headman to those in need. The current situation in Adams Rural is that there is land which is already occupied and yet that land is under the control of the King. Some of those who occupy land in Adams Rural make land available to others by selling their properties. Nevertheless, the headman still has to facilitate the process of allocation and attend to the administration of that land. No one is allowed to obtain land in Adams Rural without the involvement of the headman. Traditional methods are still being practiced when allocating land. Natural features and non-fixed pegs are used for parcel demarcation. However, these features are mistakenly removed during the construction of houses.

There is a growth of residential settlements in Adam Rural, therefore better land allocation and demarcating methods might be ideal. When an individual is offered and allocated a piece of land, he or she is given a one year time frame to make use of that piece of land. The land goes back to the chief if it's not being used during the given one year period, even if it was purchased from a resident at Adams Rural. The allocated land is constantly monitored, and the owner is contacted to remind him or her that she or he must make use of the land. If the one year time frame is not enough, this must be reported with valid reason to the headman. People are not limited to obtain one piece of land. However, a satisfactory reason has to be given as to why one would need more land. This contributes to the speedy development in the area. The headman supported the findings of the change detection analysis which showed that there were very few residential houses in the in the early 1990s, and that much of the land was used for sugarcane plantations. However, residential settlements started to develop after the turn of the millennium. According to the headman, there is still land available to the public and there is land which has been allocated which people are expected to use within the one year time frame. This means that in the next couple of years Adams Rural is possibly going to be vastly developed with residential settlements.

6.6 Predictive settlements development, conceptual model

The results from the change detection, analysis and the output from the questionnaire were used as the main inputs for developing a conceptual land development predictive model. This model attempts to provide an estimate of possible future expansion of Adams Rural based on what is currently occurring in the area. The Mean Annual Expansion Rate (A_{CR}) was determined by dividing the total change in land use (T_C) by the number of years (n) for built-up areas and agriculture (Equation 6.4). Using the figures in Table 6.17, magnitude of change in 11 years is calculated for both built-up and agriculture. Thereafter an annual change was calculated for both these land use classes.

Table 6.17: Measured Land cover/ land use for 2001and 2012 from Classified Imagery.

Class Name	2001	2012
Bare land	572	766
Forest	830	965
Built-up Area	120	253
Agriculture	1634	1173

$A_{CR} = \frac{T_C}{n}$...................................... Equation 6.4

From table 4.15 it can be seen that:

Built-up Area Change in 11 years (2001 - 2012) = 253 – 120 = 133 ha

Therefore Built-up Area Annual Change: $A_{CR} = \frac{133\text{ha}}{11\,years} = 12.09ha/year$

Agriculture Area Change in 10 years (2001 - 2012) = 1172 – 163 = - 461 ha

Therefore Agriculture Area Annual Change: $A_{CR} = \frac{-461\text{ha}}{11\,years} = -41.91ha/year$

Using the annual change rate, an estimation of the future status of built-up area versus agriculture is determined as shown in Table 6.19 (Openyemi, 2006). These two land uses are compared because it has been established from the imagery, questionnaire and the change detection analysis that the settlement growth results in the loss of agricultural use.

Table 6.19: Data Table estimating the future status of Built-up areas and Agriculture in Adams Rural based on change detection results.

Land Use	Epochs					
	2012	**2014**	**2016**	**2018**	**2020**	**2022**
Built-up Area	253	277.18	301.36	325.54	349.72	373.9
Agriculture	1173	1089.18	1005.36	921.54	837.72	753.9

The information obtained from the land use survey conducted with the community and the headmen resonate with the estimation data table 6.19, as it illustrates that the settlements will continue to grow as long as there is unoccupied land. If the land continues to be developed, more people will be attracted, resulting in more residential growth in Adams Rural. Figure 6.25 is a simplification of the inputs in the growth of residential settlements in Adams Rural.

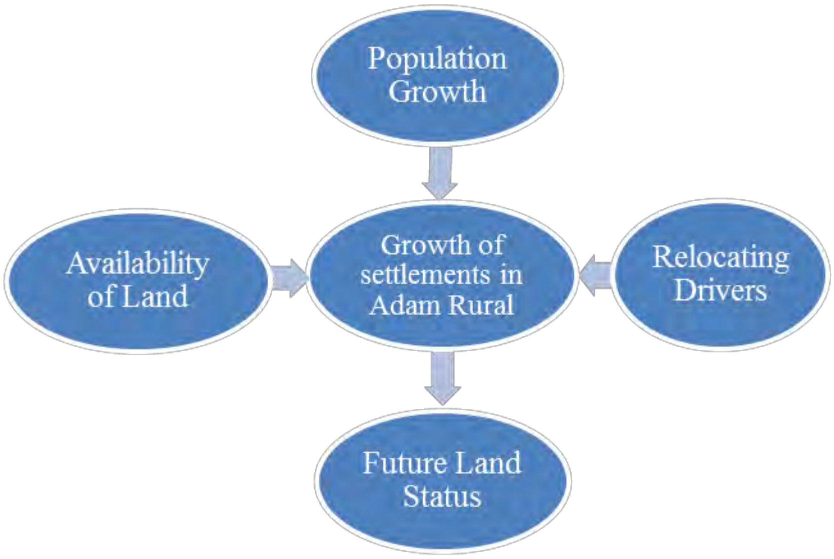


Figure 6.25: Conceptual model based on questionnaire responses and literature review.

There are three basic factors that contribute to the growth of settlements in Adam Rural: the availability of land, population growth and what drives people to relocate to the area. Thus, if these three contributors continue to exist, the future land status of Adams Rural will see more development of residential settlements in the area. The growth of settlements in the region resulted in land use change. The main affected land use class is the sugarcane plantations. Thus the following are the key factors in developing a basic hierarchical conceptual land development model:

1 Population Growth
2 Relocating Drivers
3 Availability of Land
4 Land Use Change
5 Future Land Use Status

1. Population Growth

Human population growth in Adams Rural is the most significant cause of the land use change in the region. There are two elements which contribute to the increasing population in Adams Rural, they are, natural births and people relocating to the area. The significant element which is responsible for land use change is the migrants moving from urban areas to this customary area. This has been established from the questionnaire results.

2. Relocating Drivers

In customary areas young adults prefer to work in cities and then return to rural areas, not to farm but to build and improve their homes. This results in urban communities being enticed to relocate to customary land. The survey conducted at Adams Rural revealed that a low cost of living, bigger parcel extents, area development and proximity to the city are among the drivers which make people relocate to Adams Rural.

3. Availability of Land

The majority of land use in most rural areas is farming or plantation of crops. However, some of the people in Adams Rural have now stopped having sugarcane plantations and divide their land to make it available to the public for residential settlements. This phenomenon was noticed after the turn of the millennium and it is now continuously occurring in this region. A visual analysis on the latest Adams Rural imagery shows that there is still un-occupied land and this is confirmed by the Adams Rural headman. (see Appendix J).

4. Land Use Change

Human activities in Adams Rural have transformed the landscape from sugarcane plantation to residential settlements. The land use change is the result of people accessing this rural region. Change detection analysis has shown that the residential settlements have doubled from 2001 to 2012. The demographics shown in Statistics South Africa have also shown that the population has doubled over the same period (Statistics SA Census, 2011). The questionnaire revealed that the major contributor to the increase in population, are people relocating to this customary region which results in land use change. Thus, settlement expansion in Adams Rural resulted in land use change.

5. Future Land Use Status

The future land use status of Adam Rural is predicted to have more growth in residential settlements. Based on the calculated annual change rate of 13.3ha/year (see chapter 4).), the future status is predicted to have residential settlements expanding up to 306.2 ha / year by 2022. This will therefore cause a decrease in sugarcane plantations. The increase in residential settlements will require construction of roads and municipal services (such as water and electricity). There are still sugarcane plantations and un-occupied land in Adams Rural. Therefore, as long as there is still land available or not under residential use, the growth of settlements in the area is likely to continue to increase. The model in figure 6.26 further addresses these factors that lead to the expansion of settlements in the area, namely, population growth, availability of land, and the drivers. The model also takes into account the future status of the area.

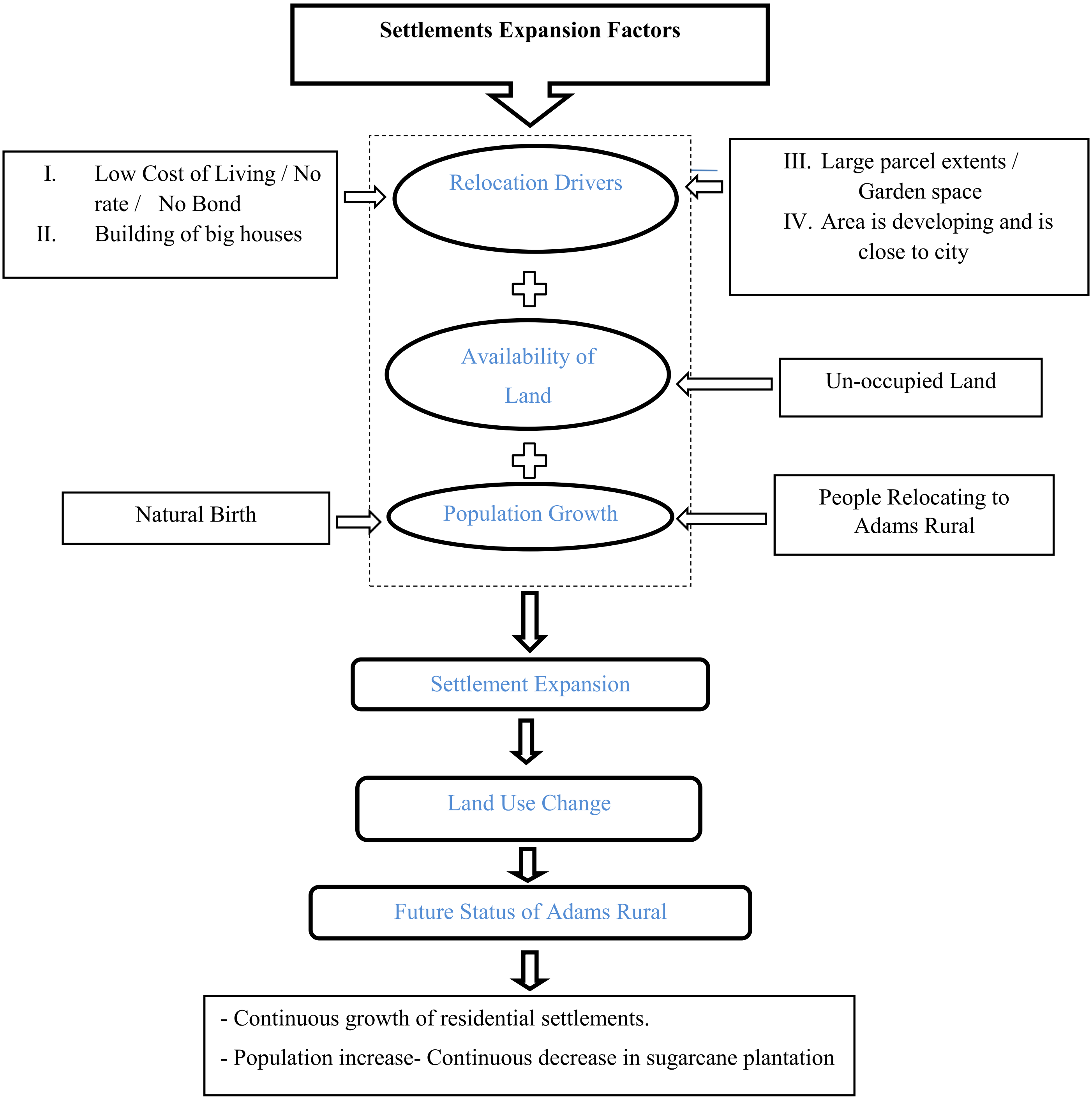


Figure 6.26: Hierarchical Conceptual Land Development model

The population in Adams Rural has increased in the past decade, and this is confirmed by the South African Statistics of 2001 and 2011 survey (Statistics SA Census, 2001 and 2011). The questionnaire revealed that the major contributor to population growth in the area is people moving into the area. This led to land use change as people who access the area need a place to live. The result is that the sugarcane plantations are affected as shown in the change detection analysis. This means that it has not been prohibited to convert land used for agriculture into residential use in Adams Rural. Figure 4.26 shows that in 2001 only four percent land was used as residential and in 2012 this increased to eight percent in a period of 11 years. These results were obtained from the change detection analysis. The growth of settlements resulted in the increase of bare land as the building platforms needed to be opened. The increase in forestry is the result of the misclassification of pixels where agricultural land was classified as forest. This was shown in the change detection analysis.

The questionnaire survey revealed that the low cost of living appears to be the major driver for people who relocate to Adams Rural, as there are no rates payable. Moreover, people who own land or occupy land in Adams Rural make land available due to their disinterest in plantations or the lure of money. The majority of people sell their houses in urban areas, pay off their bonds if this is the case, and use the money to obtain land and build in Adams Rural. Therefore, as time goes by, more people are attracted to this developing area, where residents have bigger parcel extents which allows them flexibility when building. The imagery shows that there is still land under agricultural use in the area and the headman also confirmed that there is still land available. Thus, if this trend continues, the future land use of Adams Rural will see more expansion of residential settlements in the area. This will also result in the need for municipal services such as water and electricity to become available to residents.

Chapter 7

Discussion

7.1 Introduction

For centuries migration has been a trend where people move from areas with poor resources to areas which promise a better life. In the modern era the dominant pattern is that of people moving from rural to urban areas. There is however, an ongoing trend occurring in Adams Rural, a rural area south of Durban in South Africa, where the migration norms appear to have reversed. People have been moving from urban areas to this rural region. This trend is observable as an increase in human settlements in this area over the past decade and is confirmed by annual aerial imagery of the area captured by the eThekwini Municipality. The growth of settlements in Adams Rural has increased the demand for land in this customary region as there are more people attracted by the ongoing residential settlements in the area. This action results in loss of land previously reserved for agriculture, predominantly in the form of sugarcane plantation.

This study employed Remote Sensing and GIS technology in order to perform spatial analysis using the Change Detection Technique. The Change Detection Technique was performed on selected orthophoto imagery to assess spatial change patterns, and to quantify the amount and rate of change in human settlements of the Adams Rural area during the period 2001 to 2012. The post-classification change detection employed confirmed that human settlements have been increasing. The spatial coverage for the built-up areas in Adams Rural obtained from the analysis, demonstrated a steady expansion over the period under investigation. The increase in built-up areas is estimated at 112% from 2001 to 2012, having increased from 119.488 ha in 2001 to 253.265 ha in 2012. This is shown in Figure 7.1 which shows a trend in the line graph illustrating the growth of built-up areas in Adams Rural.

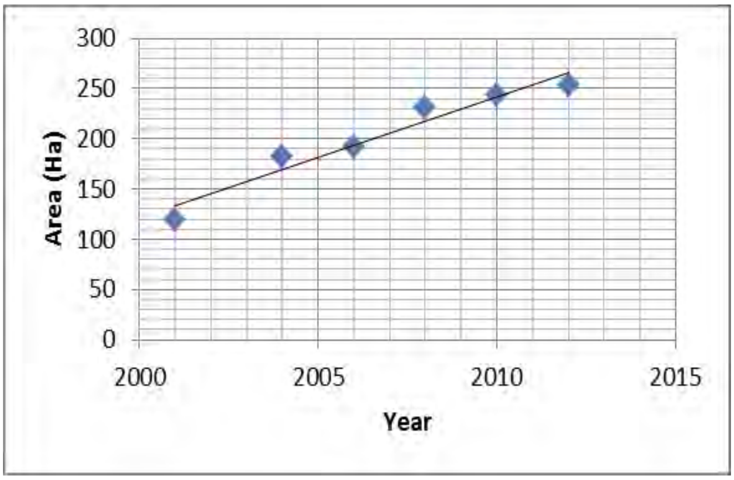


Figure 7.1: Growth of built-up areas in Adams Rural.

The post classification results also showed that whenever there is an increase in built-up area there is a decrease in agricultural land. This is due to the construction of building sites and gravel access roads; these are two competing ends which have seen a gain in one at the expense of the other. The increase in residential settlements is further confirmed by the demographic data obtained from Statistics SA which shows a 98% increase in Adams Rural population from 15763 in 2001 to 31164 in 2011 (Figure 7.2) (Statistics SA Census, 2011). The general land use in Adams Rural is sugarcane plantations. However, the increasing population requires residential land. Therefore the phenomenon observed of people moving from urban areas to Adams Rural has resulted in the increase in population and growth of settlements in this customary area. The Adams Rural region is indeed experiencing this reverse migration trend.

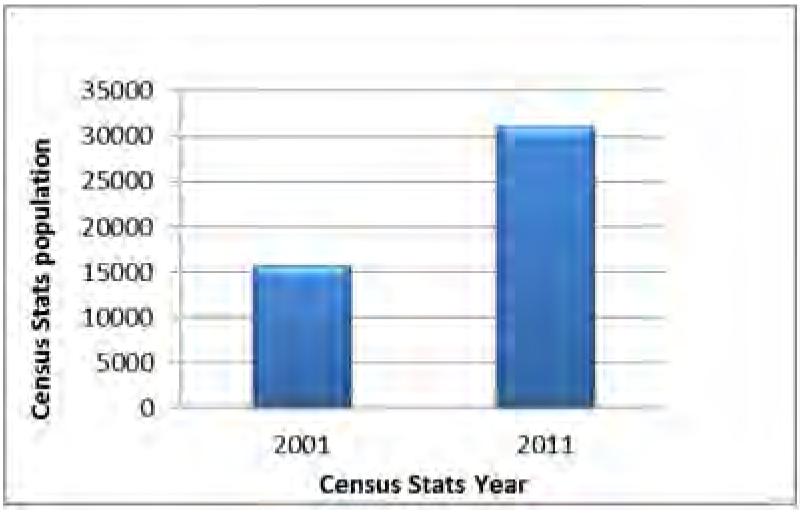


Figure 7.2: Population statistics of Adams Rural

The use of questionnaires administered to randomly selected Adams Rural community members provided information regarding the motive behind people relocating to the Adams Rural region. The questionnaire confirmed that the increase in population is mainly due to urban community relocation to Adams Rural. The engagement with the Adams Rural community using questionnaires provides a clear indication that people had moved to the area because they needed larger parcel extents and a lower cost of living. However, it is not clear what the sources of finance may be for residents of Adams Rural, as the study did not address the financial aspects related to the building of dwellings. The type of dwellings and the question of finance were s beyond the scope of this study. Two of the houses which were recently built in Adams Rural are depicted in Figures 7.3 and 7.4.

Figure 7.3: Newly Built House 1 in Adams Rural

Figure 7.4: Newly Built House 2 in Adams Rural

The proximity of Adams Rural to the urban areas of Durban may lead to the perception that the expansion in human settlements in the region is part of a trend observable in the urban fringes throughout South Africa. However, this is not the case as Adams Rural is being managed under the system of customary tenure, thus there has been no alienation of land which would suggest expansion of an urban area by the municipality. It may be further argued that the houses do not possess any characteristics of informal settlements and neither could they have been a result of land invasion, as the land in the area is administered in accordance with the customary tenure system.

7.2 Land Use Classification and Mapping

The study adopted the supervised classification method and used the maximum likelihood classifier in conducting an image classification using the orthophoto imagery. Pillay (2009) stated that the advantage of this approach is that the result of a classified image is more accurate due to validation through ground-truthing. Openyemi (2006) concur that the maximum likelihood classifier provides the better results compared to others classifiers. However, this may vary with the type of data used and the analysis being conducted. The supervised classification experienced misclassification of pixels in this study. However, it was expected that the orthophoto imagery would experience pixel misclassifications as the image classification is not subjective. This means that in any image classification there would be those individual pixels that would inevitably be misclassified. This is due to spatial features having a similar spectral reflectance (Singh, 2013). The area that was most affected by this misclassification was the ploughed agricultural land as it was misclassified as bare land. The strong green leaves of sugarcane plantation were also misclassified as forest as they had a similar spectral reflectance. The misclassification of pixels could underestimate the true area as they are represented by these misclassified pixels (Schneider and Fernando, 2010). However, the 2001 and 2012 images did not experience much pixel misclassification. The results obtained from post classification analysis show good accuracy, thus allowing for a reliable change detection analysis and annual change rate of 12.09% of built-up area using 2001 and 2012 classified imagery. Orthophoto imagery was used in this research. However, Pillay (2009) used satellite images (Landsat TM images) in conducting their studies. Nevertheless, the same traditional image classification approach was used. Pillay`s (2009) results showed good accuracies when using the Landsat TM images (see Table 7.1). Singh (2013) also obtained good accuracies of 81.4% for 2009 and 94.4% for 2011 in his research using Landsat TM images.

Table 7.1: Overall post-classification accuracies using Landsat TM images. (Pillay, 2009:p34-35)

Year	**Accuracy**
1991	83.3 %
2001	100 %
2006	88.8%

Table 7.2: Overall post-classification accuracies using Orthoporto images

Year	Accuracy
2001	94.7 %
2004	89.4 %
2006	94.4 %
2008	92.5 %
2010	97.3 %
2012	95.6 %

This study also obtained good accuracies which are comparable with the literature (see Table 7.2). Therefore, the type of data used for carrying out the classification did not have an effect on the accuracy as they compared well with the literature (Pillay, 2009; Singh 2013). However, the advantage of using the orthophoto imagery was that no ground truthing and GPS points for geo-referencing was needed. Another advantage was that the training data was easily obtainable from the orthophoto imagery. Hence, it was also easy to identify the type of classes in the region using the panning tool in ArcGIS and Erdas. The planning tool was also used to visually analyse the images for the growth pattern. The urban community who relocated to Adams Rural in the early stages of settlement development obtained larger parcel extents.

However, the parcel extents obtained by those who relocated during the later stages of development was observed to be smaller. The ground land use survey conducted also confirmed that the parcel extents allocated to individuals moving into the area decreased as more people are moving into this rural region. The post-classification change detection showed that there is a 112% (2001-2012) growth of settlements in Adams Rural. Figure 7.5 shows that out of the total area of Adams Rural, built up areas only constituted 4% in 2001. The built-up area has doubled in 2012 covering eight percent of the region's total areas. The growth of settlements resulted in the increase in bare land as more gravel access roads are built. Agricultural land decreased because settlements and roads have been constructed on this land and pixels were misclassified as forest. The pixels` misclassification of agriculture as forest resulted in the increase of forest class (see Figure 7.5). The forest figures were noted to be an inaccurate reflection of what is actually on the ground when carrying out a visual analysis of the images of 2001 and 2012.

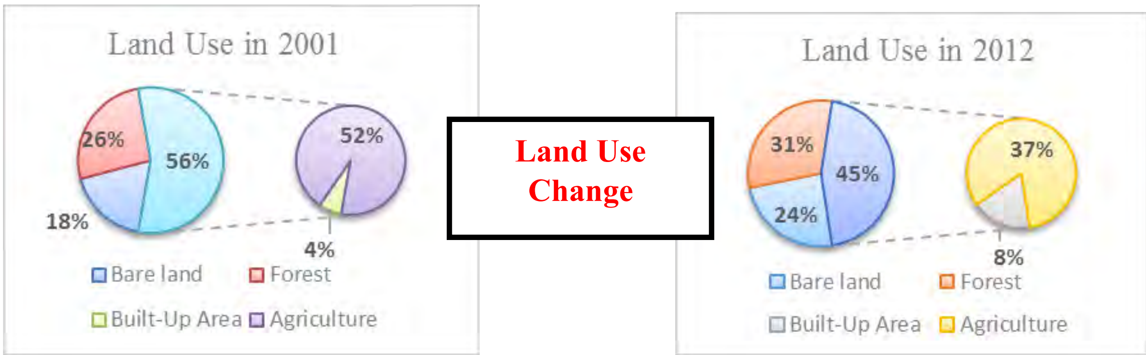


Figure 7.5: Land use change in Adams Rural over a period of 11 years from 2001-2012.

Pillay (2009) conducted a change detection analysis of small-scale sugarcane land using LandSat imagery, with Umbumbulu as a case study. Umbumbulu is also a customary region under the Ingonyama Trust Board, and is adjacent to Adams Rural. Pillay (2009) found that the sugarcane plantation experienced a decrease from 1991 (98 387ha) to 2001 (44 884ha) and built-up areas increased from 126673ha (1991) to 214 360ha (2001). The sugarcane plantation increased in 2006 to 80 795ha and Pillay (2009) posited that this was due to the conversion of mixed bush shrub to sugarcane plantation. The built-up area further increased in 2006 to 255656ha. Pillay`s (2009) findings indicated that the increase of built-up areas was due to a population increase in customary land. These findings resonate with the findings of this study. This means that the idea of using land previously used for sugarcane plantation is not only occurring in Adams Rural, but in other surrounding areas as well. Pillay`s (2009) study shows that this phenomenon is also noted in other customary regions such as Umbumbulu. Pillay (2009) did not address the issue of the driving forces behind this as his study focused specifically on the conversion of land previously used for other purposes that is now small-scale sugarcane plantation. However, the findings show that there is an increase in the population, which results in an increase in residential settlements in the customary regions of KwaZulu-Natal. Therefore, the findings of the growth of settlement in Adams Rural, has resonance with Pillay`s (2009) findings in Umbumbulu customary regions.

The growth pattern of settlements shows that the early settlements were closer to the main roads. When there was not enough land close to the main roads, the growth pattern increased from the adjoining properties, which are closer to the main roads, to parcels further inland. Thereafter, the pattern observed is one where settlements developed all over and are scattered in the Adams Rural region. This resulted in more roads being constructed. An increase was evident in bare land class when the post-classification change detection was conducted. The change detection technique was vital to conduct this research. Utilising a change detection analysis using GIS and Erdas allowed for the mapping of land use in Adams Rural. Orthophotos were used to create Adam Rural maps from the traditional boundaries in ArcGIS. These maps facilitated an understanding of the past and current situations and also to determine the different land use in the region. The land use maps played a vital role in producing the land use classes to perform the image classification. The land use maps created from the classified images were also successfully produced. These are the raster data maps from which the land use class were measured from their pixels.

Openyemi's (2006) study aimed at producing a land use land cover map of Llorin in Nigeria at different epochs in order to detect the changes that had taken place particularly in the built-up land. This current study followed the same methodological approach that Openyemi's (2006) study employed even though Openyemi (2006) used satellite imagery. However, the land use maps were successfully produced. Although this study used orthophoto images, the results obtained compare favourably with the findings of other studies (see Openyemi 2006; Pillay 2009).

7.3 Relocation Drivers and Land Development Model

The first task in estimating the future settlement status of Adams Rural was to calculate the growth rate from the change detection results. The obtained average annual growth rate of settlement development in Adams Rural was 12.09%. . The 12.09 % annual rate of change was then multiplied by the number of years to simulate the next future change of built-up area and agriculture value up to 2022. Thereafter, a settlement development prediction table was produced which estimated the future status of settlements in Adams Rural (See chapter 4). The effect of observed changes from change detection in the land use between 2001 and 2012 and the land use survey result from the questionnaire were the major criteria in developing the hierarchy settlement development model. The hierarchy settlement development model was created to describe the current situation in Adams Rural as well as to determine what the possible future status of the region might be.

Openyemi (2006) made an attempt to predict likely changes that might take place in the future at Llorin in Nigeria. Openyemi (2006) made use of the annual change rate. However, Openyemi (2006) further used the Markov chain analysis and cellular automata analysis integrated in IDRISI software. Openyemi (2006) stated that this approach is convenient for modeling land use change when changes and processes in the landscape are difficult to describe. This study took a different approach as the changes and processes information were obtained and described from a land use survey, which resulted in the creation of the Land Development Model. The unavailability of IDRISI software made it difficult to follow Openyemi's (2006) approach in this study.

The land use survey of Adams Rural supported the spatial analysis result from the classified images. Residential settlements are increasing in the area and are driven by the low cost of living and larger parcel extent in the customary land. The ownership in Adams Rural was cross tabulated with the ownership from the urban areas and with gender. The chi-square analysis associated with this cross-tabulation showed that the respondents` perceptions of their land ownership in Adams Rural was dependent on their previous form of ownership in urban areas (See chapter 4). This was concluded as the participants have a perception that they have full ownership of the customary land. However, in customary tenure the land belongs to the King in KwaZulu-Natal. The custodian of customary land is the Ingonyama Trust Board. The participants therefore do not have full ownership of the land parcels that they occupy in Adams Rural.

The chi-square test further shows that the desire to own land does not depend on gender, which means that everyone who relocates to Adams Rural, regardless of their gender, wants to own land. Moreover, the test demonstrated that even those who were renting or living with their parents relocate to Adams Rural in the hope of securing land to own.

7.4 Summary

Performing spatial analysis using change detection techniques proved to be a suitable approach for measuring the extent of land use change in Adams Rural. The land use survey that was conducted for the growth of settlements in Adams Rural resonates with the results obtained from the classified images. The post-classification change detection shows that there is a growth of settlements. The land use survey also revealed that there is land not used for residential purposes remains sugarcane planation, thus there is a possibility of further settlements to be erected in Adam Rural. The settlements are developing increasingly close to the main road and thereafter they develop towards the inland. The questionnaire survey also provided an understanding of the drivers of the expansion of settlements in Adams Rural, which include the low cost of living, larger parcel extent, proximity to the city, the development occurring in the area and land ownership. Integrating the post-classification and land use survey allowed for the construction of a basic settlement development predictive model for Adams Rural. A data table presented the approximation of the settlements up to the year 2022 in Adams rural.

Chapter 8

Conclusion and Recommendations

8.1 Introduction

The study has demonstrated the utilization of orthorectified images, GIS and image processing techniques in carrying out a spatial analysis of land use changes from 2001 to 2012 in Adams Rural. The results of the present land use and the changing patterns over time are important in Adams Rural especially for the management of land distribution and its resources. It can therefore be concluded that orthophoto imagery and spatial analysis can be effective tools in establishing patterns in land use change and can be used to facilitate spatial planning and land management in customary areas. This study used Adams Rural to explore and confirm this phenomenon. It was further observed from the imagery that settlements are expanding particularly in the areas closer to the main tarred roads. Therefore, the drivers of this change had to be determined to understand this phenomenon.

The growth of residential settlement is the apparent cause of land cover change in the area. The loss of agricultural land in Adams Rural implies that human settlement activities are affecting the environment in rural areas peripheral to Durban which is the major city in KZN. Therefore there was a need to understand the social forces that drive the relocation process to customary land. A survey of the perceptions of local stakeholders in the study area was then conducted to gain insight into this phenomenon in Adams Rural. This assisted in acquiring a broader understanding of environmental changes. The low cost of living and the desire for land ownership emerged as the main reasons for the urban community`s decisions to relocate to Adams Rural.

8.2 The review of objectives

8.2.1 Objective 1: Creating a Land Use classification scheme

Through the use of spatial analysis, mapping, GIS and Remote Sensing, a land use scheme was successfully created. The classification scheme was successfully developed, based on the knowledge of the study area obtained from orthophoto images and with additional information from a reconnaissance survey. Four classes of land use were identified, namely bare land, forestry, built-up area and agriculture. Recent previous change detection research relied on satellite imagery, however, this study used photogrammetric imagery which was based on availability. The advantage of the photogrammetric imagery is that it shows a true and detailed reflection of what appears on the ground.

The imagery also has a good spatial resolution of 30 * 30 cm. A supervised classification approach was adopted and it proved to be more accurate than an unsupervised classification in this study. The maximum likelihood was found to be a suitable classifier, and this resonates with the cited literature. Acceptable classification accuracy was attained for the 2001, 2004, 2006, 2008, 2010 and 2012 imagery. Thereafter, a change detection analysis was successfully conducted and an annual change rate of 12.09ha per year of residential settlements was obtained. In achieving these procedures it ensures that objective one of the study was successfully achieved.

8.2.2 Objective 2: Mapping land use / land cover change between years 2001-2004, 2004-2006, 2006-2008, 2008-2010 and 2010-2012 in Adams Rural

The imagery obtained from the source had to be pre-processed in order to produce land use maps. The boundary of the traditional authorities` shape-files together with imagery was obtained from eThekwini Municipality. The imagery was pre-processed in ArcGIS to produce the Adams Rural region imagery. Thereafter, a spatial analysis was successfully conducted and raster data imagery was obtained from image classification conducted in ERDAS. Using the product of change detection analysis, the land use was measured and mapped in ArcGIS. Therefore objective two was successfully achieved.

8.2.3 Objective 3: Determining the drivers of relocating from urban area to Adams Rural and understanding the current land use in the region

The high cost of living in urban areas appeared to be the main factor that drives members of the urban community to relocate to customary regions. The relocation of the urban community to Adams Rural is a trend that is going to continue as long as there is still unoccupied land in Adams Rural. This was established by conducting a statistical analysis of the responses from the questionnaire. Furthermore, the headman of Adams Rural stated that there is still land available for the public to access.

The assumption that members of the urban community are relocating to Adams Rural, made at the beginning of the study, was successfully validated from the land use survey. The cross tabulation findings show that urban community members relocate to Adams Rural with the expectation that they would gain full ownership of land. Other driving forces were found to be the larger parcel extents obtained in Adams Rural; the ability of buildings to become customized homes; the fact that Adams Rural is in close proximity to the city and the fact that the area is developing. Thus this objective to determine the drivers regarding people`s decisions to relocate to Adams Rural was also achieved through the use of a questionnaire.

8.2.4 Forecasting the future status of land use in the area

The annual change detection rate was used to estimate the future status of settlements in Adams Rural, which is predicted to expand up to 306ha by the year 2020. The results from the questionnaire together with change detection results were then integrated to create a basic hierarchical flow chart of a settlement development model for Adams Rural. The contributing factors to the predictive model are the availability of land, relocation drivers, and population growth. This objective was achieved through integrating the change detection findings with the land use survey findings.

8.3 Review of aim and the research question

Achieving of all four objectives of this research contributed to achieving the aim of the research. The aim was to use spatial analysis to assess the changes of land use and subsequently estimate likely future changes that might take place in Adams Rural. In achieving the research aim, the research question was then answered. The research question asked how spatial analysis could be adequately utilized to monitor spatial changes of land use and land cover and to approximate the likely future of spatial patterns in settlements in the customary region of Adams Rural in KwaZulu-Natal. Therefore, the research question was answered by using spatial analysis techniques, such as change detection. Using imagery, GIS and remote sensing software allowed for the monitoring of spatial changes and the construction of a basic prediction model for the future status of spatial patterns on land. Therefore it can be concluded that spatial analysis is a good technique in monitoring change in land.

8.4 Limitations of the research

The images obtained in this research were not captured on the same annual date. Some of the images were captured before sugarcane ploughing season, while others were captured after ploughing season. This contributed to the misclassification of pixels, which resulted in the unreliability of classification results. However, the misclassification was limited by producing a strong training site, and repeating the image classification until possible best results were obtained. The other limiting factor was the unavailability of IDRISI software, which was available in other research and was used to conduct a predictive model and image classification. This resulted in an alternative approach to produce a basic predictive model using change detection rate, integrated with the land use survey. Although IDRISI software was not used in this study, the land use survey (questionnaire) was used to establish the socio-economic factors which assisted in understanding the changes occurring on land and thereby strengthening the model. The predicted future land cover was based on the past land cover change transition. However, the changes on land often occurs independent of each other, yet both this study's approach and the cited approaches in the literature (Openyemi, 2006) assume that the changes are dependent. There may be other factors triggering some of the changes in Adams Rural which were not incorporated into the study due to their complexity and the particular scope of this research.

8.5 Recommendations

It is recommended that research on the growth of settlements be conducted in other customary regions especially those on the periphery of cities, in order to determine whether settlement growth is also occurring elsewhere, or whether Adams Rural is an isolated occurrence. Even though the settlement expansion was observed in Umbumbulu by Pillay (2009), the drivers of this expansion were not determined. Pillay's (2009) assumptions suggested that during the period between 1990 and 1994 people moved out of the area due to violence in the area which resulted in a population decrease. Pillay (2009) stated that after 1994 the population numbers began to increase which resulted in the growth of the built-up areas. However, this does not reveal whether it is urban or rural communities that moved into Umbumbulu after 1994, but it does show that the sugarcane plantation was affected by built up areas.The research could be expanded further and could address factors such as challenges faced by the municipalities in providing services and those faced by the customary land authorities. The idea of customary land GIS cadastre for land management and the source of finance for building upmarket houses could also be addressed. This could also be an ideal opportunity to demonstrate a sample of a customary land GIS cadaster`s capabilities to the customary land authorities. Furthermore, it is recommended that LandSat imagery be used for image classification and be compared to photogrammetric data results. Perhaps a sub-pixel classification could be more accurate. The use of LandSat imagery in IDRISI could provide better predictive results.

8.6 Concluding Remarks

Spatial analysis can be used to monitor land use changes using different types of imagery and could also be used for land management. There is an expansion of residential settlements occurring in Adams Rural due to the urban community accessing this customary region. The more these residential settlements are increasing, the more pressing the need for an accurate management system becomes, or else this trend could result in a poor and uncontrollable settlement development. For instance, schools, clinics, roads, community halls and opens spaces could be designed in a layout for a specific population and placed in an appropriate location for better access. Therefore, there is a need to produce a proper layout to help manage the developing customary regions.

References:

Adams College (online) Available at: www.adamscollege.org.za (Accessed March, 2013).

Adeniyi P.O and Omojola A. (1999). *Landuse landcover change evaluation in Sokoto – Rima Basin of North Western Nigeria* based on Archival of the Environment (AARSE) on Geoinformation Technology Applications for Resource and Environmental Management in Africa. Pp 143-172.

Anderson, et al. (1976). *A Land Use and Land Cover Classification System for Use with Remote Sensor Data.* Geological Survey Professional Paper No. 964, U.S. Government Printing Office, Washington, D.C. p. 28.

Arvind C. Pandy and Nathawat, M.S. (2006). *Land Use Land Cover Mapping Through Digital Image Processing of Satellite Data – A case study from Panchkula, Ambala and Yamunanagar Districts.* Haryana State, India.

Babykalpana Y. and ThanushKodi K. (2011). *Classification of Land Use Land Cover Change detection Using Remotely Sensed Data.* Akshya College of engineering and Technology, Anna University, Coimbatore, India.

Baltsavias, E.P. (1996). Digital ortho-images – a powerful tool for the extraction of spatial- and geo information. *ISPRS Journal of Photogrammetry & Remote Sensing, 51*(1996), pp.63-77.

Bangamwabo, V.H (2009). *Spatial and temporal extent of land degradation in a communal landscape of KwaZulu-Natal*. Master's Thesis of Science in the School of Environmental Sciences, Faculty of Science and Agriculture , University of KwaZulu-Natal, South Africa.

Batty, M (2012). A generic framework for computational spatial modeling. In A.J. Heppenstall, A.T. Crooks, L.M. See, M. Batty (Eds.). *Agent-based models of geographical systems* (pp. 19-50). Dordrecht: Springer.

Beaver, B.M., Beaver, R.J. and W. Mendenhall. (2009). *Introduction to Probability and Statistics,* 13th edition. Brooks/Cole, Cengage Learning: Belmont, CA.

Bennett, J., et al. (2013). Contested institutions? Traditional leaders and land access and control in communal areas of Eastern Cape Province, South Africa. Land Use Policy 32 (0): 27-38.

Biesele, M.A., Hubbard, D., Ford, J., (1991). Land issues in Nyae Nyae: a communal areas example in Namibia. Nyae Nyae Development Foundation of Namibia, Windhoek.

Bitelli G., Capra A., Zanutta A. (2001). *Photogrammetric surveying of "Nymphea in Pompeii",* International Society for Photogrammetry and Remote Sensing, Archives, Proc. Of the XVIIIth CIPA International Symposium (Potsdam, Germany, 18-21 September 2001), Vol. XXXIV, 5/C7, pp. 236-252.

Blaschke, T. (2004). "Towards a framework for change detection based on image objects." In Erasmi, S., Cyffka, B. and M. Kappas (eds.). *Göttinger Geographische Abhandlungen* 113: 1-9.

Bocco, G., Sanchez, R. (1995). Quantifying urban growth using GIS: the case of Tijuana, Mexico (1973–1993). *Geographic. Infomartion. Sysemt.* 5 (10), 18–19.

Bornstedt, G.W. (1977). *Reliability and Validity in Attitude Measurement*. In: G.F. Summers (Ed.),

Attitude Measurement (pp. 80-99). Kershaw Publishing Company: London.Bowling, A. (1997). *Research Methods in Health.* Open University Press, Buckingham.

Bryman, A. and Cramer, D. (1997). *Quantitative Data Analysis with SPSS for Windows.* Routledge, London.

Burley, T.M. (1961). “Land use or land utilization.” *Patten Recognition*, 13, 18-19.

Byeong-Hyeok, Y. and Kwang-Hoon, C. (YEAR?). *An application research of multi-temporal satellite images for forest reclamation monitoring in the abandoned mine area.* Geoscience Information Center, Korea Institute of Geoscience and Mineral Resources.

Campbell, J. B. (2007). *Introduction to remote sensing.* 4th edition. United States of America, The Guildford press.

Chen, D., Stow, D., (2002). The effect of training strategies on supervised classification at different spatial resolutions. *Photogrammetric Engineering and Remote Sensing 68*, 1155–1161.

Chen, D., Stow, D.A., Tucker, L., Daeschner, S., (2001). Detecting and enumerating new building structures utilizing very-high resolution image data and image processing. *Geocarto International 16,* 69–82.

Chief Directorate: National Geo-Spatial Information (2010). *Standard for the 1: 50 000 Topographical Map Series*. Department of Rural development and Land Reform.

Chimhowu, A. &Woodhouse, P. (2006).Customary vs. Private Property Rights? Dynamics and Trajectories of Vernacular Land Markets in Sub-Saharan Africa. Journal of Agrarian Change, 6, 346-371.

Chitade A.Z, Katyar S.K, (2010). Impact analysis of open cast coal mines on land use/ land cover using remote sensing and GIS technique: A case study, *International journal of engineering science and technology, 2* (12), pp.7171-7176,

Chitade A.Z, Katyar S.K, I (2010 *Impact analysis of open cast coal mines on land use/ land cover using remote sensing and GIS technique:* A case study, International journal of engineering science and technology, Vol. 2 (12), pp.7171-7176

Cochran, W.G. (1977). *Sampling techniques*. Wiley, New York.Cohen, et al. 2000

Coppin, P. & Bauer, M. (1996). Digital Change Detection in Forest Ecosystems with Remote Sensing Imagery. *Remote Sensing Reviews*. Vol. 13. p. 207-234.

Coppin, P., Jonckheere, I., Nackaerts, K., Muys, B. and Lambin, E. (2004). Review Article Digital change detection methods in ecosystem monitoring: a review. *International Journal of Remote Sensing, 25* (9), pp. 1565-1596.

Costello, A.B., & Osborne, J.W. (2005). Best Practices in Exploratory Factor Analysis: Four Recommendations for Getting the Most from Your Analysis. *Practical Assessment, Research and Evaluation*, 10, 1-9.Covalini et al, 2006

Daniel, et al, 2002 *A comparison of Landuse and Landcover Change Detection Methods.* ASPRS-ACSM Annual Conference and FIG XXII Congress pg.2.

De Bruijn, C.A. (1991). Spatial factors in urban growth: towards GIS models for cities in developing countries. *ITC J. 4,* 221–231.DeFries, R.S. and Belward, A.S. (2000). Global and regional land cover characteristics form satellite data: An introduction to the Special Issue. *International Journal of Remote Sensing, 21*, 1083-1092.

Diallo Y., Hu G. & Wen X., 2009. *Applications of Remote Sensing in Land Use/Land Cover Change Detection in Puer and Simao Counties*, Yunnan Province, Journal of American Science, 5, 157-166

Dougan, H (2004). Securing property rights in land: politics on the land frontier in postcolonial Ghana and Botswana.

Eiden, G., Vidal, C. and Georgieva, N. (2002) Land Cover / Land Use change detection using pointarea frame survey data: Appilcation of Teruti. Bancik and Lucas. EC report EUR 20521. 55-74

ERDAS (1999). *Earth Resources Data Analysis System.* ERDAS Inc. Atlanta, Georgia.

Ezeomeodo, I and Joel Igbokwe, J. (2013). *"Mapping and Analysis of Land Use and Land Cover for a Sustainable Development Using High Resolution Satellite Images and GIS"*. Environment for Sustainability,Abuja, Nigeria,

Fonmanu, K. R. (1990). Dispute Resolution for Customary Lands in Fiji. Department of Geomaics.

Feleke, A.K. (2003). *Land use and Land cover in relation to Chromolaena Odorata distribution: mapping and change detection in St. Lucia wetland area, South Africa.* M. Sc Thesis, International Institute for Geo-Information Science and Earth Observation, Enscheda, Netherlands.

Franklin, J., Phinn, S.R., Woodcock, C.E., Rogan, J. (2003). Rationale and conceptual framework for classification approaches to assess forest resources and properties. In: Wulder, M., Franklin, S.E. (Eds.), *Methods and Applications for Remote Sensing of Forests: Concepts and Case Studies.* Kluwer Academic Publishers, Dordrecht, pp. 279–300.

Franklin, J., Woodcock, C.E., Warbington, R. (2000). Digital vegetation maps of forest lands in California: integrating satellite imagery, GIS modeling, and field data in support of resource management. *Photogrammetric Engineering and Remote Sensing 66*, 1209–1217.

Franklin, S.E. (2001). *Remote Sensing for Sustainable Forest Management*. Lewis Publishers, Boca Raton, FL, pp.407

Furze G, Lewin RJP, Roebuck A, Thompson DR & Bull P (2001). *Attributions and misconceptions in angina: an exploratory study*. Journal of Health Psychology 6, 501–510.

Gardner, G. (1978). *Social Surveys for Social Planners.* Holt, Rinehart and Winston, Sydney.

Fazal, S. (2000). "*Urban expansion and loss of agricultural land – a GIS based study of Saharapur.* Department of Geography, Aligarh Muslim University, Aligarh.

Foody, G.M.(1999). The continuum of classification fuzziness in thematic mapping. *Photogrammetric Engineering and Remote Sensing 65*, 443–451.

Foukana, J. (2010*). Management of Customary Land as a Form of Communal Property in Solomon Islands. Vanuatu and Fij*i. Inn Comparative Perspectives on Communal Lands and Individual Ownership: Sustainable Futures. London: Rutledge.

Giri, C.P. (2012). *Remote sensing of land use and land cover principles and applications*. Boca Raton, pp 3 – 12.

Goodchild, M.F. (2005). *GIS and Modeling Overview: National centre for geographic information and analysis.* Santa Barbara, University of California.

Hassen, M.C. and DeFries, R.S. (2004). Detecting long-term global forest change using continuous field of tree-cover map from 8-km advanced very high resolution radiometer.

Heppenstall, A.J., Crooks A.T., See, L.M. (2012). *Agent-based models of geographical systems. Introduction to Agent-Based Modelling* (pp. 85-105). M. Batty (Ed.) Dordrecht: Springer.

Hsiung Huang, H. and Ju Hsiao, C. (2000). *Post-classification and detection of simulated change for natural grass.* ACRS. Retrieved from http://www.gisdevelopment.net. pp. 1–3. Date accessed??

Ezeomedo, I. and Igbokwe, J. (2013). *Mapping and Analysis of Land Use and Land Cover for a Sustainable Development Using High Resolution Satellite Images and GIS*. Department of Surveying and Geoinformatics Nnamdi Azikiwe University, Awka Anambra State, Nigeria.

Jack, B. and Clarke, A. (1998). The purpose and use of questionnaires in research. *Professional Nurse 14*, 176–179.

Jensen, J. R. (2005). Introd*uctory Digital Image Processing: A Remote Sensing Perspective.* (3rd edn). Prentice-Hall, Upper Saddle River, NJ.

Jones, M.C. & Johnston DW (1999). *The derivation of a brief student nurse stress index*. Work and Stress 13, 162–181.

Kalabamu, F. T. (2000). Land tenure and management reforms in East and Southern Africa – the case of Botswana. Land Use Policy 17 (4): 305-319.

Kiernan, N. E. (2004). *Useful Categories: Tipsheet #44,* University Park, PA: Penn State Cooperative Extension. Available at http://extension.psu.edu/Evaluation/pdf/TS44.pdf

Kish, L. (1965). *Survey Sampling*. John Wiley and Sons, New York. Lambin, E. and Meyfroid, P. (2011). Global land use change economic globalization, and the looming land scarcity. *Proceedings of National Academies of Science. 108*, 3456-3457

Landau, S. and Everitt, B.S. (2004). *A Handbook of Statistical Analyses using SPSS.* Chapman and Hall/ CRC. Boca Raton London, New York Washington, D.C.

Levin, R. and D. Weiner (1997). No more tears: Struggles for land in Mpumalanga, South Africa, Trenton, and N. J: African World Press.

Lillesand, T.M. and Kiefer, R.W. (2004). *Remote sensing and image interpretation.* Fifth Edition. John Wiley and Sons Inc: New York.

Lo´pez, E., Boccoa,G., Mendozaa, M., Duhau, E.(2001). *Predicting land-cover and land-use change in the urban fringe - A case in Morelia city, Mexico.*

Loveland, T.R., Sohl, T.L., Stehman, S.V., Gallant, A.L., Sayler, K.L. and Napton, D.E. (2002). A strategy for estimating the rates of recent United States land-cover changes. *Photogrammetric Engineering and Remote Sensing 68,* 1091–1099.

Lu, D., Mausel, P., Brondizio, E. and Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing, 25* (12), 2365–2407.

Lu, D. and Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing, 28* (5), pp.823-870.

Lunetta, R.S., Ediriwickrema, J., Johnson, D., Lyon, J.G.and McKerrow, A. (2002). Impacts of vegetation dynamics on the identification of land-cover change in a biologically complex

Majumder, B. (2011). "Land Use and Land Cover Change Detection Study at Sukinda Valley using Remote Sensing and GIS", Department of Mining Engineering National Institute of Technology. Community in North Carolina, USA. *Remote Sensing of Environment 82*, 258–270.Majumder, B. (2011). "*Land Use and Land Cover Change Detection Study at Sukinda Valley using Remote Sensing and GIS",* Department of Mining Engineering National Institute of Technology. CITY?

Mallupati, P.K. and Reddy, J.R.S., (2013). *Analysis of Land Use/Land Cover Changes Using Remote Sensing Data and GIS at an Urban Area*, Tirupati, India.

Market Research, (2015). *Choosing Survey Analysis Software.*

http://mktresearch.org/wiki/Choosing_Survey_Analysis_Software#cite_note-0

Mather, P. M. (2001). *Computer Processing of Remotely-Sensed Images: An introduction.* 2nd ed. United States of America, John Wiley and Sons.

Beaver, B.M., Beaver, R.J. and Mendenhall, W., (2009), *Introduction to Probability and Statistics, 13th ed*., Brooks/Cole, Cengage Learning: Belmont, CA.

Meek, C. K. (1957). Land tenure and land administration in Nigeria and the Cameroons.Lisa M.G. (2008). The Sage Encyclopedia of Qualitative Research Methods. Sage: Thousand Oaks, CA, Vol.2, pp.697-698.

Meyer, W.B. and Turner, B.L. (1992). Human-population growth and global land use over change. *Annual Review of Ecology and Systematics, 23*, 39-61

Mithofer, K. (2006). *"Development of GIS-Based land registry for Tanzania".* MSc Thesis of Geographical Information Science and Systems, Salzburg University, Nairobi.

Mudenda, M. M. (2006). The challenges of customary land tenure in Zambia.

Neuman, L. (2008). Social research methods: Qualitative and Quantitative Approaches (3rd Ed.) USA: Allyn and Bacon

Ntuli B.K. (2003). *"An appropriate application of the land use schemes in tribal rural areas: a case study of Ceza"*. MSc thesis, University of KwaZulu-Natal, KwaZulu-Natal.

Ololade, O., Annegarn, H.J., Limpitlaw, D., Kneen, M.A., (2008). *Abstract Of land-use/cover mapping and change detection in the Rustenburg mining region using landsat images,* IGARSS.

Ololade O, Annegarn H.J, Limpitlaw D, Kneen M.A, Abstract of land-use/cover mapping and change detection in the Rustenburg mining region using landsat images, IGARSS 2008.

Olorunfemi J.F. (1983). Monitoring Urban Land – Use in Developed Countries – An aerial photographic approach. *Environmental Int.9,* 27 – 32.

Openyemi, Z.A. (2006). *Change detection in land use and land cover using remote sensing data and GIS:A case study of Ilorin and its environs in Kwara State.* The Department Of Geography: University Of IBADAN: Nigeria.

Pakeman, R.J., Marrs, R.H., Howard, D.C., Barr, C.J. and Fuller, R.M. (1996). The bracken fern problem in Great Britain: its present extent and future changes. *Applied Geography, 16* (1), pp. 65-86.

Phinn, S., Stanford, M., Scarth, P., Murray, A.T. and Shyy, P.T. (2002). Monitoring the composition of urban environments based on the vegetation-impervious surface-soil (VIS) model by sub-pixel analysis techniques. *International Journal of Remote Sensing 23*, 4131–4153.

Pillay, K. (2009). *Land Use Change Detection of Small Scale Sugarcane: A Case Study of Umbumbulu, South Africa,* Centre for Environment, Agriculture and Development School of Environmental Sciences, University of KwaZulu-Natal, KwaZulu-Natal.

Porter, J. (2005). *Principles of GIS Modeling.* University of Virginia, CITY?

Priest J., McColl, B. A, Thomas L. and Bond, S. (1995). Developing and refining a new measurement tool. *Nurse Researcher 2,* 69–81.

Provost, F. and Kohavi, R. (1998) Guest editor's introduction: On applied research in machine learning. *Machine learning, 30*, 127-132.

Queeensland Health, (2007). *Population Plan 2007-2012*. The State of Queensland Health. November 2007.

Quinlan, J. (1992). *C4.5: programs for machine learning.* Morgan Kaufmann, San Fransisco, CA.

Ramankutty, N. and J.A. Foley. (1998). Characterizing Patterns of Global Land Use: An analysis of Global Croplands Data, *Global Biogeochemical Cycles, 12*, 667-685.

Rattray, J.C., & Jones, M.C. (2007), Essential elements of questionnaire design and development. Journal of Clinical Nursing, 16, 234-243.

Mallupati, P.K and Reddy, J.R.S., (2013) Analysis of Land Use/Land Cover Changes Using Remote Sensing Data and GIS at an Urban Area, Tirupati, India

Rietveld, T. & Van Hout, R. (1993). Statistical Techniques for the Study of Language and Language Behaviour. Berlin - New York: Mouton de Gruyter

Roberts, D.A., Batista, G.T., Pereira, J., Waller, E.K. and Nelson, B.W. (1998). Change identification using multi-temporal spectral mixture analysis: applications in Eastern Amazonia. In: Lunetta, R.S., Elvidge, C.D. (Eds.). *Remote Sensing Change Detection: Environmental Monitoring Methods and Applications*, Ann Arbor Press, Chelsea, MI, p. 318.

Rogan, J. and Yool, S.R. (2001). Mapping fire-induced vegetation depletion in the Peloncillo Mountains, Arizona and New Mexico. *International Journal of Remote Sensing 22*, 3101–3121.

Schneider, L.C. and Frenando, D.N. (2010). An untidy cover: invasion of Bracken fern in the shifting cultivation systems of the Sothern Yucantán, Mexico. *Biotropica, 42* (1), pp.41-48.

Shoshany, M, et al (1994). Monitoring Temporal Vegetation Cover Changes in Mediterranean and Arid Ecosystems Using a Remote Sensing Technique: case study of the Judean Mountain and the Judean Desert. *Journal of Arid Environments, 33:* 9 – 21.

Singh, A. (1989). Digital change detection techniques using remote sensed data. International Journal of Remote Sensing 10 (6), 989–1003.

Singh, K. (2013). *Change detection of invasive bracken fern (Pteridiumaquilinum [L.] Kuhn) in the royal Naatal national park and rugged Glen nature Reserve*. MSc thesis in Land Surveying. College of Agriculture, Engineering and Science, University of KwaZulu-Natal. KwaZulu-Natal.

Sonneveld, M.P.W., Everson, T.M. and Veldkamp, A. (2005). 'Multi-scale analysis of soil erosion dynamics in KwaZulu-Natal, South Africa'. Land Degradation and Development, 16, pp. 287 – 301.

EThekwini Municipality (2012). Spatial Development Plan. Annual Review.

Tabachnik, B.G., & Fidell, L.S. (2001) *Using Multivariate Statistics* Pearson: Needham Heights, MA *(*4th ed.).

Tappan, G.G., and Cushing, W.M., (2004). The West Africa Land Use and Land Cover Project, Ecoregions and land cover trends in Senegal: Journal of Arid Environments, v. 59, no. 3 427-462

Taylor-Powell, E. (1998). *Questionnaire Design: Asking questions with a purpose.* University of Wisconsin Cooperative Extension. Available at http://learningstore.uwex.edu/QuestionnaireDesign-Asking-Questions-with-a-PurposeP1028C0.aspx.

Townshend, J.R., Justis, C., Li, W., Girney, C., and MacManus, J. (1991). Global land Cover classification by remote-sensing-present capabilities and future possibilities. *Remote Sensing of Environment, 35,* 243-255.

Turok, I. (2012). *Urbanisation and Development in South Africa: Economic Imperatives, Spatial Distortions and Strategic Responses*. INCOMPLETE

UCSD Student Research and Information. (2013). *Writing Good Survey Questions Tips and Advice.* http://studentresearch.ucsd.edu/_files/assessment/workshops/2013-02-21_Writing-Good-Survey-Questions-Handouts.pdf

Ubink, J. M. and J. F. Quan (2008).How to combine tradition and modernity? *Regulating customary land management in Ghana*. Land Use Policy 25 (2): 198-213.

U.S. Congress, (July 1993). The Future of Remote Sensing From Space: Civilian Satellite Systems and Applications. Office of Technology Assessment, OTA-ISC-558: Washington, DC: U.S. Government Printing Office,

Vincent, O.O. (2009). *"Exploring spatial growth patterns of informal settlements through Agent-based simulation"*. MSc thesis of Science in Geographical Information Management and Applications, Utrecht University. Utrecht.

Wilson, F. (1972). *Labour in the South African Gold Mines, 1911–1969.* Cambridge University Press, Cambridge.

Wischmeier, W. C., and D. D. Smith. (1978). *predicting rainfall erosion losses: A guide to conservation planning.* Agricultural Handbook 537. Washington, D.C.: Department of Agriculture.

Witten, I. And Frank, E. (2005). Data mining: practical machine learning tools and techniques. Morgan Kaufmann Publishers. City?Yudelman, D. and Jeeves, A. (1986). New labour frontiers for old: black migrants to the South African gold mines, 1920–51. Journal of Southern African Studies 13(1) 101–124.

Appendices

Apendix A: Orthorectified images of 2004, 2006, 2008 and 2010

Figure A1: 2004 Orthorectified imagery of Adams Rural

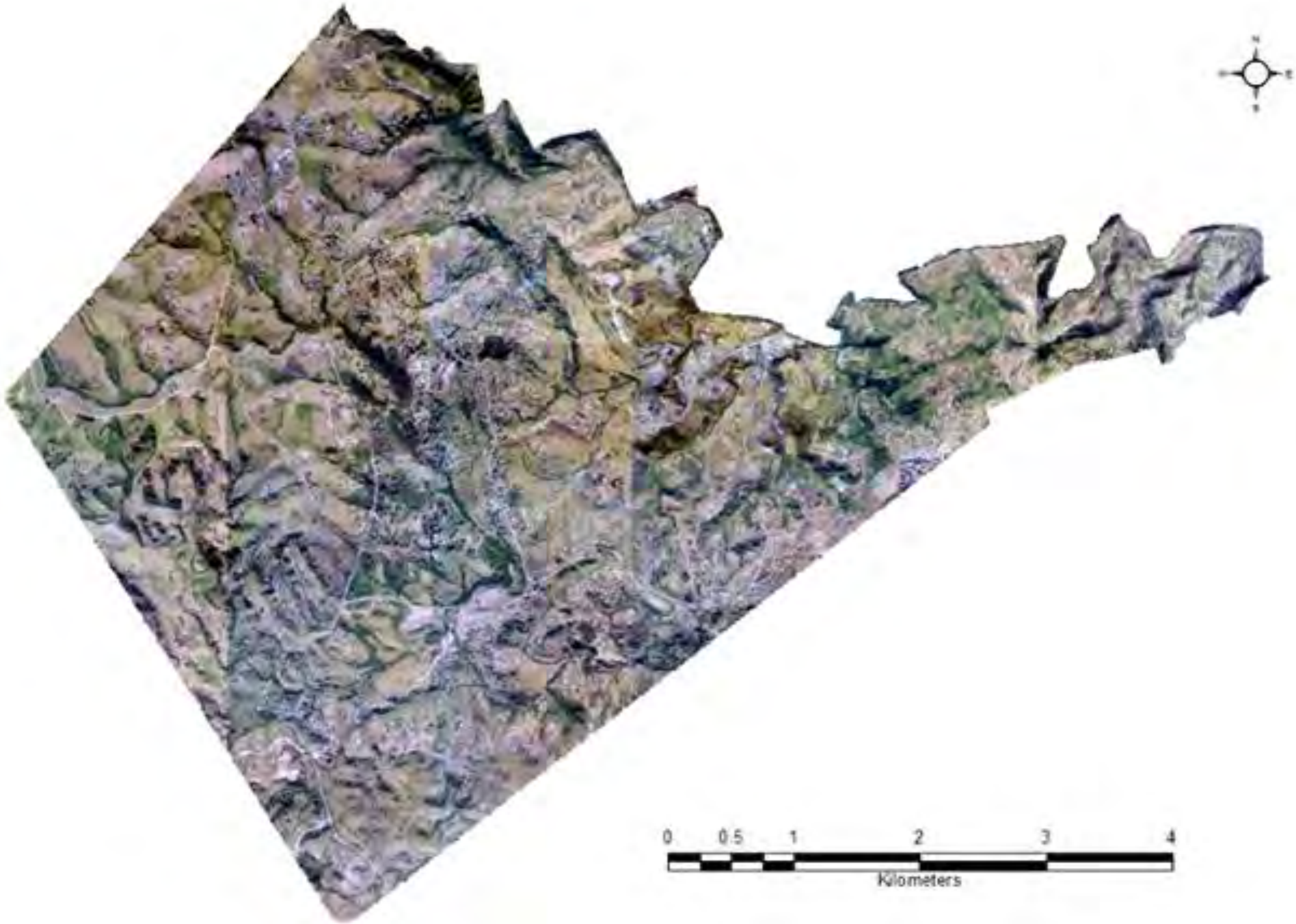


Figure A2: 2006 Orthorectified imagery of Adams Rural

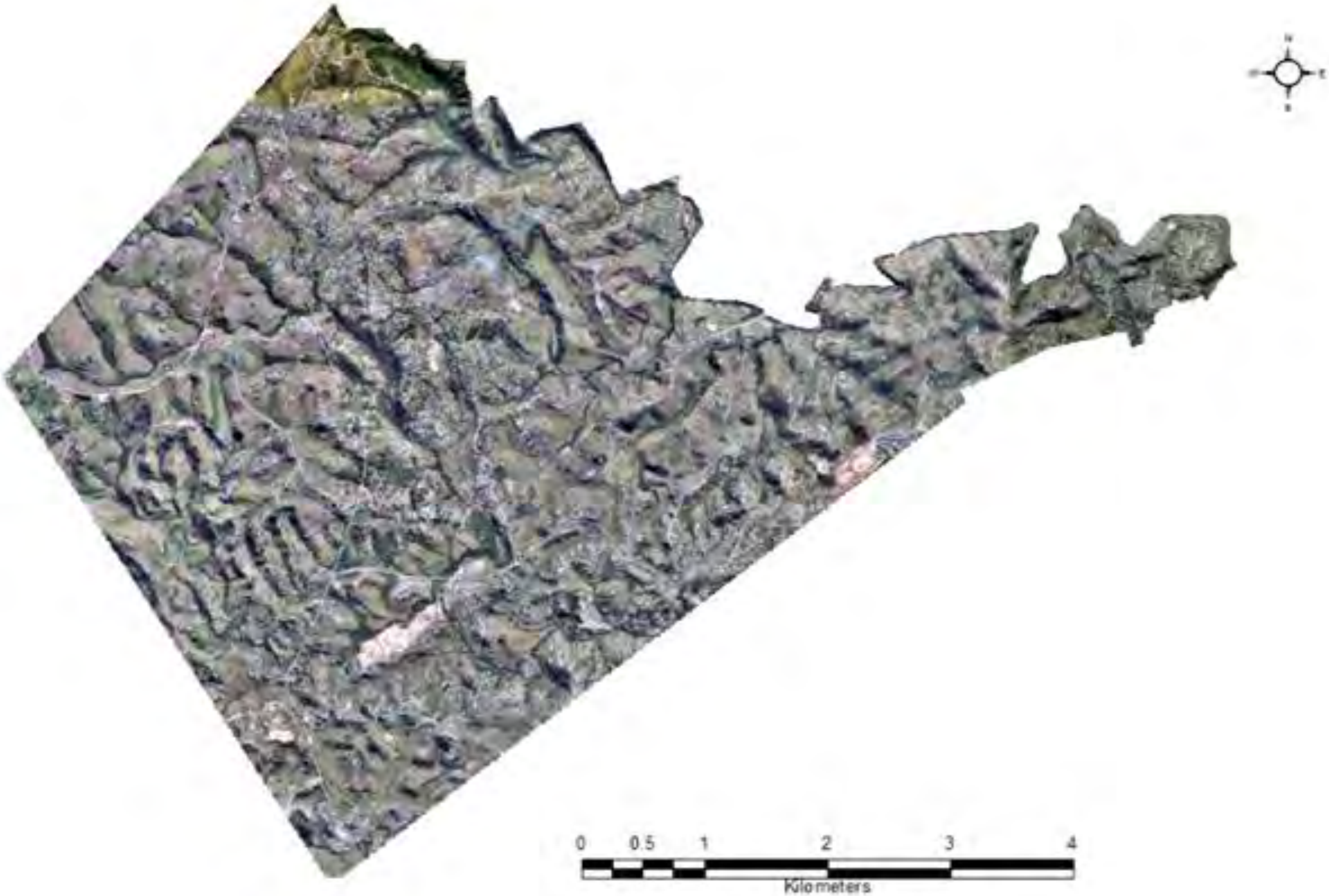


Figure A3: 2008 Orthorectified imagery of Adams Rural

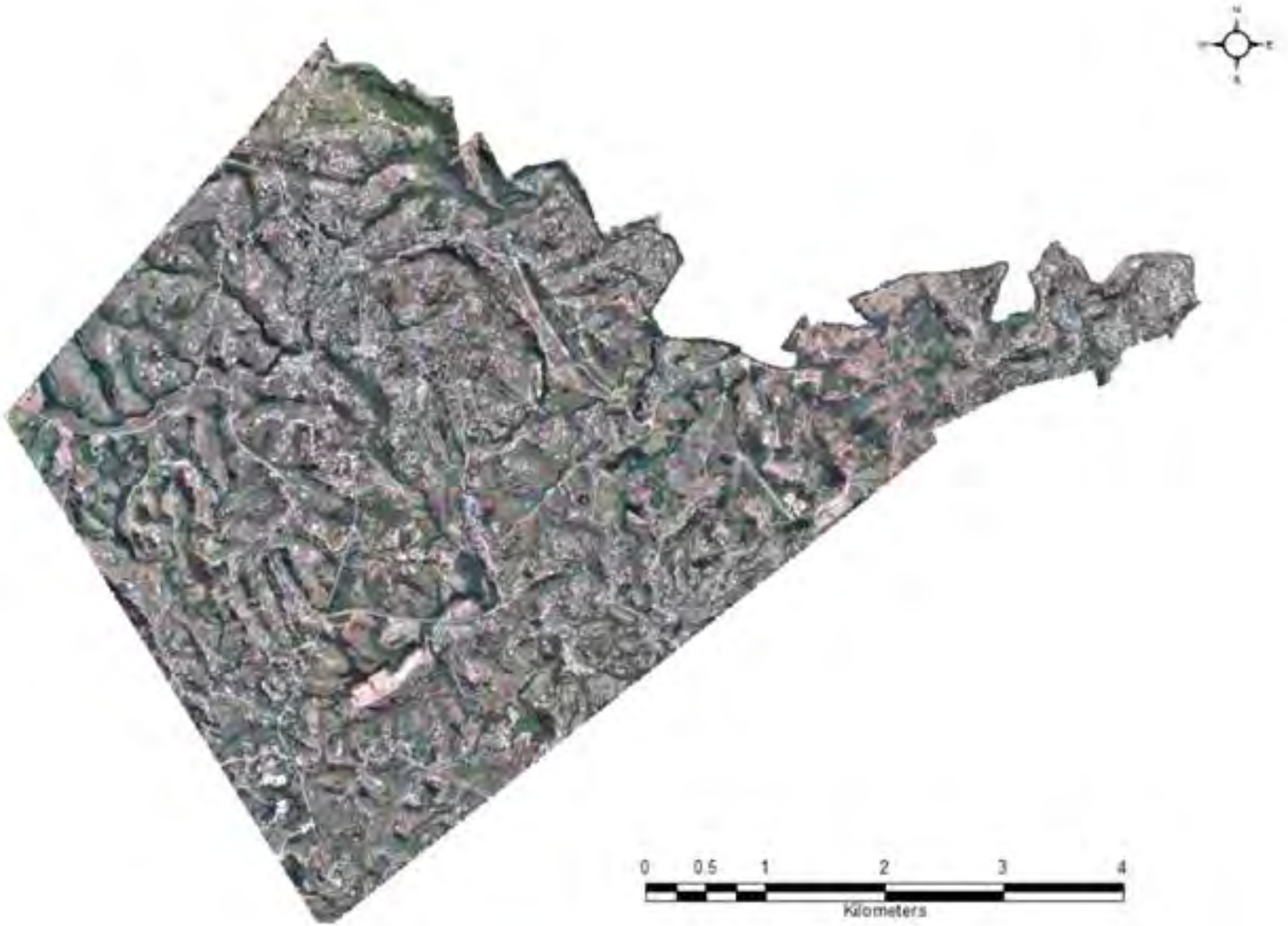


Figure A4: 2010 Orthorectified imagery of Adams Rural

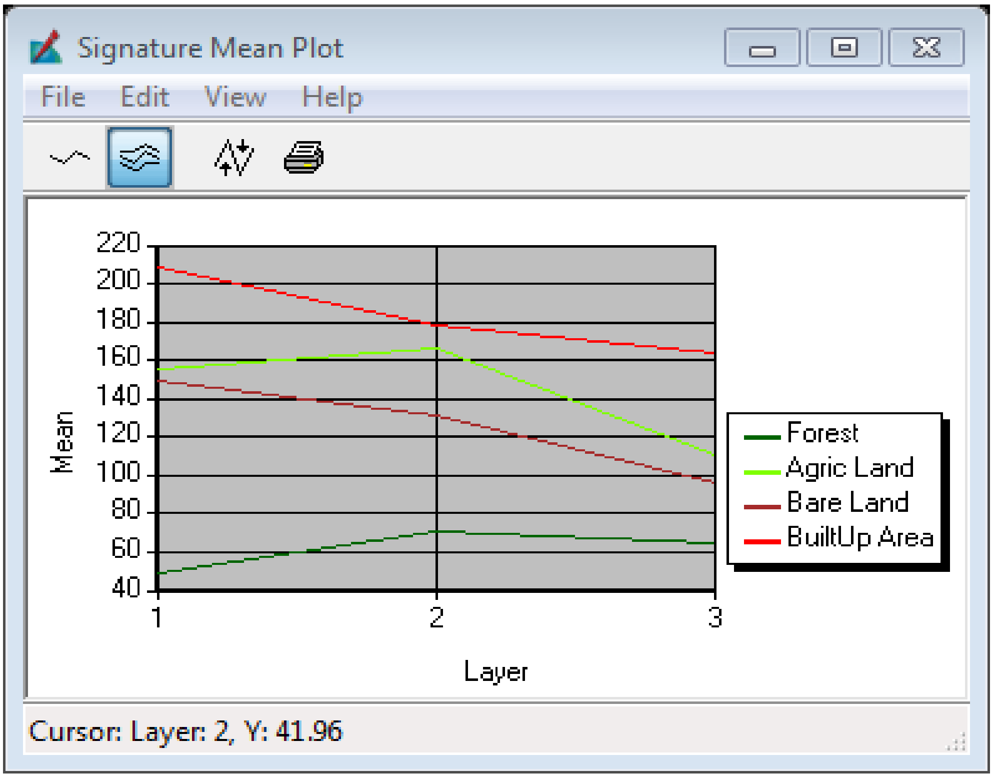
Figure A5: 2012 Orthorectified imagery of Adams Rural

Appendix B: Image Processing and Accuracy Assessment Result of 2004 Image.

- **Separability of the of the classes using Euclidean Distances**

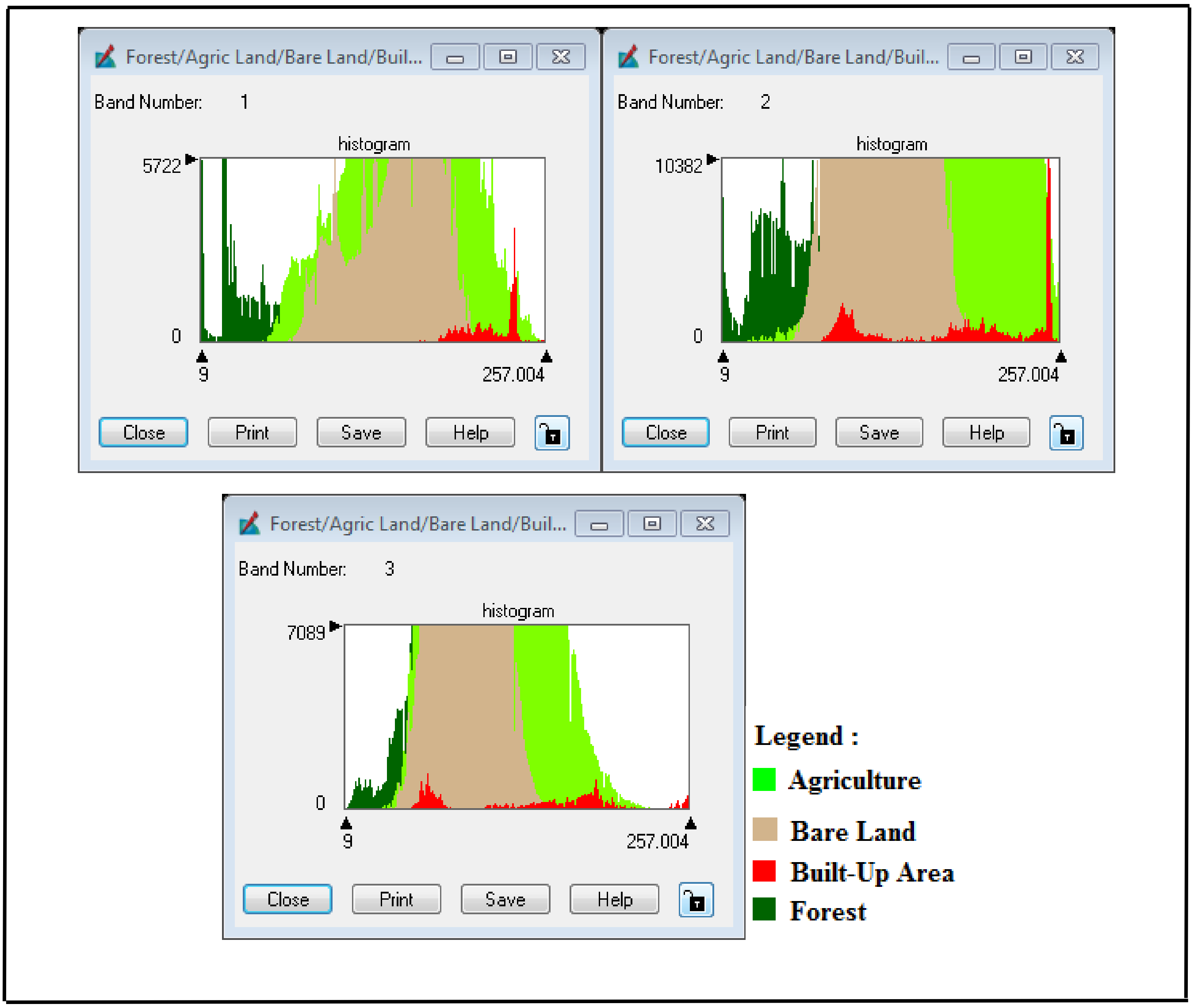
Separability Listing								
Bands	**Ave**	**Min**	**Class Pairs:**					
			1:2	**1:3**	**1: 4**	**2: 3**	**2: 4**	**3: 4**
1 2 3	117	39	150	120	216	39	76	102

Legend: 1 = Forest; 2 = Agriculture ; 3 = Bare Land; 4 = Built-Up Areas



- **Line graph representing the signature mean plot of 2004.**

Appendix B: Continued………………………



Pixel confusion histogram of all 4 classes on Band 1, Band 2 and Band 3 in 2004.

- **Contingency Matrix**

Reference Data

Classified Data	**Forest (%)**	**Agriculture (%)**	**Bare Land (%)**	**Built-Up Areas (%)**
Forest	97.13	2.55	0.08	0.27
Agriculture	2.54	85.45	3.88	5.45
Bare Land	0.26	10.16	94.23	1.24
Built-Up Areas	0.07	1.83	1.81	93.04

Reference Data

Classification Data	Forest	Bare Land	Agriculture	Built-Up Area	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Forest	**18**	**0**	**2**	**0**	**20**	**18**	**85.71%**	**90.00 %**
Bare Land	**0**	**26**	**0**	**4**	**30**	**26**	**92.86 %**	**86.67 %**
Agriculture	**3**	**0**	**39**	**0**	**41**	**39**	**95.12 %**	**92.86 %**
Built-Up Area	**0**	**2**	**0**	**10**	**12**	**10**	**71.43 %**	**83.33 %**
Reference Total	**21**	**28**	**41**	**14**				
Total		**100**		**100**		**100**		**100**

Appendix B: Continued………………………

Error Matrix for the classification of the orthorectified image for 2004.

Overall Classification Accuracy = 89.42%

- **KAPPA (K^) STATISTICS**

Overall Kappa Statistics = 0.8508

Conditional Kappa for each Category.

Class Name	**Kappa**
--------------	-------
Forest	0.8747
Bare Land	0.8175
Agriculture	0.8821
Built-Up Areas	0.8074

Appendix B: Continued……………………….

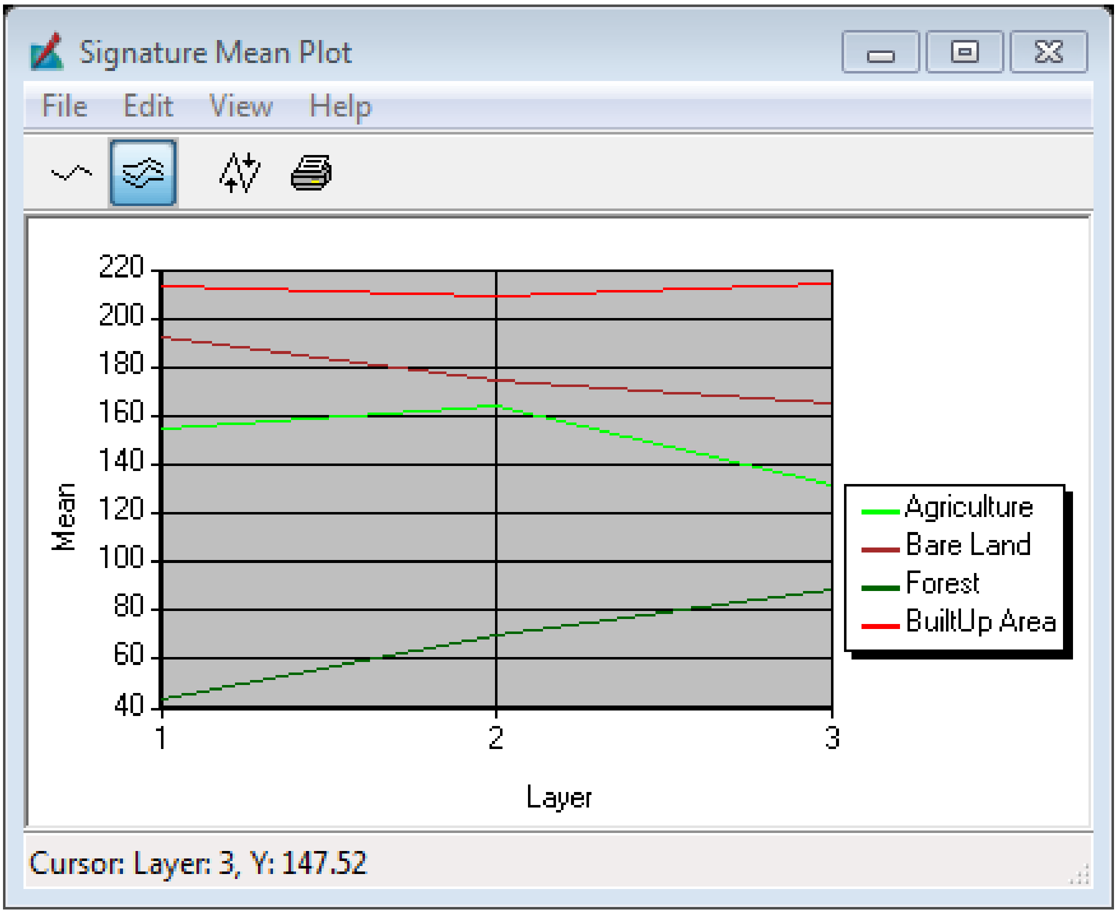
Land Use Cover Map of 2004

Appendix C Image processing and : Accuracy Assessment Result of 2006 Image.

- **Separability of the of the classes using Euclidean Distances**

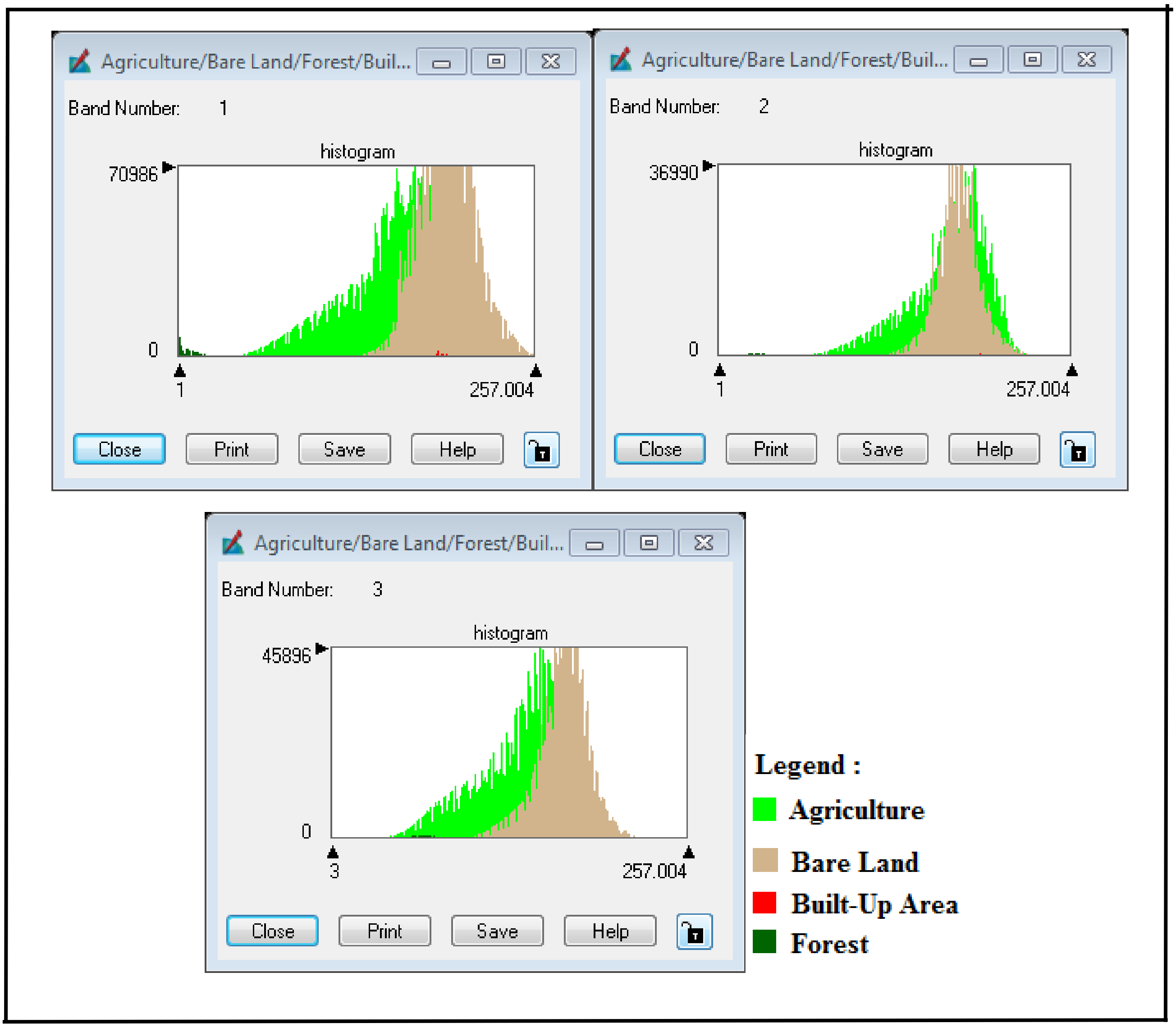
Separability Listing									
Bands			**Ave**	**Min**	**Class Pairs:**				
					1:2	**1:3**	**1: 4**	**2: 3**	**2: 4**	**3: 4**
1	**2**	**3**	138	52	52	152	110	198	63	253

Legend: 1 = Agriculture; 2 = Bare Land ; 3 = Forest; 4 = Built-Up Area



- **Line graph representing the signature mean plot of 2006.**

Appendix C: Continued……………………….



Pixel confusion histogram of all 4 classes on Band 1, Band 2 and Band 3 in 2006

- **Contingency Matrix**

Reference Data

Classified Data	**Agriculture (%)**	**Bare Land (%)**	**Forest (%)**	**Built-Up Areas (%)**
Agriculture	93.98	4.13	2.60	0.10
Bare Land	4.55	90.76	0.06	0.68
Forest	1.10	0.00	96.54	0.00
Built-Up Areas	0.37	5.11	0.79	99.22
Total	**100**	**100**	**100**	**100**

Appendix C: Continued……………………….

Error Matrix for the classification of the orthorectified image for 2006.

Reference Data

Classification Data	Forest	Built-Up Area	Bare Land	Agriculture	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Forest	**14**	**0**	**0**	**0**	**14**	**14**	**87.50 %**	**100.00 %**
Built-Up Area	**0**	**12**	**0**	**0**	**12**	**26**	**85.71 %**	**100.00 %**
Bare Land	**0**	**2**	**18**	**0**	**20**	**39**	**100.00 %**	**90.00 %**
Agriculture	**2**	**0**	**0**	**23**	**25**	**10**	**100.00 %**	**92.00 %**
Reference Total	**16**	**14**	**18**	**23**				

Overall Classification Accuracy = 94.37%

- KAPPA (K^) STATISTICS

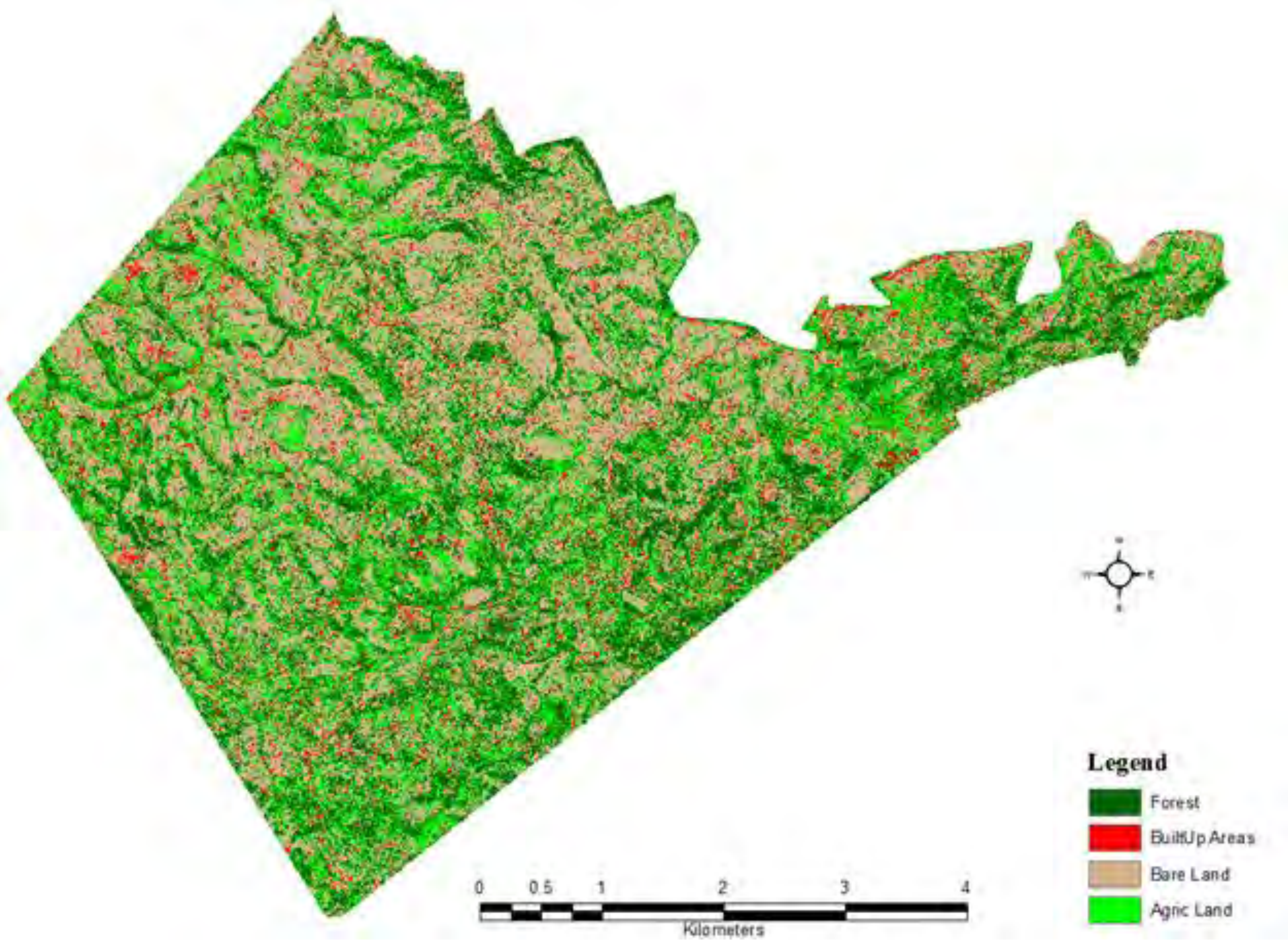
Overall Kappa Statistics = 0.9235

Conditional Kappa for each Category.

Class Name	**Kappa**
----------	---------
Forest	1.0000
Built-Up Area	1.0000
Bare Land	0.8660
Agriculture	0.8817

Appendix C: Continued……………………….

Land Use Cover Map of 2006

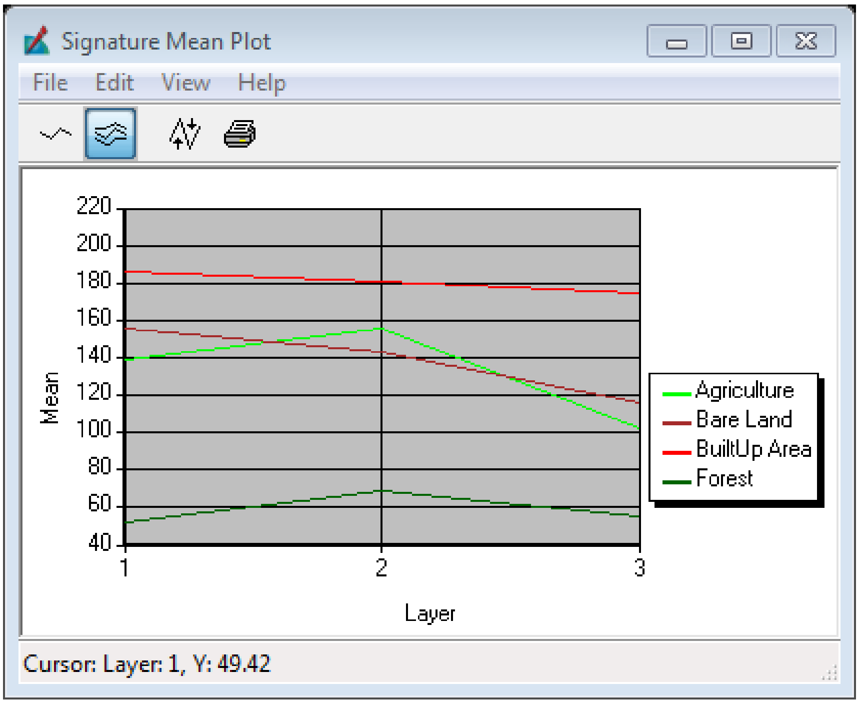


Appendix D: Image processing and Accuracy Assessment Result of 2008 Image.

- **Separability of the of the classes using Euclidean Distances**

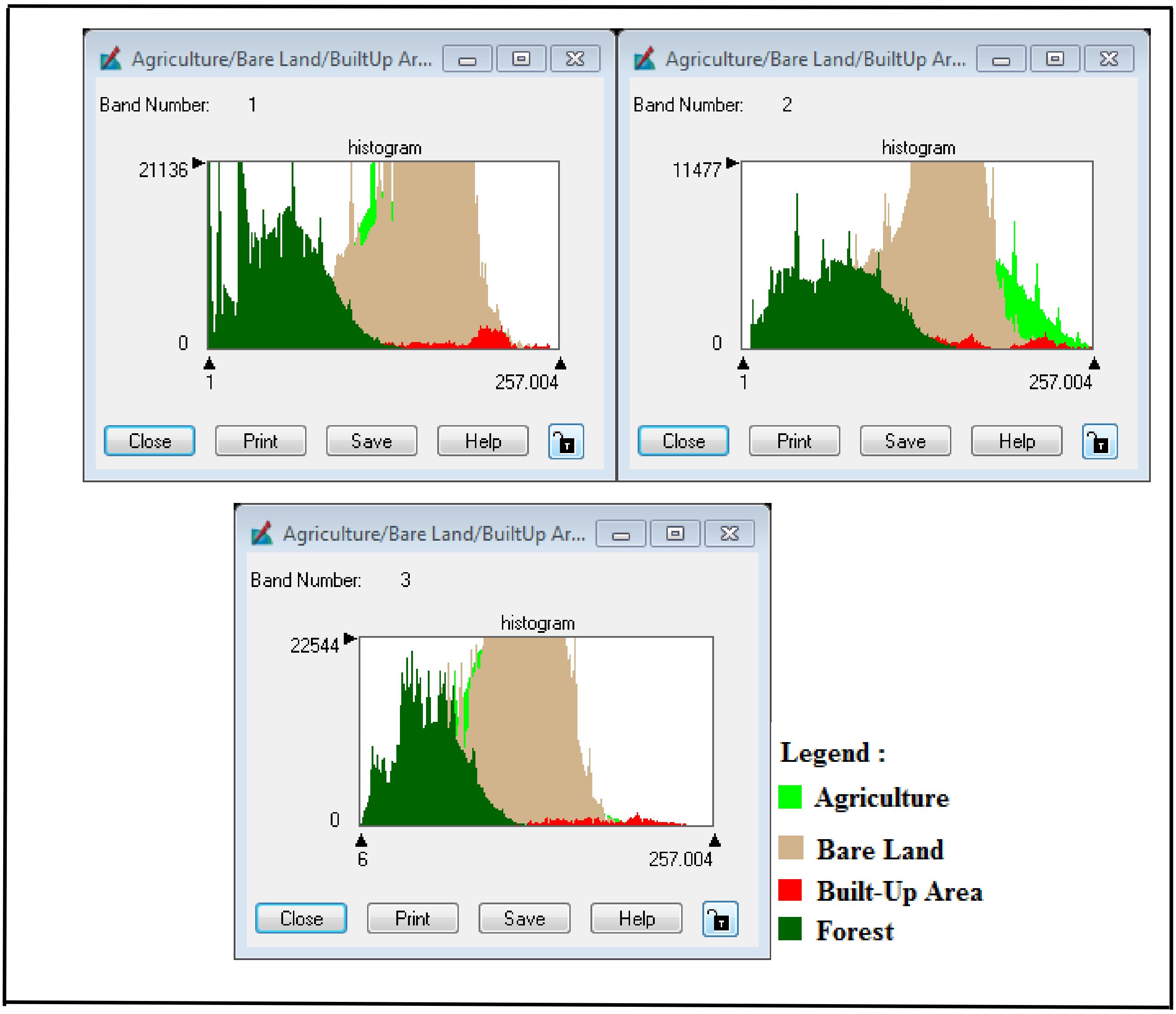
Separability Listing											
					Class Pairs:						
Bands			**Ave**	**Min**	**1:2**	**1:3**	**1: 4**	**2: 3**	**2: 4**	**3: 4**
1	**2**	**3**	112	25	25	89	132	75	141	211

Legend: 1 = Agriculture; 2 = Bare Land ; 3 = Built-Up Area; 4 = Forest



Line graph representing the signature mean plot of 2008

Appendix D: Continued……………………….



Pixel confusion histogram of all 4 classes on Band 1, Band 2 and Band 3 in 2008.

- **Contingency Matrix**

Reference Data

Classified Data	**Agriculture (%)**	**Bare Land (%)**	**Built-Up Areas (%)**	**Forest (%)**
Agriculture	87.14	4.56	0.02	5.70
Bare Land	7.19	90.06	0.29	1.21
Built-Up Areas	0.23	4.60	99.67	0.12
Forest	5.44	0.77	0.01	92.12
Total	**100**	**100**	**100**	**100**

Appendix D: Continued………………………

Error Matrix for the classification of the orthorectified image for 2008.

Reference Data

Classification Data

	Built-Up Area	Bare Land	Forest	Agriculture	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Built-Up Area	**5**	**0**	**0**	**0**	**5**	**5**	**100.00 %**	**100.00 %**
Bare Land	**0**	**15**	**2**	**0**	**17**	**15**	**88.24 %**	**88.24 %**
Forest	**0**	**2**	**16**	**0**	**18**	**16**	**88.89 %**	**88.89 %**
Agriculture	**0**	**0**	**0**	**13**	**13**	**13**	**100.00 %**	**100.00 %**
Reference Total	**5**	**17**	**18**	**13**				

Overall Classification Accuracy = 92.45 %

- KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8941

Conditional Kappa for each Category.

Class Name	**Kappa**
----------	---------
Forest	0.8317
Built-Up Area	1.0000
Bare Land	0.8268
Agriculture	1.0000

Appendix D: Continued……………………….

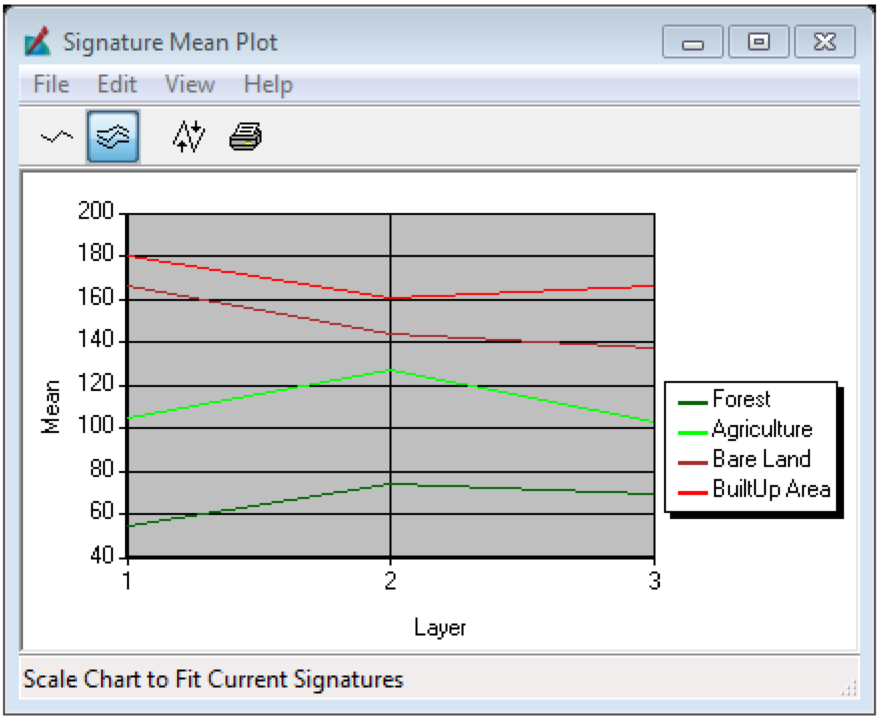
Land Use Cover Map of 2008

Appendix E: Image processing and Accuracy Assessment Result of 2010 Image.

- **Separability of the of the classes using Euclidean Distances**

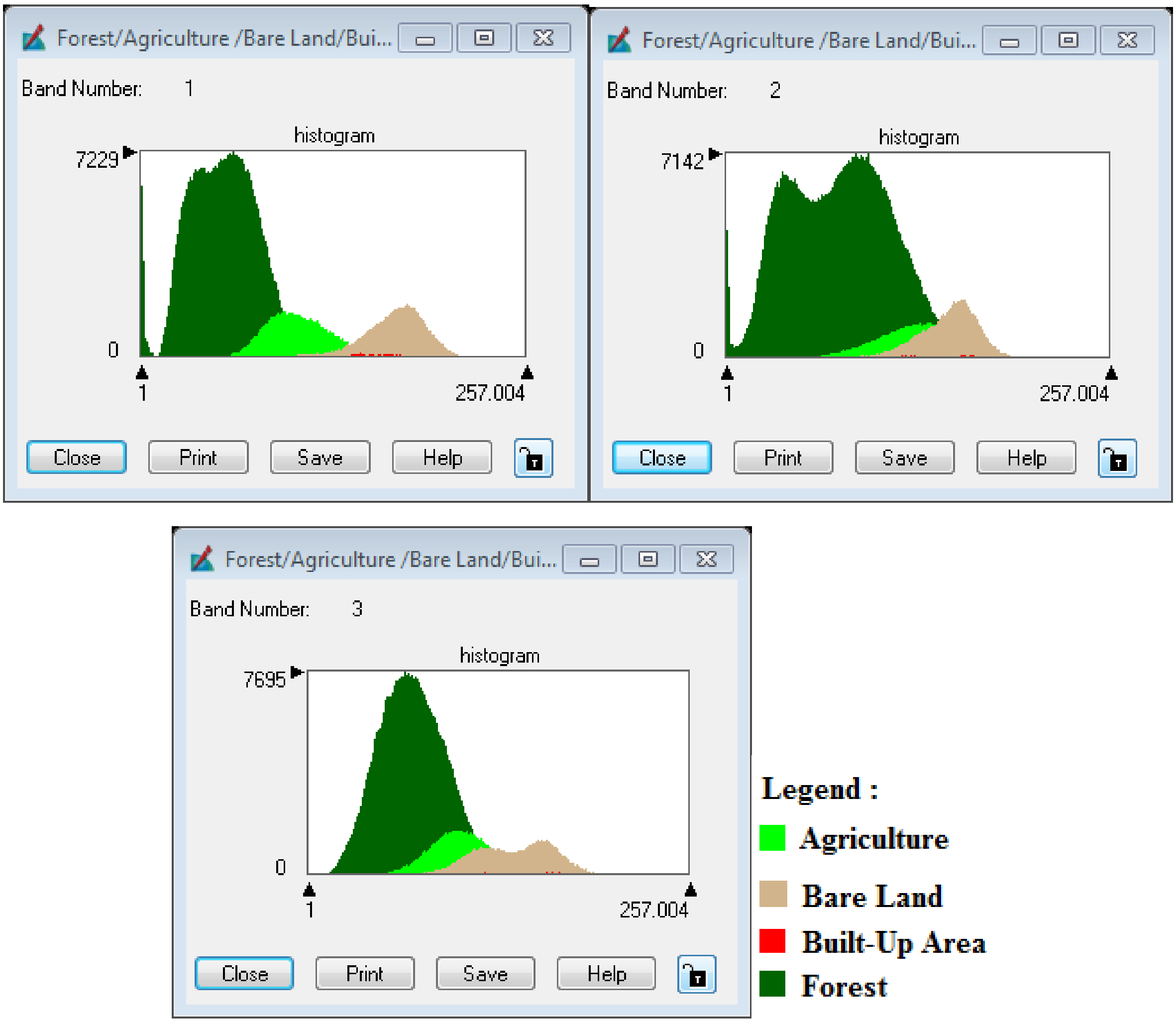
Separability Listing								
Bands	Ave	Min	Class Pairs:					
			1:2	1:3	1: 4	2: 3	2: 4	3: 4
1 2 3	104	36	80	148	181	72	104	36

Legend: 1 = Forest; 2 = Agriculture ; 3 = Bare Land; 4 = Built-Up Area



Line graph representing the signature mean plot of 2010

Appendix E: Continued………………………



Pixel confusion histogram of all 4 classes on Band 1, Band 2 and Band 3 in 2010.

- **Contingency Matrix**

Reference Data

Classified Data	**Forest (%)**	**Agriculture (%)**	**Bare Land (%)**	**Built-Up Area (%)**
Forest	92.58	9.53	0.00	0.02
Agriculture	8.23	88.40	3.401	0.13
Bare Land	0.00	1.73	90.91	12.92
Built-Up Area	0.18	0.33	5.69	86.93
Total	**100**	**100**	**100**	**100**

Appendix E: Continued……………………….

Error Matrix for the classification of the orthorectified image for 2010.

Reference Data

Classification Data

	Built-Up Area	Bare Land	Forest	Agriculture	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Built-Up Area	**13**	**1**	**0**	**0**	**13**	**13**	**92.86 %**	**92.86 %**
Bare Land	**1**	**13**	**0**	**0**	**14**	**13**	**92.86 %**	**92.86 %**
Forest	**0**	**0**	**20**	**0**	**20**	**20**	**100.00 %**	**100.00 %**
Agriculture	**0**	**0**	**0**	**26**	**26**	**26**	**100.00 %**	**100.00 %**
Reference Total	**14**	**14**	**20**	**26**				

Overall Classification Accuracy = 97.30 %

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.9631

Conditional Kappa for each Category.

Class Name	**Kappa**
Agriculture	1.0000
Forest	1.0000
Bare Land	0.9119
BuiltUp Areas	0.9119

Appendix E: Continued………………………..

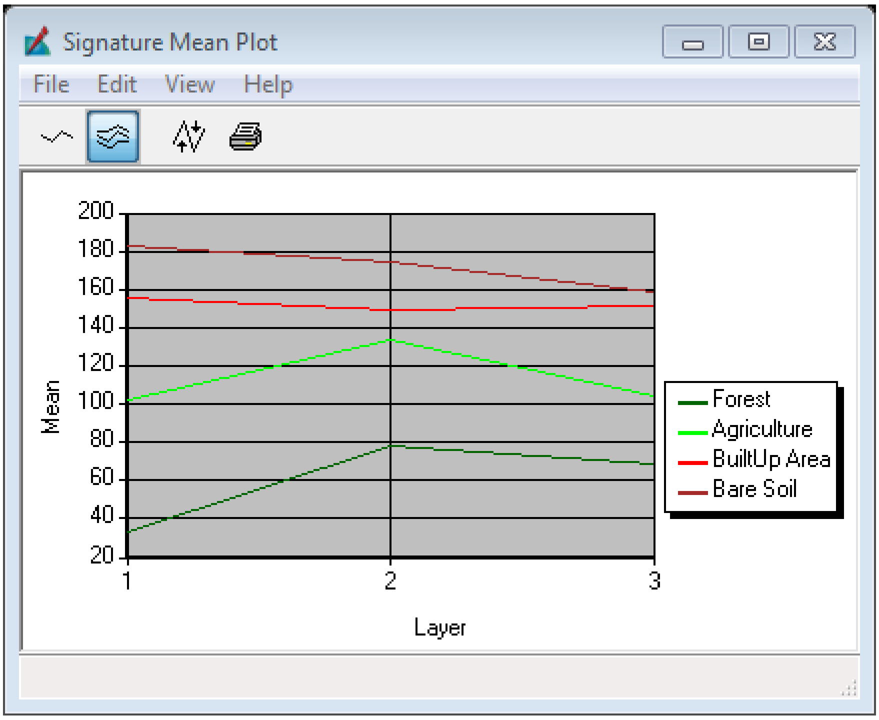
Land Use Cover Map of 2010

Appendix F: Image processing and Accuracy Assessment Result of 2012 Image.

- **Separability of the of the classes using Euclidean Distances**

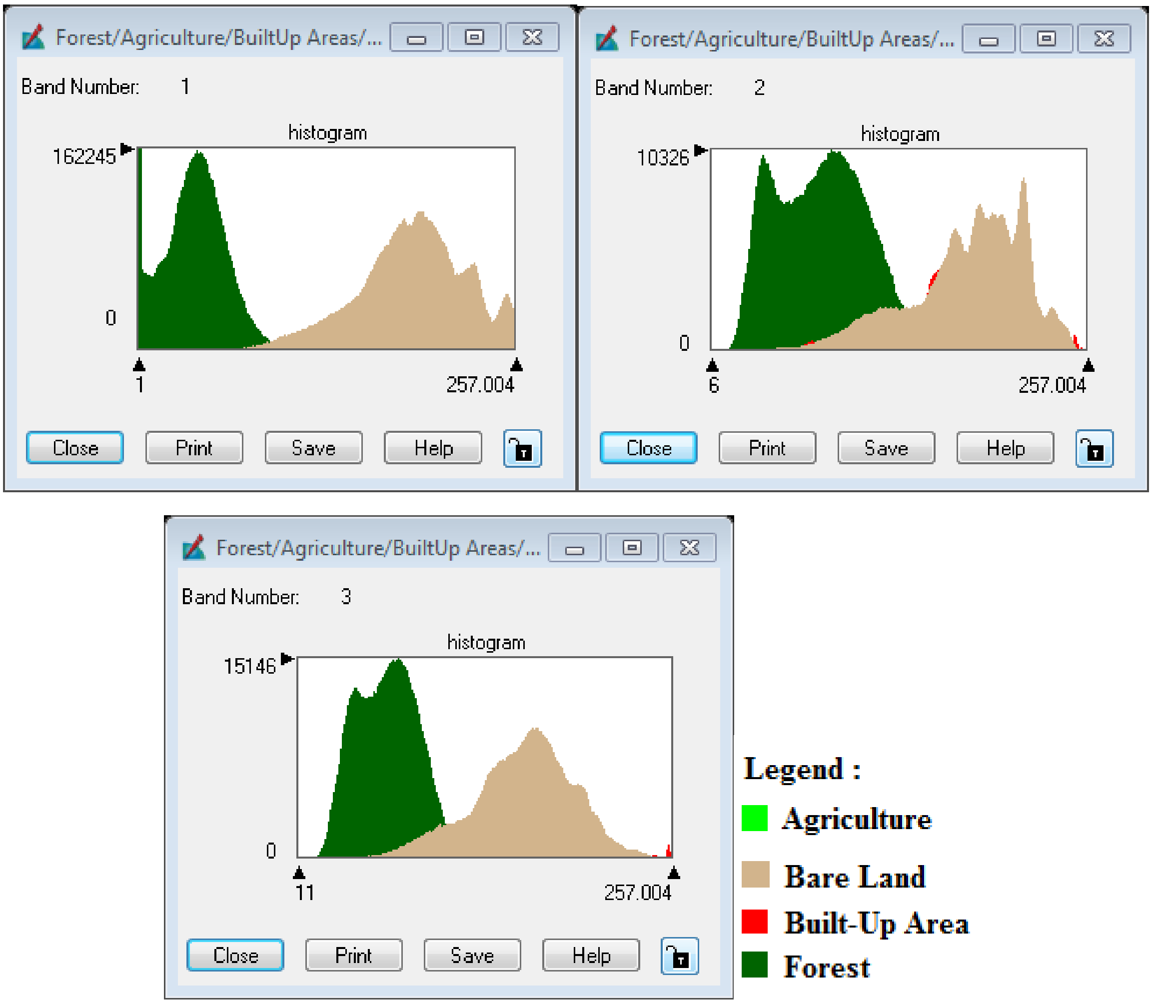
Separability Listing								
Bands	**Ave**	**Min**	**Class Pairs:**					
			1:2	**1:3**	**1: 4**	**2: 3**	**2: 4**	**3: 4**
1 2 3	113	41	47	136	136	79	167	208

Legend: 1 = Agriculture; 2 = Bare Land ; 3 = Forest; 4 = Built-Up Area



Line graph representing the signature mean plot of 2012

Appendix F: Continued………………………



Pixel confusion histogram of all 4 classes on Band 1, Band 2 and Band 3 in 2012.

- **Contingency Matrix**

Reference Data

Classified Data	**Agriculture (%)**	**Bare Land (%)**	**Forest s (%)**	**Built-Up Area (%)**
Agriculture	89.58	1.36	6.88	0.02
Bare Land	2.82	90.71	0.09	0.13
Forest	5.77	0.00	92.93	12.92
Built-Up Area	1.56	7.92	0.10	86.93
Total	**100**	**100**	**100**	**100**

Appendix F: Continued……………………….

Error Matrix for the classification of the orthorectified image for 2012.

Reference Data

Classification Data

	Built-Up Area	Bare Land	Forest	Agriculture	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Built-Up Area	**7**	**0**	**0**	**0**	**7**	**7**	**87.50%**	**100.00 %**
Bare Land	**1**	**15**	**0**	**1**	**17**	**15**	**100.00 %**	**88.24 %**
Forest	**0**	**0**	**16**	**0**	**16**	**16**	**94.12 %**	**100.00 %**
Agriculture	**0**	**0**	**1**	**32**	**33**	**32**	**96.97 %**	**96.97%**
Reference Total	**0**	**15**	**17**	**33**				

Overall Classification Accuracy = 95.89 %

KAPPA (K^) STATISTICS

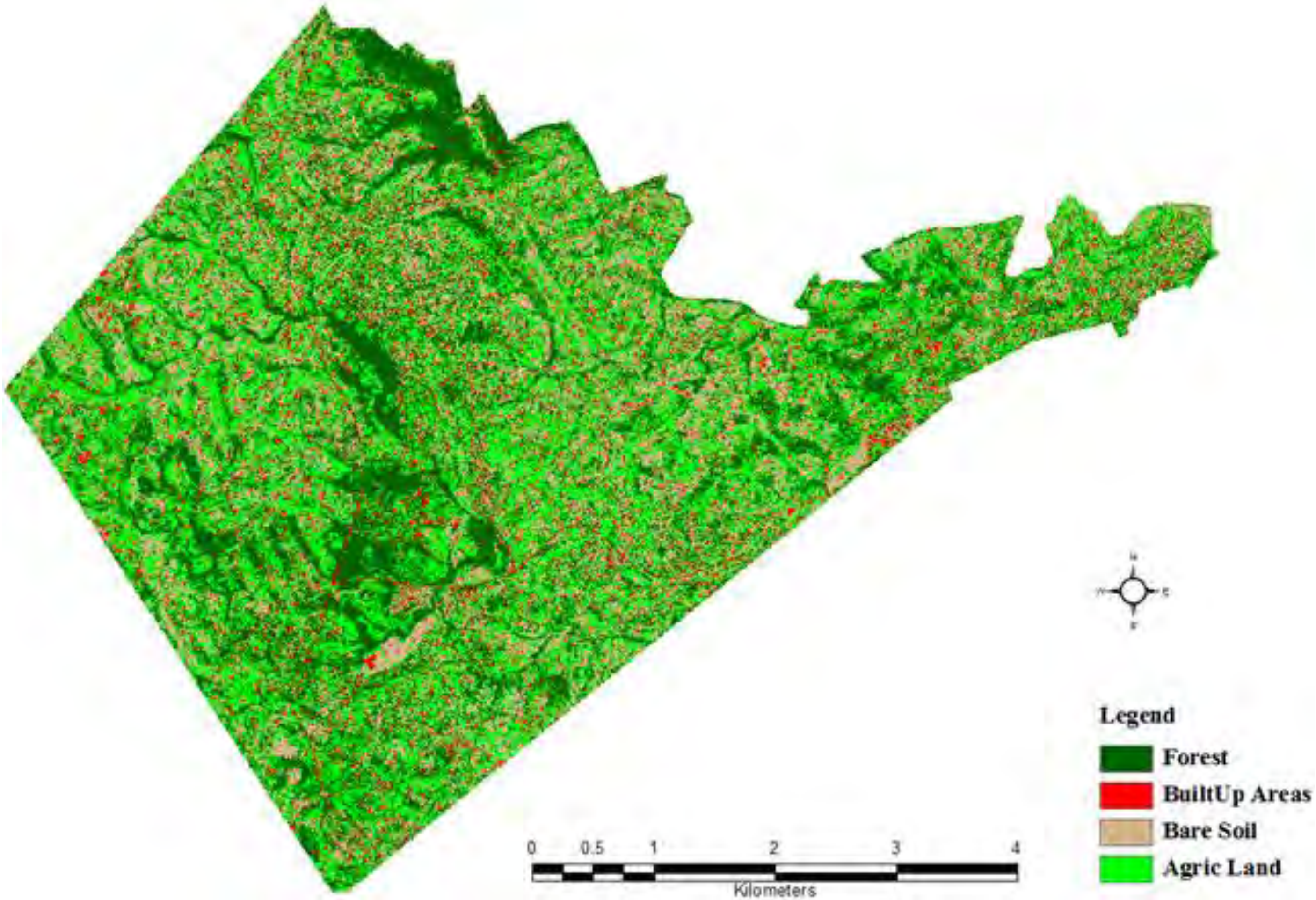
Overall Kappa Statistics = 0.9401

Conditional Kappa for each Category.

Class Name	Kappa
Agriculture	0.9447
Forest	1.0000
Bare Land	0.8519
BuiltUp Areas	1.0000

Appendix F: Continued……………………….

Land Use Cover Map of 2012

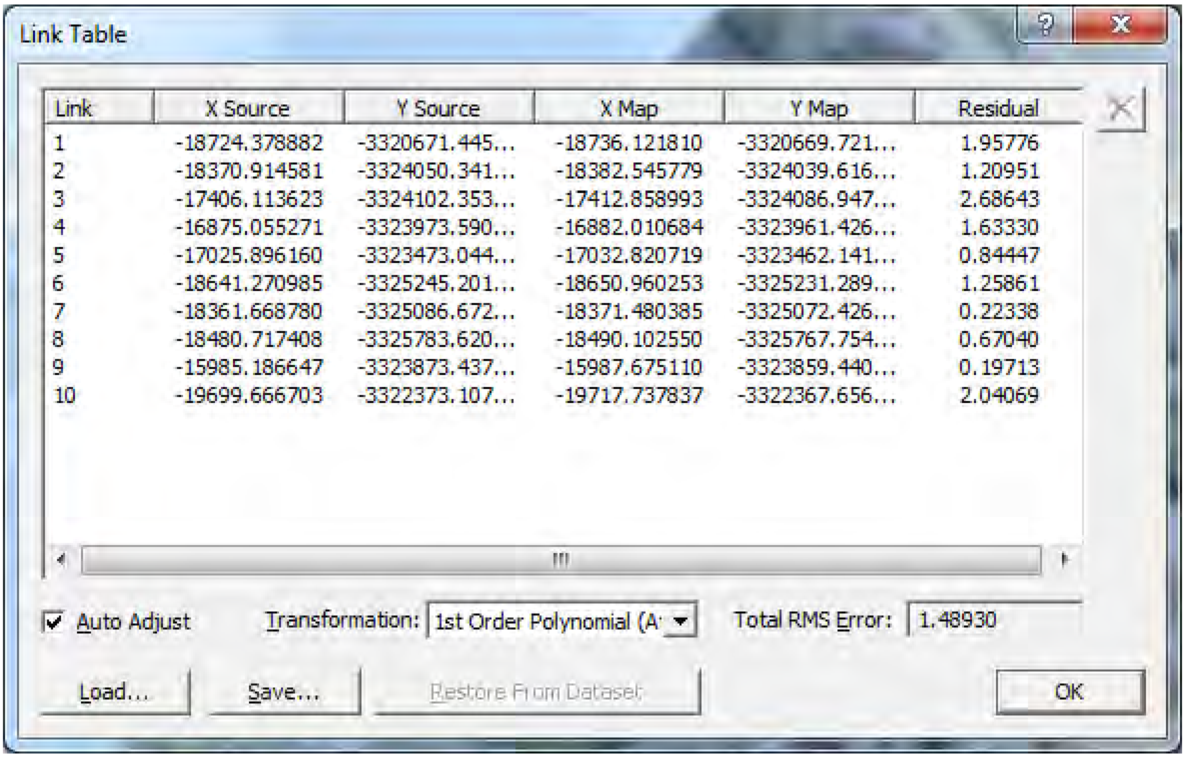


Appendix G – Comparison between random selected Topographic Map coordinates and images coordinates for 2004, 2006, 2008, 2010 and 2012

2004

	Image					Map		Relative Accuracy	
Name	**Y**	**X**	**DY**	**DX**	**DS**	**Y**	**X**	**Y**	**X**
1	19028.62	3320896.55	0.38	0.96	1.04	19029.00	3320897.52	**99.998**	**100.000**
2	18735.40	3320670.12	0.72	-0.40	0.83	18736.12	3320669.72	**99.996**	**100.000**
3	19651.60	3322319.92	0.36	0.17	0.40	19651.96	3322320.09	**99.998**	**100.000**
4	18382.46	3324039.51	0.09	0.10	0.14	18382.55	3324039.62	**100.000**	**100.000**
5	18651.01	3325232.01	-0.05	-0.72	0.72	18650.96	3325231.29	**100.000**	**100.000**
6	18371.23	3325072.22	0.26	0.21	0.33	18371.48	3325072.43	**99.999**	**100.000**
7	17412.73	3324086.56	0.13	0.39	0.41	17412.86	3324086.95	**99.999**	**100.000**
8	16881.73	3323962.32	0.29	-0.90	0.94	16882.01	3323961.43	**99.998**	**100.000**
9	15988.56	3323860.63	-0.88	-1.19	1.48	15987.68	3323859.44	**100.006**	**100.000**
10	17032.53	3323462.60	0.29	-0.46	0.54	17032.82	3323462.14	**99.998**	**100.000**

Root Mea Squere.



Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	-18724.378882	-3320671.445...	-18736.121810	-3320669.721...	1.95776
2	-18370.914581	-3324050.341...	-18382.545779	-3324039.616...	1.20951
3	-17406.113623	-3324102.353...	-17412.858993	-3324086.947...	2.68643
4	-16875.055271	-3323973.590...	-16882.010684	-3323961.426...	1.63330
5	-17025.896160	-3323473.044...	-17032.820719	-3323462.141...	0.84447
6	-18641.270985	-3325245.201...	-18650.960253	-3325231.289...	1.25861
7	-18361.668780	-3325086.672...	-18371.480385	-3325072.426...	0.22338
8	-18480.717408	-3325783.620...	-18490.102550	-3325767.754...	0.67040
9	-15985.186647	-3323873.437...	-15987.675110	-3323859.440...	0.19713
10	-19699.666703	-3322373.107...	-19717.737837	-3322367.656...	2.04069

Auto Adjust Transformation: 1st Order Polynomial (A Total RMS Error: 1.48930

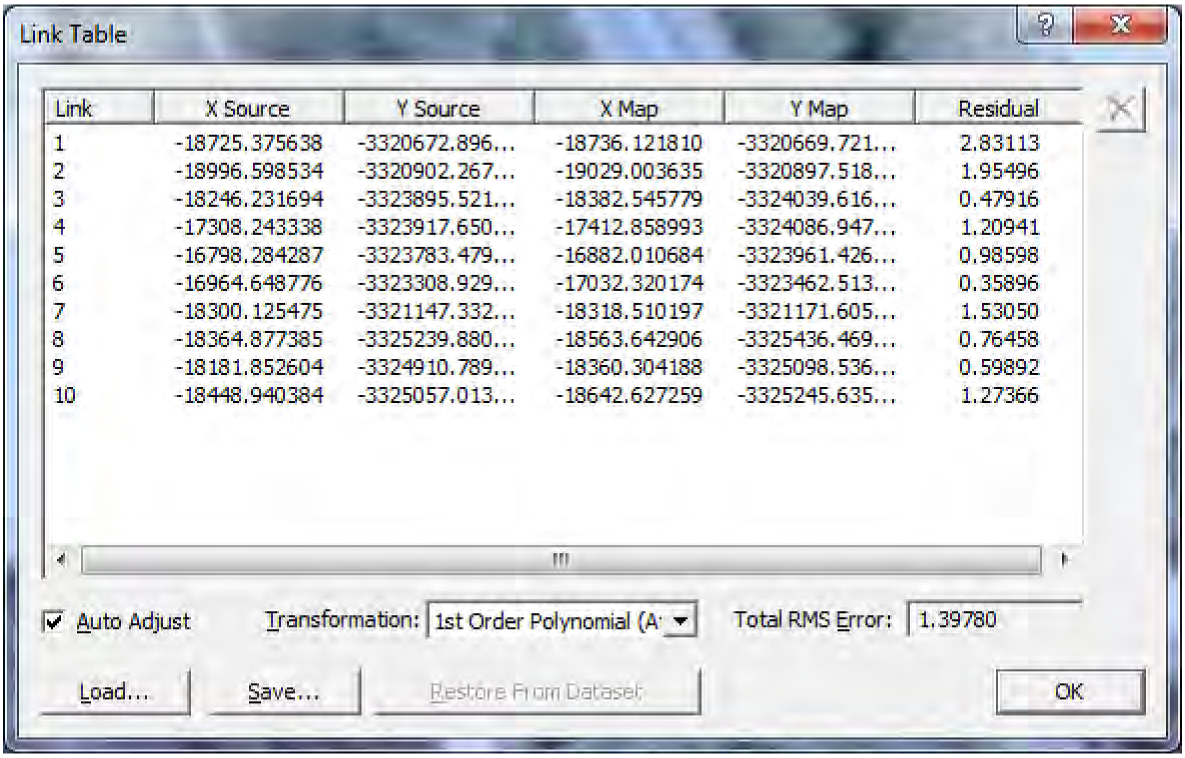
Load... Save... Restore From Dataset OK

Appendix g: Continued……………………….

2006

	Image					Map		Relative Accuracy	
Name	Y	X	DY	DX	DS	Y	X	Y	X
1	19028.493	3320896.323	0.511	1.195	1.300	19029.004	3320897.518	**99.9973**	**100.0000**
2	18735.785	3320670.360	0.337	-0.639	0.722	18736.122	3320669.721	**99.9982**	**100.0000**
3	19651.596	3322319.920	0.363	0.167	0.399	19651.959	3322320.087	**99.9982**	**100.0000**
4	18382.456	3324039.512	0.090	0.105	0.138	18382.546	3324039.617	**99.9995**	**100.0000**
5	18650.910	3325231.890	0.050	-0.601	0.603	18650.960	3325231.289	**99.9997**	**100.0000**
6	18371.225	3325072.221	0.255	0.206	0.328	18371.480	3325072.427	**99.9986**	**100.0000**
7	17412.730	3324086.558	0.129	0.389	0.410	17412.859	3324086.947	**99.9993**	**100.0000**
8	16881.512	3323962.007	0.499	-0.581	0.765	16882.011	3323961.426	**99.9970**	**100.0000**
9	15988.490	3323860.120	-0.815	-0.679	1.061	15987.675	3323859.441	**100.0051**	**100.0000**
10	17032.104	3323462.007	0.717	0.134	0.729	17032.821	3323462.141	**99.9958**	**100.0000**

RMSE


Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	-18725.375638	-3320672.896...	-18736.121810	-3320669.721...	2.83113
2	-18996.598534	-3320902.267...	-19029.003635	-3320897.518...	1.95496
3	-18246.231694	-3323895.521...	-18382.545779	-3324039.616...	0.47916
4	-17308.243338	-3323917.650...	-17412.858993	-3324086.947...	1.20941
5	-16798.284287	-3323783.479...	-16882.010684	-3323961.426...	0.98598
6	-16964.648776	-3323308.929...	-17032.320174	-3323462.513...	0.35896
7	-18300.125475	-3321147.332...	-18318.510197	-3321171.605...	1.53050
8	-18364.877385	-3325239.880...	-18563.642906	-3325436.469...	0.76458
9	-18181.852604	-3324910.789...	-18360.304188	-3325098.536...	0.59892
10	-18448.940384	-3325057.013...	-18642.627259	-3325245.635...	1.27366

Auto Adjust Transformation: 1st Order Polynomial (A Total RMS Error: 1.39780

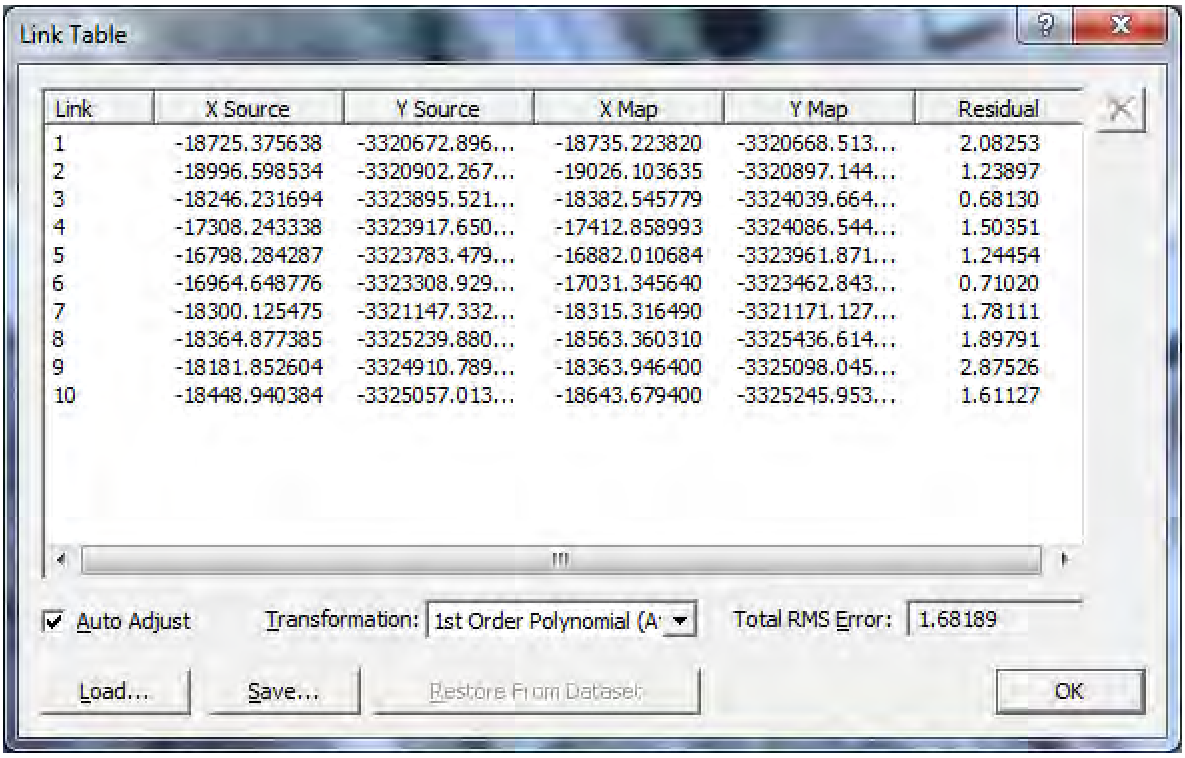
Load... Save... Restore From Dataset OK

Appendix F: Continued………………………

2008

Name	Image		Differences			Map		Relative Accuracy	
	Y	X	DY	DX	DS	Y	X	Y	X
1	19028.76	3320897.51	0.25	0.01	1.30	19029.00	3320897.52	**99.997**	**100.000**
2	18735.79	3320670.36	0.34	-0.64	0.72	18736.12	3320669.72	**99.998**	**100.000**
3	19651.60	3322319.92	0.36	0.17	0.40	19651.96	3322320.09	**99.998**	**100.000**
4	18382.32	3324039.74	0.22	-0.12	0.14	18382.55	3324039.62	**100.000**	**100.000**
5	18650.91	3325231.40	0.05	-0.11	0.60	18650.96	3325231.29	**100.000**	**100.000**
6	18371.94	3325072.22	-0.45	0.21	0.33	18371.48	3325072.43	**99.999**	**100.000**
7	17412.78	3324086.96	0.08	-0.01	0.41	17412.86	3324086.95	**99.999**	**100.000**
8	16881.61	3323962.55	0.40	-1.13	0.94	16882.01	3323961.43	**99.998**	**100.000**
9	15988.11	3323860.55	-0.43	-1.11	1.48	15987.68	3323859.44	**100.006**	**100.000**
10	17032.78	3323462.42	0.04	-0.28	0.54	17032.82	3323462.14	**99.998**	**100.000**

RMSE


Link Table

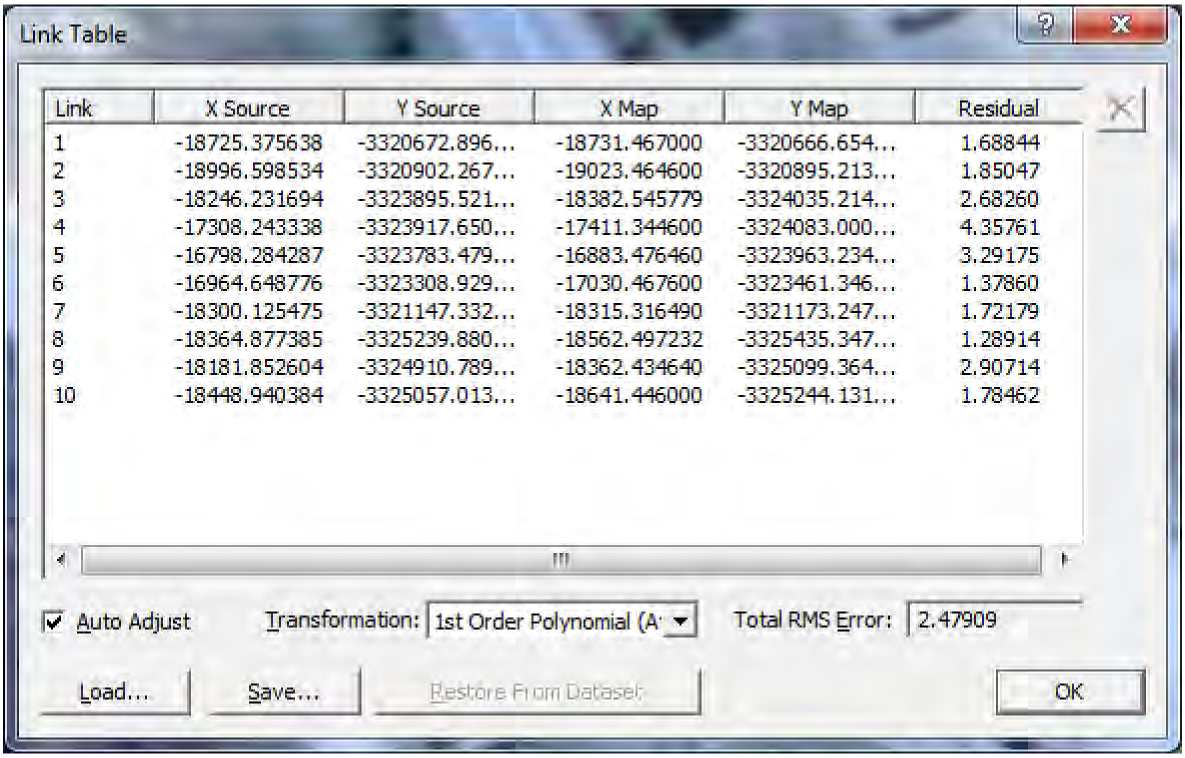
Link	X Source	Y Source	X Map	Y Map	Residual
1	-18725.375638	-3320672.896...	-18735.223820	-3320668.513...	2.08253
2	-18996.598534	-3320902.267...	-19026.103635	-3320897.144...	1.23897
3	-18246.231694	-3323895.521...	-18382.545779	-3324039.664...	0.68130
4	-17308.243338	-3323917.650...	-17412.858993	-3324086.544...	1.50351
5	-16798.284287	-3323783.479...	-16882.010684	-3323961.871...	1.24454
6	-16964.648776	-3323308.929...	-17031.345640	-3323462.843...	0.71020
7	-18300.125475	-3321147.332...	-18315.316490	-3321171.127...	1.78111
8	-18364.877385	-3325239.880...	-18563.360310	-3325436.614...	1.89791
9	-18181.852604	-3324910.789...	-18363.946400	-3325098.045...	2.87526
10	-18448.940384	-3325057.013...	-18643.679400	-3325245.953...	1.61127

Appendix F: Continued……………………….

2010

	Image					Map		Relative Accuracy	
Name	Y	X	DY	DX	DS	Y	X	Y	X
1	19029.210	3320897.121	-0.206	0.397	0.448	19029.004	3320897.518	**100.0011**	**100.0000**
2	18737.000	3320670.123	-0.878	-0.402	0.966	18736.122	3320669.721	**100.0047**	**100.0000**
3	19652.108	3322319.323	-0.149	0.764	0.779	19651.959	3322320.087	**100.0008**	**100.0000**
4	18381.797	3324038.630	0.749	0.987	1.239	18382.546	3324039.617	**99.9959**	**100.0000**
5	18651.460	3325232.269	-0.500	-0.980	1.100	18650.960	3325231.289	**100.0027**	**100.0000**
6	18371.230	3325071.980	0.250	0.447	0.512	18371.480	3325072.427	**99.9986**	**100.0000**
7	17412.987	3324087.000	-0.128	-0.053	0.138	17412.859	3324086.947	**100.0007**	**100.0000**
8	16882.260	3323964.402	-0.249	-2.976	2.986	16882.011	3323961.426	**100.0015**	**100.0001**
9	15987.202	3323862.332	0.473	-2.891	2.930	15987.675	3323859.441	**99.9970**	**100.0001**

RMSE

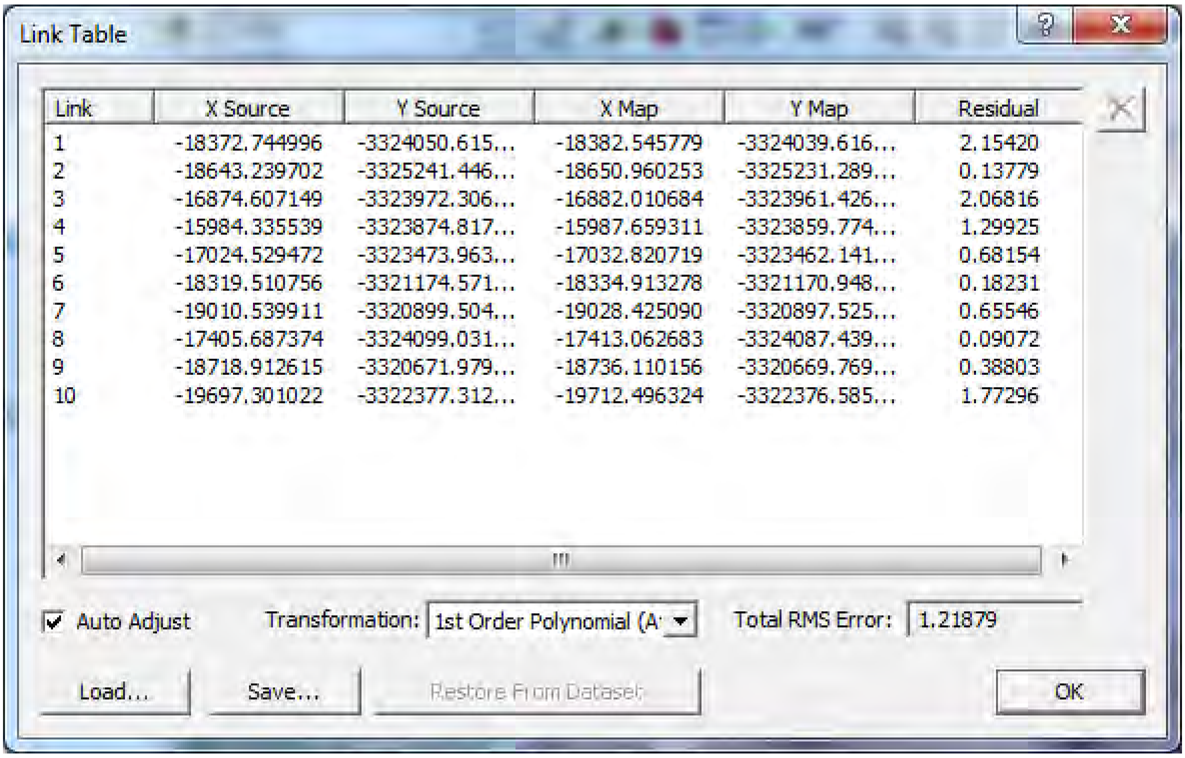


Appendix F: Continued………………………

2012

	Image					Map		Relative Accuracy	
Name	**Y**	**X**	**DY**	**DX**	**DS**	**Y**	**X**	**Y**	**X**
1	19029.985	3320897.301	-0.981	0.217	1.005	19029.004	3320897.518	**100.0052**	**100.0000**
2	18736.130	3320670.419	-0.008	-0.698	0.698	18736.122	3320669.721	**100.0000**	**100.0000**
3	19652.022	3322319.966	-0.063	0.121	0.137	19651.959	3322320.087	**100.0003**	**100.0000**
4	18382.230	3324039.120	0.316	0.497	0.588	18382.546	3324039.617	**99.9983**	**100.0000**
5	18651.230	3325232.269	-0.270	-0.980	1.016	18650.960	3325231.289	**100.0014**	**100.0000**
6	18371.225	3325072.221	0.255	0.206	0.328	18371.480	3325072.427	**99.9986**	**100.0000**
7	17412.730	3324086.558	0.129	0.389	0.410	17412.859	3324086.947	**99.9993**	**100.0000**
8	16881.725	3323962.322	0.286	-0.896	0.940	16882.011	3323961.426	**99.9983**	**100.0000**
9	15987.550	3323859.530	0.125	-0.089	1.482	15987.675	3323859.441	**100.0055**	**100.0000**
10	17032.230	**3323462.630**	0.591	-0.489	0.543	17032.821	3323462.141	**99.9983**	**100.0000**

RMSE



Link Table

Link	X Source	Y Source	X Map	Y Map	Residual
1	-18372.744996	-3324050.615…	-18382.545779	-3324039.616…	2.15420
2	-18643.239702	-3325241.446…	-18650.960253	-3325231.289…	0.13779
3	-16874.607149	-3323972.306…	-16882.010684	-3323961.426…	2.06816
4	-15984.335539	-3323874.817…	-15987.659311	-3323859.774…	1.29925
5	-17024.529472	-3323473.963…	-17032.820719	-3323462.141…	0.68154
6	-18319.510756	-3321174.571…	-18334.913278	-3321170.948…	0.18231
7	-19010.539911	-3320899.504…	-19028.425090	-3320897.525…	0.65546
8	-17405.687374	-3324099.031…	-17413.062683	-3324087.439…	0.09072
9	-18718.912615	-3320671.979…	-18736.110156	-3320669.769…	0.38803
10	-19697.301022	-3322377.312…	-19712.496324	-3322376.585…	1.77296

Auto Adjust Transformation: 1st Order Polynomial (A Total RMS Error: 1.21879

Load… Save… Restore From Dataset OK

Appendix H: LETTER OF INFORMED CONSENTS

PERMISSION TO CONDUCT A RESEARCH PROJECT

UNIVERSITY OF KWAZULU-NATAL

INYUVESI YAKWAZULU-NATALI

My name is Siboniso Msinsi Dlamini doing a Masters Degree at the University of KwaZulu Natal in the School of Engineering. I am currently doing a research study dealing with Exploring spatial growth pattern of Settlements in Customary Land – a GIS based study of Adams Rural, KwaZulu-Natal. The aim of this study is to assess the spatial changes using GIS and Remote sensing techniques of land use and subsequently predict likely future changes that might take place in Adams Rural.

I kindly request your permission to interview people living in your area. Issues of voluntary participation and confidentiality will be ensured.

For more information concerning this research project, you may contact my supervisor Dr M Akombelwa on this number: 0312607556. If you wish to obtain information on your rights on this matter, please contact Ms Phumelele Ximba, Research Office, UKZN, on 031 360 3587.

I will be greatly honoured if my request is granted.

Yours Faithfully

SM Dlamini

Appendix J : Community Questionnaire

PERMISSION TO CONDUCT A RESEARCH PROJECT

My name is Siboniso Msinsi Dlamini doing a Master's Degree at the University of KwaZulu Natal in the School of Engineering. I am currently doing a research study dealing with Exploring spatial growth pattern of Settlements in Customary Land – a GIS based study of Adams Rural, KwaZulu-Natal. The aim of this study is to assess the spatial changes using GIS and Remote sensing techniques of land use and subsequently predict likely future changes that might take place in Adams Rural. A requirement of my degree is to complete a research study. There will be no direct benefit to you if you participate in this research, but your participation is likely to help generate the land monitoring system in Customary Land.
Confidentiality will be ensured through the questionnaires being available to the researcher and his supervisor only. Anonymity will be ensured by omitting any identifying characteristic, such as your name, or department. Data collected will not be shared with anybody outside the research team. If you have any queries please feel free to contact me (Siboniso Dlamini at smdlamini@ymail.com or my supervisor Dr. M Akombelwa at 0312607556/ akombelwa@ukzn.ac.za). If you wish to obtain information on your rights as a participant, please contact Ms Phumelele Ximba, Research Office, UKZN, on 031 360 3587.

I………………………………………………………………………… (*Full names of participant*) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire without any consequence to me.

SIGNATURE OF PARTICIPANT:……………………………………..

DATE…………………………………

Community Questionnaire

Note: Participants are not obligated to participate and are at liberty to withdraw from the project at any time, should they wish to do so without any consequence to them.

Section A: Demographics Information

1. Gender

Male ☐ or Female ☐

2. Age ☐

3. Race

i) Black/ African ☐ ii) Coloured ☐ iii) Asian/ Indian ☐ iv) White ☐

v) Other (please specify) ………………

4. What is your home language?

i) Tswana ☐ ii) Sotho ☐ iii) Zulu ☐ iv) Xhos v) SiSwati ☐

v) Ndebele) ☐ vi) English ☐ vii) Afrikaans ☐ viii) Other (pleasespecify) ☐

5. How would you describe the school in which you matriculated

i) Rural School ii) ☐ wnship School iii) ☐ l model School ☐

ii) iv) Missionary school ☐ Private School ☐ viii) other (please specify)

6. How long have you been living In Adams Rural? ☐

Section B: Living conditions

1. Do your Ancestors come from Adams Rural?

   i) Yes ☐ ii) No ☐

2. If no to 2, how did you know about Adams Rural?

....
....
....

3. Are you living here throughout the year?

   i) Yes ☐ ii) No ☐

4. How do you earn a living?

....
....
....
....

Section C: Land Acquisition

5. Did you come from an urban area or rural area?

   i) Urban Area ☐) Rural Area ☐ii) other ....

6. If Urban Area to 6, what type of ownership were you residing under?

   i) Full ownership ☐i) Renting ☐i) other ....

7. How did you obtain the land in Adams Rural?

   i) King / Induna ☐ ii) Residence ☐ iii) other
   ....

8. What kind of ownership do you have on your land?

   ☐ ☐

i) Full ownership ii) Renting iii) Not Sure ☐ iv) Other…………

9. What are the reasons for relocating to Adams Rural?

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

10. When did you start living in Adams Rural?

i) 2001 – 2004 ☐ ii) 2004 – 2006 ☐ iii) 2006 – 2008 ☐

iv) 2008 – 2010 ☐ v) 2010-2012 ☐

Section D: Land Use

11. What do you use your land for?

i) Agricultural Use ☐ ii) Residential Use ☐ iii) other ……………….

12. Do you know what this land was used for before?

I) Yes ☐ II) No ☐

13. If yes to 13, what was it used for?

i) Agricultural Use ☐ ii) Residential Use ☐ iii) other ………

14. What future plans do you have for your land?

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

Appendix J: Continued……………………….

Community Questionnaire (Zulu Version)

Isicelo semvume yokwenza ucwaningo

Igama lami ngingu Siboniso Msinsi Dlamini ngenza izifundo eziphakeme enyuvesi ya KwaZulu Natal kwiskole sobu njiniyela. Ngimatasa ngenza ucwaningo lokubheka ukuthuthuka kwezindawo zase makhayan ngisebenzisa i-Adams Rural, eKwaZulu-Natal.

Imhloso ukubuka intuthuko ekukhuleni kokwakhiwa kwemizi nokusuka kwabantu emadolobheni kuzokwaka emakhaya kusukela ngonyaka ka-2001 kuya ku-2012. Ngisenzisa izithombe zalendowo zeminyaka ka-2001, 2004,2006,2008,2010 no-2012. Kudingeka ngihambele umphakathi ngibue imibuzo embalwa ukuthola ulwazi olungcono noluqavile ngale ndawo yaseAdams rural.

Ngicela ube nolwazi ukuba awukho umvuzo ozowuvuza siqusakho kepha lolu lwazi lungasika ukuba kube khona ukunakwa komhlaba okungcono kusetshenziswa itekhunologi yesimanje. Imininingwanye yakho ayisoze yadalulwa nanoma yilaphi iyohlezi iyiomfihlo. Uma ufuna ukwazi okunye noma ukuqinikisekisa ungathintana no Dr M Akombelwa kule namba 0312607556. Uma unemibuzo ngamalungelo akho ungathintana no Phumelele Ximba ku 0312603587

Nima ……………………………………… (amagama aphelele) ngiyagcizelela ukuthi ngiyayiqonda lencwadi futhi ngivumile ukuthi ngiphendule imibuzo. Ngiyazi ukuthi ngingayeka namoma inini ukuphendula lemibuzo

Sayina **usuku**

……………… **……………………**

Imibuzo Yomphakathi

Ulwazi oluyisisekelo

1. **Ubilili**

   Silisa ☐ noma Sifazane ☐

2. **Ngabe okhokho bakho badabuka khona lapha e-Adams Rural?**

   ii) Yebo ☐ ii) Cha ☐

3. **Uma ngabe uCha ku-2, Ngabe wazi kanjani nge-Adams Rural?**

....
....
....
....
....

4. **Ngabe uhlala lapha ngaso sonke isikhathi sonyaka?**

   ii) Yebo ☐ ii) Cha ☐

5. **Ngabe uziphilisa kanjani?**

....
....
....
....

<u>Ukuthola Umhlaba</u>

6. **Ngabe uqhamuka edolobheni noma emakhaya?**

ii) Edolobheni ☐ i) Emakhaya ☐ i) Kwenye indawo.................

7. **Uma ngabe edolobheni ku-6, ngabe wawuhlala ngaphansi kobunikazi bendawo obunjani?**

ii) Ubunikazi obugcwele ☐) ukuqasha ☐ i) Noma ☐ obunye…………….............................

8. **Wawuthola kanjani umhlaba e-Adams Rural?**

ii) eNkosini / eNduneni ☐ Kwisakhamuzi ☐

iii) iii) Noma ngenye indlela…………………………..

9. **Ngabe unabuphi ubunikazi kumhlaba wakho?**

i) Ubunikazi obugwele ☐ Uqashile ☐ i) Awunasiqiniseko ☐

iv) Noma obunye………………………

10. **Iziphi izizathu zokusuka lapho ubuhlala khona uze e-Adams Rural?**

………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

11. **Ngabe uqale nini ukuhlala e-Adams Rural?**

☐ ☐ ☐

ii) 2001 – 2004 ii) 2004 – 2006 iii) 2006 – 2008

v) 2008 – 2010 ☐ v) 2010-2012 ☐

<u>**Ukusetshenziswa koMhlaba**</u>

12. Ngabe uwusebenzisela ini umhlaba wakho?

ii) Uyalima ☐ ii) Wakhile iii) Noma okunye ☐…………………

13. Ngabe unalo ulwazi lokuthi loMhlaba wawu setshenziselwa msebenzi muni ngaphambilini?

II) Yebo ☐ II) cha ☐

14. Uma ngabe uyebo ku-13, wawu setshenziselwa msebenzi muni ngaphambilini?

ii) Kwakulinywa ☐ ii) Kwa kwakhiwe ☐

iii) iii) Noma okunye ……………………

15. Ngabe iziphi izinhlelo onazo ngomhlaba wakho?

………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

Appendix K : Headman Questionnaire

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

PERMISSION TO CONDUCT A RESEARCH PROJECT

My name is Siboniso Msinsi Dlamini doing a Master's Degree at the University of KwaZulu Natal in the School of Engineering. I am currently doing a research study dealing with Exploring spatial growth pattern of Settlements in Customary Land – a GIS based study of Adams Rural, KwaZulu-Natal. The aim of this study is to assess the spatial changes using GIS and Remote sensing techniques of land use and subsequently predict likely future changes that might take place in Adams Rural. A requirement of my degree is to complete a research study. There will be no direct benefit to you if you participate in this research, but your participation is likely to help generate the land monitoring system in Customary Land.

Confidentiality will be ensured through the questionnaires being available to the researcher and his supervisor only. Anonymity will be ensured by omitting any identifying characteristic, such as your name, or department. Data collected will not be shared with anybody outside the research team. If you have any queries please feel free to contact me (Siboniso Dlamini at smdlamini@ymail.com or my supervisor Dr. M Akombelwa at 0312607556/ akombelwa@ukzn.ac.za). If you wish to obtain information on your rights as a participant, please contact Ms Phumelele Ximba, Research Office, UKZN, on 031 360 3587.

I M P Makanya .... (*Full names of participant*) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire without any consequence to me.

SIGNATURE OF PARTICIPANT M P Makhanya DATE 17/08/2014

Customary Land Administrators Questionnaire.

Note: Participants are not obligated to participate and are at liberty to withdraw from the project at any time, should they wish to do so without any consequence to them.

Position: Headman of Adams Rural (Induna)

Section A: Demographics Information

1. Gender

   Male [x] or Female [ ]

2. Age 76

3. Race

   i) Black/ African [x] ii) Coloured [ ] iii) Asian/ Indian [ ] iv) White [ ]

   v) Other (please specify) ....

4. What is your home language?

   i) Tswana [ ] ii) Sotho [ ] iii) Zulu [x] iv) Xhosa [ ] v) SiSwati [ ]

   v) Ndebele) [ ] vi) English [ ] vii) Afrikaans [ ] viii) Other (please specify) ....

5. How would you describe the school in which you matriculated

   i) Rural School [x] ii) Township School [ ] iii) Old model School [ ] iv) Missionary school [ ]

   v) Private School [ ] viii) other (please specify) ....

6. How long have you been living In Adams Rural? [ ] 76 years

Section B: Land Administration

1. **What is the reason for making land available to the public?**

   In customary land, land is available to everyone

2. **Who qualifies to obtain land in Adams Rural?**

   Any person above the age of 21 years old.

3. **What procedures are followed when allocating land in Adams Rural?**

   firstly you have to be above 21 years of age. There has to be a land which is vacant / does not belong to anyone. In some cases / mostly people obtain land from residences. Therefore after agreement we allocate land. Thereafter use pegs or plant or natural feature to mark / demarcate the land. Then we register that person at the chief office.

4. **Upon allocation of land, is there a time frame given to make use of the land?**

   Yes There should be an activity on site in a year, if not you must report that it not yet possible. Other than that the land goes back to the chief.

5. **Is it possible for one to be allocated more than one piece of land?**

   I) Yes ☒ II) No ☐

6. **If Yes to 5, how many pieces of land can an individual be allocated at most?**

   Not limited but there should be valid reasons why you need many.

7. **If No to 5, why can't more than one piece of land be allocated?**

....
....
....

8. **Do you still have more land in your area that has not been allocated?**

   i) Yes ☒ ii) No ☐

9. **If yes to 8, what are your plans for this unallocated land?**
   Grant to those who need land for residential purposes or planted or any allowable on customary land. Also there is land reserve for services

Section C: Land Use

10. **In 2001 a year after the millennium, what was the major land use in Adams Rural?**

    i) Agricultural Use ☒ ii) Residential Use ☐ iii) other ....

11. **In 2012 two years after the 2010 FIFA soccer world cup is South Africa, what was the major land use in Adams Rural?**

    i) Agricultural Use ☐ ii) Residential Use ☒ iii) other ....

12. **Which land use is permitted on the allocated land?**

    ii) Agricultural Use ☐ ii) Residential Use ☐ iii) other Any use

Appendix L : LETTER OF PERMISSION TO CONDUCT A RESEARCH PROJECT

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

30 July 2014

Mr Siboniso Msinsi Dlamini 206515147
School of Engineering
Howard College Campus

Protocol reference number: HSS/0853/014M
Project title: Exploring spatial growth pattern of Settlements in Customary Land – a GIS based study of Adams Rural, KwaZulu-Natal.

Dear Mr Dlamini

Expedited Approval

In response to your application dated 23 July 2014, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

Please note: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....
Dr Shenuka Singh (Chair)

/px

cc Supervisor: Dr M Akombelwa
cc Co-Supervisor: Mr M Chilufya
cc Academic Leader Research: Professor Christina Trois
cc School Administrator: Ms Fiona Higgins

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

1910 - 2010
100 YEARS OF ACADEMIC EXCELLENCE

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville