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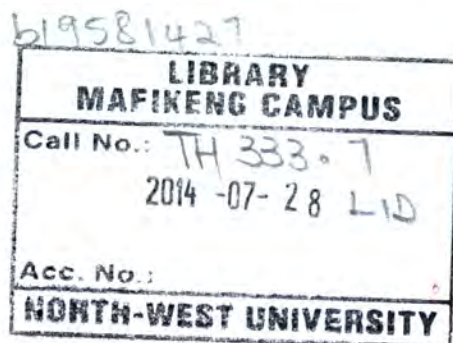
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**RESEARCH TITLE: Land Use and Land Cover Change as a Consequence of the
South African Land Reform Programme: A Remote Sensing Approach**

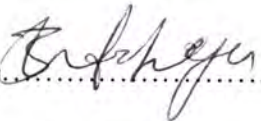
STUDENT NAME : ZWIDOFHELANGANI LIDZHEGU
STUDENT NUMBER : 23229144
QUALIFICATIONS : BSC (HONS) BACHELOR OF
ENVIRONMENTAL SCIENCES HONOURS IN
GEOGRAPHY. UNIVERSITY OF VENDA
FACULTY : AGRICULTURE, SCIENCE AND
TECHNOLOGY
DEPARTMENT : GEOGRAPHY AND ENVIRONMENTAL
SCIENCE
PROPOSED DEGREE : MSc GEOGRAPHY
SUPERVISORS : DR. L.G PALAMULENI
DATE OF SUBMISSION : SEPTEMBER 2012

(This research is submitted in fulfilment of the Master of Science degree in Geography)



DECLARATION

I, Lidzhegu Zwidothelangani, student No. 23229144, hereby declare that the dissertation in fulfilment for a Master's of Science in Geography at North-West University (Mafikeng campus) hereby submitted by me has not previously been submitted for a degree at this university or any other university and is my own work, and that all reference material contained herein has been fully acknowledged.

Signature 

Date. 10-10-2012

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God bless you all.

ABSTRACT

Over 18 years after the democratic government took power in South Africa, environmental changes relevant to the land reform policies are taking place because of unintended consequences of land reform policy. This study aimed at investigating the effects of the South African land reform policy on land use and land cover change on a land restitution project in Makotopong, Limpopo province, South Africa. The study used remote sensing techniques through the analysis of Landsat TM images acquired in 1994 and 2007 to produce landscape maps and derive land cover change. Statistics deriving the nature of the decline in the general condition of the land restitution project gave an insight into the kind of landscape transformation that has taken place before and after land restitution program. Quantification of land cover classes have shown a decline in post-transfer activities with a decline in agricultural productivity, as illustrated by the decline in area covered by agricultural crops (showing a decline from 78.03 ha in 1994 to 20.43 ha in 2007). The study recommends that spatial data analysis through remote sensing procedures should form the information base in monitoring and evaluating the land reform projects. Results of this study demonstrated that quantification of the changes in land use and land cover types can be very useful in deriving the nature of the general environmental and social condition of the land reform project.

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Definition of Concepts

Remote sensing: the science and art of identifying, observing, and measuring an object without coming into direct contact with it

Land cover: refers to the type of feature present on the surface of the earth

Change detection: a technique used in remote sensing to determine the changes in a particular research object between two or more periods

Land restitution: refers to the process of returning land or providing compensation to those who were dispossessed under apartheid government

Land redistribution: refers to the process of increasing black ownership of rural land for agricultural purposes

CHAPTER ONE

1. INTRODUCTION

This introductory chapter provides a brief background, the general aims of the study and reasons for investigating the problem as well as a brief description of the study area

1.1. Background and Rationale

In the first quarter of the 20th century, the apartheid regime through the Native Land Act of 1913, the 1936 Native Trust and Land Act, and the Group Area Act of 1950, as according to The Centre for Development and Enterprise (2005), facilitated an uneven distribution of land in South Africa. Moreover, the implementations of these Acts resulted in a forced removal of black communities into overcrowded homelands while on the other hand, catering the very same land for commercial white farmers in the form of subsidies (The Centre for Development and Enterprise, 2005). However, this long history of dispossession and forced removal under South Africa's colonial and apartheid government continued until the end of the second quarter of the 20th century. The Surplus People Project (SPP) of the 1980s (Hering, 2004), estimated that 3.5 million black people had been forcibly removed from their land between 1960 and 1983.

Leading to the 21st century with the democratic government gaining power in 1994, the new government made an ambitious commitment in the 1994 Reconstruction and Development Program (RDP) to redistribute 30 percent of agricultural land to black communities through the land reform programme as from 1994 to 2014 (a revised date) (Hering, 2004). The South African land reform policies under the democratic government are therefore designed to redress the inequality of land ownership by aiming to reverse the land ownership injustice that had occurred in the past era as a deliberate act of policy by the colonial and the apartheid government (Department of Agricultural Economics and Extensions, 2004).

1.2. History of Land Restitution in Makotopong

The present land claimants of Makotopong are descendent from two cultural groups (Pedi and the Nguni group of Shangaan origin) who were residents on Roodewal. This community was dispossessed of their land between the 28th of June and 4th of July 1967 in terms of the

Development Trust and Native Land Act of 1936 (Act 18 of 1936) (Moabelo, 2007). The area making up the Makotopong Communal Property Association (CPA), restituted land comprises of farm Roodewal 808 LS, Ruigedraai 809 LS, and Salamis 807 LS. The land transfer to the Makotopong community took place in 2002 under the land restitution (Restitution of Land Right, Act 22 of 1994). However, the transfer of the land to the Makotopong CPA quickly led to a standstill of farming operations and a rapid decline in the general condition of restituted land (Moabelo, 2007). The reason behind the decline of the condition of the land after restitution has been linked by Moabelo (2007) to the complexity and integrated nature of the farming operations and the lack of necessary skills and experience of the Makotopong management committee.

1.3. Statement of the Problem

Over 18 years after the democratic government took power in South Africa, environmental changes relevant to the land reform policies are taking place because of unintended consequences of land reform policies but are not taken fully into account. This was evident from a study by Moabelo (2007) on *Land Claims Process in Limpopo Province: A Case Study of the Makotopong Community, South Africa*. The research findings indicated that after the land transfer, farming activities came to a standstill while the general conditions of the land declined rapidly with some orchards being converted into cattle grazing land. However, the study methodology was mainly qualitative with data collected mainly from questionnaires and interviews. In this context, it can be argued that the study did not quantify the nature of the decline in the general conditions of the land. This study, therefore, with the use of remote sensing techniques, through the analysis of digital satellite images was designed to bridge the gap left by the previous study. Remote sensing image classifications were used in this study to produce accurate landscape change maps and statistics deriving the nature of the decline in the general condition of the restituted land in Makotopong community, Limpopo province. Distinguishing and quantifying where potentially risky changes occur is critical to the initiation of regular monitoring of resources and the environment in general.

1.4. Aim and Objectives of the Study

The principal aim of this study was to investigate the effects of the South African land reform policy on land use and land cover change on restituted land in Makotopong, Limpopo province, South Africa.

1.4.1. Specific objectives

- To map land use and land cover types between dates of imagery (before, and after land restitution)
- To detect and quantify changes in land use and land cover between dates of imagery.
- To develop strategies that will ensure sustainable land utilisation in the study area

1.4.2. Research assumptions

- The research assumes that land restitution significantly alters land use and land cover types
- The kind of landscape transformations that took place after land restitution leads to a decline in the status of the restituted land as they lead to a decline in agricultural productivity
- The implementation of land reforms leads to marked environmental and socio-economic changes.
- The current land restitution policy in South Africa has negative impacts on sustainable land utilisation

1.5. Significance of the Study

This study, with the use of remote sensing imagery in its broadest sense was designed to help in updating the status of natural vegetation cover in and around Makotopong, 25km North East of Polokwane city, Limpopo province, South Africa. The principal goal of the study was to investigate the effects of the South African land reform policy on land use and land cover distribution in Makotopong. Therefore, the study also makes a contribution in addressing the issue of unintended consequences of land restitution on land cover dynamics. The study also updates the current status of land restitution programme in Makotopong and gives insights into the kind of landscape transformations that have taken place before and after land restitution. Land cover maps produced in digital formats could easily be applied to a variety of future GIS applications. In addition, the study of this nature helps in providing key elementary information on land use activities and land cover types which are central

components for managing natural resources and monitoring environmental changes (Kesgin and Nurlu, 2009). The study can be helpful to the Makotopong CPA for informed decision making in achieving sustainable land management by providing information that can be used as baseline data for decision support.

1.6. Description of the Study Area

The study area (Makotopong village) is located approximately 25km North East of Polokwane, on the R81 road, and the Makotopong CPA is located 35km North of Polokwane along the N1 road in Limpopo, South Africa (Figure 1).

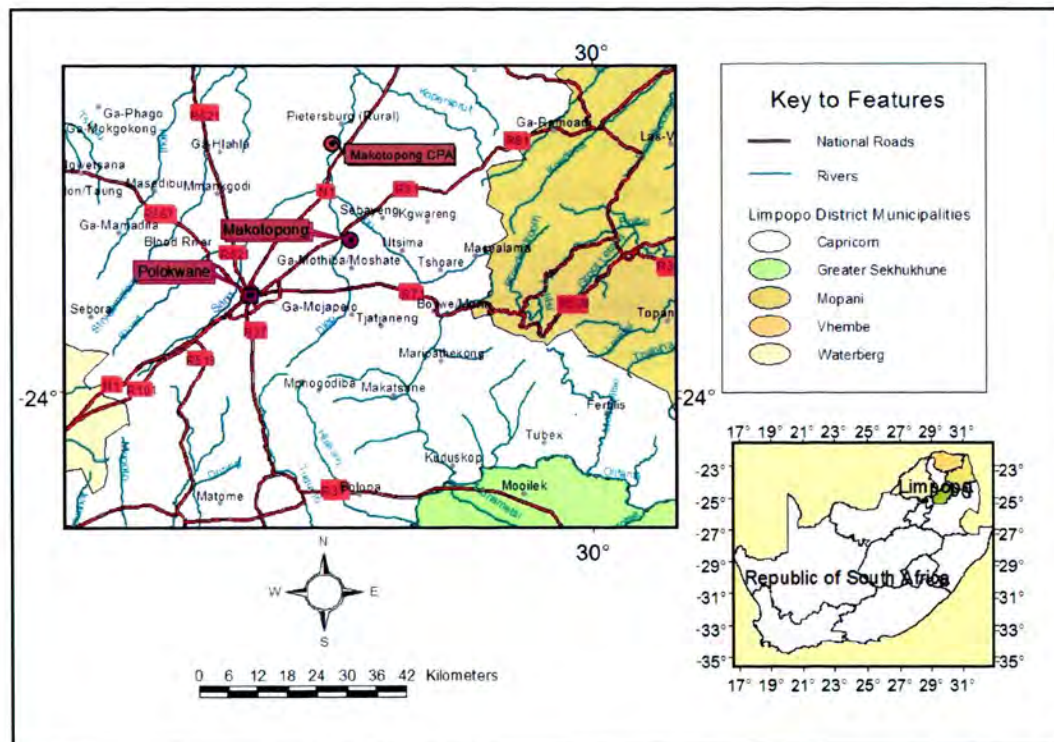


Figure 1: Map of the location of Makotopong in Limpopo, South Africa

1.6.1. Climate

The Makotopong community is located within the Polokwane local Municipality and falls within the Pietersburg plateau that is characterised by a semi-arid climate. The average temperature of the area reaches 21-22°C in January and 11°C in July, while the area experiences a summer rainy season and a dry spell during winter. The maximum daily precipitation (77mm) falls in January and the lowest precipitation (0mm) falls in June, with rainfall averaging between 400-600mm annually. With this type of climate, crops entirely reliant on rainfall require a supplementary irrigation system (City of Polokwane, 2011).

1.6.2. Hydrology

Although the Sand River runs through the eastern portion of the study area, it is a seasonal river and often dries in winter but water can be found at shallow depths in the river bed throughout the year. However, there appears to be a large underground water resource within the Polokwane municipality and the study area. The utilisation of water within the project area therefore is mainly underground water abstracted through boreholes (City of Polokwane, 2011).

1.6.3. Soil

The Pietersburg plateau contains mainly grey iron-containing lateritic soil types which are sandy or gravelly in texture and usually contain a hard iron containing bottom layer of hardpan. Whereas in certain parts none leached, black clay soil and the light brown sandy soil occur. Although these types of soils generally occurs in the low rain fall areas (300-600mm annual rain fall), they are suitable for arable farming (City of Polokwane, 2011).

1.6.4. Vegetation

The Pietersburg plateau and hence the study area is characterised by the false grassveld, which occurs in the southern parts of Molepo-maja, Chuone and in the eastern part of the Mankweng clusters, along the Strydpoort mountains. Grassveld vegetation type is of great agricultural significance as it has good potential for animal production and game farming if it is grazed wisely but when the health of the veld declines, it becomes increasingly difficult to support livestock (Reed *et al.*, 2008).

1.6.5. Population

The population growth of Polokwane municipality over the last decade has been significant, with growth figures from 1996 to 2001 showing an increase by 1639, which means an average growth rate of 3,7%. The municipality population growth has also been characterised by an increased in the number of household from R4980 (2001) census to 130360 in 2007 (Statistics South Africa, 2007). The Makotopong community lies within the Polokwane municipality and its population growth for the past few years has also been significant with

an increase in population from 8775 in December 2007 to 9044 in December 2008 and 9298 in December 2009.

1.7. Research Ethics

The research had no ethical issues to address but an ethical clearance form was still completed for the purposes of registration of the topic at the Institutional Office.

1.8. Organisation of Chapters

The organisation of this research thesis entails the six chapters structured as follows:

Chapter one: **introduction** that is comprised of the background information, problem statement, and the objectives of the study.

Chapter two: **literature review**; present an analysis of the findings of other similar studies in land reform and land use and land cover studies.

Chapter three: **research methodology**; that looks mainly at the research design and the methods of data collection, methods of data analysis and the materials used.

Chapter four: **results and discussion**; presents results of data analysis in the form of maps tables, and graphs. It also gave the discussion of the findings with reference to other studies on similar issues.

Chapter five: **conclusion and recommendations**; presents a summary of main/major findings of the study and suggestions on suitable land management. It also provides area for further study.

2. LITERATURE STUDY

The literature study gives an evaluation of work by other researchers on issues such as the application of remote sensing in land use and land cover as well as the land reform policy.

2.1. Remote Sensing

Lillesand *et al.* (2004) defined remote sensing as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by device that is not in contact with the object, area, or phenomenon under investigation. Remote sensing techniques use a variety of sensors and devices to detect and measure electromagnetic energy (emitted from the sun) reflected by earth's surfaces; these including amongst others photographic cameras, radar system as well as satellite sensor. The data acquired and produced by these devices relates to the electromagnetic properties of the earth's surface (Levin, 1999).

According to Aggarwal (2003), the basic strategy for sensing electromagnetic energy after interacting with Earth surface features is that every material on Earth's surface is unique. It has its own unique distribution of reflected, emitted and absorbed radiation and these spectral characteristic can be used to distinguish one thing from another or to obtain information about the shape, size and other physical and chemical properties. Moreover, Lillesand *et al.* (2000) argued, for any earth features under investigation, it is important to understand their spectral characteristics and the factors influencing these characteristics. Therefore, it is important to discuss the spectral characteristics of some common land cover types within various wavelengths region of the spectrum.

2.1.1. Vegetation reflectance

According to Kerle *et al.* (2004), in the visible region of the electromagnetic spectrum, the reflection of electromagnetic radiation from healthy vegetation in blue wavelength (TM1) and red (TM3) wavelength is low, since blue and red portions are absorbed by chlorophyll. In the near infrared region (TM4) of the spectrum, healthy vegetation reflectance increases to peak level, while in the mid infrared (TM5) vegetation reflectance is determined by leaf water content, with more water resulting in less reflectance. However, when the leaf dries out

during dry/harvest season this results in higher reflectance in red (TM3), and the mid infrared (TM5) region with decreasing reflectance in the near infrared region of the electromagnetic spectrum (Kerle *et al.*, 2004).

2.1.2. Soil reflectance

Soil reflectance characteristics are affected by factors such as moisture content (the presence of water in the soil decreases its reflectance), soil texture, surface roughness, and organic matter content (Lillesand *et al.*, 2000). However, Kerle *et al.* (2004) noted that soil reflectance is high from spectral bands between 0.5-1.3 μ m (that is TM2, TM3, TM4) and decreases at spectral bands between 1.45-1.95 μ m (TM5 the water absorption band).

2.1.3. Water reflectance

Lillesand *et al.* (2000) argued that pure water reflectance characteristic is restricted to the visible (TM1, TM2 and TM3) and near-infra red (TM 4), as water absorbs all energy beyond 1.2 μ m (TM5) spectral band, and it is for this reason that locating and delineating water bodies with remote sensing is mostly done in the near-infra red (TM4) region. However, turbid water associated with silt loaded water and water containing plant with chlorophyll shows the highest reflectance as compared to pure water (Lillesand *et al.*, 2000; Kerle *et al.*, 2004).

According to Lillesand *et al.* (2000), the knowledge of spectral reflectance of electromagnetic energy incident upon different earth surface material, helps in selecting the wavelength region of the spectrum suitable for a particular remote sensing application at hand. For example, in a study conducted by Ravan *et al.* (1995), it was argued that TM3, TM4 and TM5 bands combination was found to be better at recognising vegetation cover change and hence the study used TM3, TM4 and TM5 band combination in the analysis of Landsat TM imagery to produce land cover maps used to estimate vegetation cover change.

2.2. Importance of Remote Sensing Applications in Land Use and Land Cover Change Studies

A wide range of scientist and practitioners, including earth system scientists, land and water managers as well as urban planners seek information on the location, distribution type and the magnitude of land use and land cover change (Pascalini *et al.*, 2006). The information derived from satellite images is becoming increasingly important for mapping and monitoring

land cover (Boakye *et al.*, 2006). The advantage of using satellite images for land cover studies is that remotely sensed data offer both historic and recent perspectives on landscape dynamics (Kesgin and Nurlu, 2009). Sarma *et al.* (2007), state that satellite remote sensing data with their recurring data collection nature have proved to be quite useful in mapping land use and land cover pattern. Moreover, remote sensing spatial and temporal observations have significantly improved the quality and quantity of these environmental data for sustainable earth resource management and efficient environmental monitoring (Pascalini *et al.*, 2006).

However, Awotwi (2009) defines land cover as the observed (bio) physical cover of the earth's surface (e.g. bare soil, forest, grassland, etc.) while land use is the arrangement of activities and input that people undertake on a certain land cover type (e.g. agriculture, residential, etc.). Therefore, land cover change is regarded as the conversion from one land cover category to another (e.g. the conversion from forest to agricultural land) and/or the modification within one category (e.g. from dense forest to open forest) (Awotwi, 2009). Maranganti (2009) on the other hand, argued that vegetation constitutes the foremost component of land cover and their changes are a key indicator of regional environment change. Besides, Boakye *et al.* (2006) illustrated that these changes are often as a results of anthropogenic pressure (e.g. population growth) and natural factors such as variation in climate. Moreover, Boakye *et al.* (2006) further indicated that the increase in population growth rates have led to an increasing rate of conversion of forest and woodlands in developing economies all over the world, mainly for farming practice.

Moreover, globally forest land cover type constitutes some of the largest terrestrial carbon storks against the built-up of greenhouse gases, helping in combating the effects of global warming and climate change (Munyati and Kabanda, 2009). Despite the importance that natural forests play, poor planning and political interventions through policy making and human activities such as agriculture and settlement expansion have replaced natural forest cover over large area of global land surface (Ramonkutty *et al.*, 2006). In some cases, these changes in land use and land cover because of unintended consequences have major impacts on the environment. For example, Boakye *et al.* (2006) showed that forest cover change results in soil erosion and water shortage in deforested regions and in reasonable distant areas. In addition, Sohl and Saylor (2008) indicated that changes in temperate forests due to conversion of natural vegetation to urban and agricultural lands has resulted in significant

change in precipitation and temperature, with general increase in precipitation in reasonable distance areas that have been reforested. Moreover, as according to Ramankutty *et al.* (2006), agriculture is one of the most wide-spread human land use activities, covering a third of the global land surface, and several observation or model simulation studies have indicated that agricultural land use practice, deforestation, or other types of land use and land cover change have a major influence on climate. Ramankutty *et al.* (2006), further argued that replacing natural vegetation with present day cropland have resulted in increased land suitability for cultivation in some parts of the world and decreased suitability in other parts, with the global cropland suitability showing a decrease of 0.9%. In Africa, in particular the Sahel and East African region, the removal of savanna for cultivation resulted in reduced convection, decreased rainfall in spring and summer and slightly reduction in water available to plants (Ramankutty *et al.*, 2006). This however, is a clear indication that, when humans modify the landscape by clearing vegetation to grow crops, the resultant land cover change might have modified the climate in such a way that it altered the land suitability for cultivation.

2.2.1. Case studies of agriculture and land use changes

Given the status of land use and land cover changes around the world, it is clear that the accurate change detection of the earth surface features is extremely important in understanding relationships and interactions between human and natural phenomena in order to promote better decision making (Sulieman, 2010). Furthermore, this was the fundamental assumption leading to Sulieman's study where the principal aim of the study was to produce synthetic knowledge on the rapid land use and land cover changes and on the integration of change with fundamental patterns in Southern Gadarif region, Sudan, for the period 1972 to 2003. The use of remote sensing imagery (Landsat MSS and ETM+) produced results that indicated that, the land cover of the Southern Gadarif region has changed drastically since the introduction of mechanised rain-fed agriculture in the area. Sulieman (2010), further argued that the results of the study showed that agriculture did not only expand, but its expansion was at the expense of the natural vegetation cover in such a way that the average rate of vegetation clearing for agricultural purposes in the area exceeded the national deforestation average rate.

Previously Wood *et al.* (2004) conducted a study, with the primary objectives of the study being; to identify changes in land use and land cover over time, and to identify the key drivers of these changes and lastly to discuss the implication of those results for agriculture

and natural resource policy in South-Central Senegal. The study in its methodology used a baseline data set from previous research carried out between 1994 and 1999 together with semi-structured interviews. The other key data sets used included a time-series of early dry season Landsat MSS, TM and ETM+ satellite imagery. The results of the study showed that there is an increase in the amount of land devoted to agriculture in either active cultivation or short-term fallow. Furthermore, Wood *et al.* (2004), highlighted that the study placed more emphasis on agricultural expansion, based on the argument that agricultural expansion is generally recognised as a primary driver of land use/land cover change in much of Senegal and other West African countries.

Therefore, based on this argument, this indicates that remote sensing provides some of the most accurate means of measuring the extent and pattern of changes in landscape conditions. It can be argued that the pattern of change in landscape conditions as measured through the analysis of remotely sensed data play a fundamental role in studies that try to investigate the consequences of the implementation of land reform policy on natural vegetation and/or agriculture. In addition to studies that assess the success of the implementation of land reform, they seek to quantify and discuss the amount of land use/land cover changes.

2.3. Land Reform

Land reform is a process whereby land is distributed for the benefit of the society of a country and or a community by giving the land back to those who have lost or were denied ownership of the land at some time in the past (Bullard, 2001). In addition, Bullard (2001) highlighted that land reform process usually takes place at the time of independence or a change of political party following on from a dictatorship to a democratic government as it is influenced by the political manifestation of the ruling party before it gained power.

2.3.1. Case studies of land reform

This section provides a survey of case studies that relate to land reform issues in Zimbabwe, as an effort to draw inference from the Zimbabwean land reform crisis.

2.3.1.1. Land reform in Zimbabwe

Extreme examples of land reform are occurring in Zimbabwe 20 years after it gained independence (Bullard, 2001). According to Richardson (2001), in the early 1900's British explorer Cecil Rhodes and the British colonialism drove blacks off their lands forcing many

of them to farm in arid areas. This led to a legacy in Zimbabwe wherein over half of the commercial farmlands were located in fertile high rainfall regions. Moreover, it was also indicated that, at some stage in Zimbabwe whites owned most of the commercial farms, numbering about 4,500 families while 840,000 black farmers, farms on the communal lands (Richardson, 2001). However, in the run-up to the 2000 parliamentary elections, there were wide spread agreements on the need for land reform in Zimbabwe as a means of reducing poverty. Notably, in 1997 25% of the population lived below the national poverty line, including high unequal distribution of land between the white minority and the black majority (Robilliard, 2001). Arguable for these reasons, President Mugabe, after gaining power in 2000 set in motion the land reform policy that saw the seize of nearly all the 4,500 commercial farms to the hands of black Zimbabweans who unfortunately knew little about commercial farming (Richardson, 2001).

2.3.1.2. Consequences of the Zimbabwe land reform and restitution policy

Mark and Kudakwashe (2010) conducted a study in Shurugwi district aimed at determining the rates of land cover change since 1990. The study utilised three satellite images of different years to produce land use and land cover maps that were analysed together with semi-structured interviews to obtain data on the drivers of land-use and land-cover change in Shurugwi District. The results of the study showed that the rate of changes in Shurugwi District has been significant with the greatest change occurring during the 2000-2009 period. Mark and Kudakwashe (2010) highlighted that the major change was in the agriculture land cover class that was attributed to the fast-track land reform and redistribution programme. The fast-track land reform and redistribution programme saw a large influx of new black farmers occupying large areas of former white-owned commercial farms. This however led to the clearing of large forest areas for different farm related activities. The quantification of the change indicated that cropland cover increased by 52% between 2000 and 2009, as compared to 35.3% in the period of 1991-2000 (Mark and Kudakwashe, 2010). This indicates that there were significant changes in land use and land cover because of the implementation of the land reform and restitution programme that was implemented in 2000.

Furthermore, Richardson (2001) argued that the fast-track land reform and resettlement programme in Zimbabwe also resulted in an increase in the number of livestock introduced to formerly white-owned grazing land. The introduced livestock quickly depleted these farms as most former private land suddenly became common property (communal grazing land).

Richardson (2001) also argued that new farm lands in Zimbabwe, after the land reform programme were created through deforestation, while on the other hand, communal grazing areas were not tendered or managed. This mismanagement of land resulted in quick depletion of the surface vegetation leading to increasing erosion thus leaving the land more susceptible to run-off and droughts and therefore degrading the quality of the land. Besides, when the area is no longer productive, communal farmers move on to establish a new farm on the next vacant land (natural vegetation/forest land) and these results in more and more forest cutting as the process repeats itself.

2.3.2. Land use and land reform policy in South Africa

South Africa comprises about 122 million hectares of rural land, with 100 million hectares classified as farmlands. While 82 million hectares of this farmland is classified as commercial agricultural land, blacks occupy only about 3 million hectares of this land (The Centre for Development and Enterprise, 2005). This uneven distribution of agricultural land in South Africa could be attributed to the forced removal of black communities by means of colonial and apartheid government laws (Hering, 2004). The colonial and apartheid government laws resulted in white minority (constituted only 14% of the total population) controlling as much as 87% of land in South Africa during the apartheid era (McCusker, 2004).

The 1913 Natives Land Act in South Africa legalised racially biased land ownership by preventing Africans from owning land in white farming areas. African ownership of land was restricted to native recourses in rural areas where the principal mode of land fence was customary and administered by a traditional leader (Layne and Darroch, 2003). The South African first democratic government, after gaining power in 1994 was faced with a situation wherein the government had to deal with the need to balance land ownership in South Africa. Faced with the need to balance strong demands from the previously disadvantaged and the need to preserve the commercial farming sector and a fragile political compromise, the democratic government of South Africa had to develop and adopt the land reform policy (Layne and Darroch, 2003). The land reform policy was designed to redress the inequality of land ownership in South Africa (Hering, 2004). The South African three staged land reform policy is typed under land tenure reform, land redistribution, and land restitution (Anseeuw and Mathebula, 2008). Land tenure reform was designed with the aim to address insecure tenure in the former homelands, while land redistribution aims of addressing the racial imbalances in rural land ownership (Layne and Darroch, 2003).

Land redistribution programme through grants, aims to assist previously disadvantaged South Africans to purchase available land, specifically for agricultural purposes (Anseeuw & Mathebula, 2008). According to Department of Agricultural Economics and Extensions (2004), some of the objectives of land redistribution as amongst others are: to increase access to agricultural land by black people and to contribute to the redistribution of approximately 30 percent of the country's commercial agricultural lands over the duration of the programme. In addition, the program aims to enable those accessing land in communal areas at present to use their land productively, and as well as to promote environmental sustainability of land and natural resources. Land restitution programme however, allows people or communities whose land had been disposed after the implementation of the first native Land Act of 1913, to have the right to file their claims to regain ownership of their land (Anseeuw and Mathebula, 2008). The land ownership however can be regained through compensation, including amongst others agricultural lands and commercial farms, or the equivalent in the form of other land or financial compensation (Anseeuw and Mathebula, 2008). Given this type of land affairs in South Africa, there have been challenges relevant to the land policy that caught the attention of many scholars to investigate more into the state of land affairs in the country.

A study on *Community-Integrated GIS for Land Reform in South Africa*, conducted by Weiner and Harris in 2003, presented the results completed from a GIS and society project in Mpumalanga province, South Africa. The research aimed at tackling issues amongst others: the historical geography of forced removals, identifying perspectives on appropriate and inappropriate land use and identifying the areas where land reform should take place. The results on land reform issues showed that there are differential opinions between black and white communities in South Africa. Black community showed strong feelings about the need for land reform, with an argument that they want farming land and need grazing land for livestock. Weiner and Harris (2003), also highlighted that the black community argues that a significant quantity of land must be returned to the people who lived there previously while white farmers are less enthusiastic about the issue of land reform. With these results, it can be argued that there is a wide spread agreement in South Africa amongst the black community about the need for land reform.

2.4. Land Restitution in South Africa

After the introduction of the Restitution of Land Rights Act, Act 22 of 1994 in South Africa, the newly elected government invited members of the public to submit their land claims before a deadline that was further extended to 31 December 1998 (Layne and Darroch, 2003; Hering, 2004). According to Layne and Darroch (2003), 68 878 restitution claims were registered with the land claims commission and by October 2007 more than half of the claims (35 173) had been settled. However, most of the claims (~70%) relate to urban than rural land claims. Moreover, many urban claims have been settled with cash instead of land while rural claims on the other hand are more slow and complex (The Centre for development and Enterprise, 2005). Moabelo (2007) argued that rural claims are more complex as compared to urban claims as they involve a large number of people (communal claims), whereas most urban claims are individual (household) claims. The Centre for development and Enterprise (2005) further indicated that despite their complexity and slow process in nature, the developmental progress of most rural (Mpumalanga and Limpopo province in particular) restitution projects have been less satisfactory.

2.4.1. Land restitution in Limpopo

The Limpopo province of South Africa is regarded as a rural area and according to Moabelo (2007), most of the land restitution claims in Limpopo province are rural claims that involve large numbers of people and could be categorised as slow and complex. Moreover, in certain parts of the province, land restitution projects are depressing land prices, deteriorating agricultural investment and negatively affecting agricultural production (The Centre for development and Enterprise, 2005). Furthermore, Moabelo (2007) indicated that the review of several restitution projects in Limpopo province of South Africa had shown signs of unsatisfactory post transfer activities within the restituted land. For instance, in the Mahlambandlovu land restitution project, west of Polokwane, land that had been used in 1987 as crop agriculture has been abandoned after being restituted to the community and has now become grassland (McCusker, 2004). Moreover, in the Mmamathola community land claim project, of about 3,566 hectares of agricultural land that was handed to the Mmamathola community in 2001 after the community was forcefully dispossessed 44 years ago, the reach orchard bearing land collapsed due to lack of management skills (Moabelo, 2007). McCusker's (2004) study; *Land Use and Cover Change as an Indicator of Transformation on Recently Redistributed Forms in Limpopo Province*, used remotely sensed

images as well as quantitative and qualitative survey techniques. The use of remote sensing techniques in this study was to evaluate the impact of redistribution projects on land use and land cover change (as this was the main objective of the study). The research findings indicated that the redistributed land was abandoned or used less productively, with land use activities alternating between agriculture, grazing and later become abandoned. MacCuster (2004) argued that the primary reason for the lack of increase in post transfer activity amongst others was farm level general disorganisation, lack of capital and labour as well as poor land tenure relations.

Another study conducted by Moabelo (2007), *The Land Claim Process in Limpopo Province; A Case Study of Makotopong Community, South Africa*, aimed at investigating the process of rural land claim in the Limpopo province of South Africa. However, the study was confined to Makotopong CPA (Makotopong Communal Property Association) as to illustrate the consequences of slow conclusion of land claim and absence of post-transfer developmental activities. The study profiled the Makotopong land claim in the case study format, and also profiled the settled land claim with emphasis on the facilitation of developmental activities and access to agricultural services (Moabelo, 2007). The study methodology was mainly qualitative in nature with data collected and analysed using unstructured questionnaires across various stakeholders. The study indicated that after the land claim, the community was compensated with farms Roodewal 808 LS, Ruigedraai 809 LS, and Salamis 807 LS in 2002. In addition, before the land transfer, the previous owners farmed the land intensively with cattle, tobacco, peaches, grapes, olives, almonds and vegetables. However, after the transfer the farming activity declined rapidly. Moabelo (2007) argued that the complexity and integrated nature of the farming operations and the lack of necessary skills and experience of the Makotopong CPA management committee proved to be the reason for the decline in post transfer activities.

As the study methodology was mainly qualitative in nature, it is clear that the study failed to quantify the nature of the decline of the farming activities. It can also be argued that the application of remote sensing techniques can provide efficient tools that can be used in bridging the gap left by this study. Through time series analysis of satellite images, the quantification of the decline in the nature of the post transfer activity can be realised.

2.5. Application of Remote Sensing Techniques in Land Reform Studies

According to McEwen (2000), the proposal for land reform in developing countries pose two basic questions: should any land be capable of private ownership or should the state retain the legal ownership of all land subject to specified rights of use and occupancy by those individual persons or groups of person to whom the state may grant such right? With the second one being, how can the state best identify the location, size and characteristics of every land parcel, whether publicly or privately owned, and the legal rights that affect it, as part of a national land information? Bullard (2001) argued that the process of land reform should not proceed until the necessary spatial data has been designed and information collected, analysed and presented to the politician for implementation. The spatial data required includes: cadastral surveys (legal boundaries, topographic maps and plans required for the development process, land use maps and plans with access to digital data from which they are derived, aerial photographs and remote sensing imagery, in addition to other supplementary data. Moreover, McEwen (2000) highlighted that the availability of powerful tools such as GPS, GIS and remote sensing has shown that problems of land reform are susceptible largely to technological solution and through the utilisation of these technologies in land reform issues, the above questions posed by land reform proposal can be answered and proper strategies implemented thereafter.

There have been many successful studies on land reform that utilised remote sensing technologies in the quest to resolve land reform issues. Most of these studies analysed land use and land cover maps as the basis for assessing land reform issues. Tacconi and Kurnawa (2006) in a study on *Forests, Agriculture, Poverty, and Land Reform: The Case of the Indonesian, Outer Island*, used remote sensing techniques where satellite images from Modis at 500m resolution were analysed to address the question; what are the empirical relationships amongst forest, poverty, agriculture and access to market and services in the Indonesian outer island? The study also looked at the implications of these relationships for forest land reform. A very large share of land in Indonesia (71%) is classified as forest land with very little land classified as agricultural land. However, with most people in Indonesia considered poor in the mid 1960's, there have been many claims to the forest land. This led to advocating recognition of customary rights to land and the reform of the forest land administration system. The vegetation cover maps produced showed that the incidence of poverty is positively correlated with forest cover at the district level and that agricultural

sustainability of land is negatively correlated with poverty. The results also showed that agriculture provides higher financial returns than forestry. Tacconi and Kurnawa (2006) further argued that this is an indication that clearing forests located on suitable agricultural land can contribute to poverty reduction. Moreover, this implies that forests not located on suitable agricultural land could be harvested to contribute to poverty reduction or at least to support poverty mitigation.

Similarly, Kuemmale *et al.* (2006) used Landsat satellite images to assess the extent and spatial pattern of post-socialist parcelization of farmland in the border triangle of Poland, Slovakia and Ukraine. Remote sensing technologies were utilised to compare the degree of parcelization amongst countries and to assess as to whether different land reform resulted in different parcelization rates. This study was conducted owing to that most of the Eastern Europe countries before 1990 were managed by the state in large-scale agricultural co-operatives. However, after 1990 all Eastern European countries implemented land reform to break up large-scale farming structure and to privatise the agricultural sector. Kuemmale *et al.* (2006) argued that the privatisation of agricultural sector resulted in a split-up of large socialistic fields into small parcels and thereafter led to physical fragmentation of farmland (parcelization). After the analysis of remotely sensed data, the results of the study indicated that Poland did not experience much change in parcelization because land ownership did not change substantially. Nevertheless, the study revealed that farmland parcelization changed considerably in Ukraine and Slovakia with strongest changes observed in Ukraine since the land was distributed amongst the people. On the other hand, the restitution process in Slovakia preserved the large-scale farming sector partially as many new owners sold their lands to agricultural enterprises. Based on the findings from this study, it can be argued that the implementation of land reforms leads to marked environmental and socio-economic changes.

In conclusion, literature study has indicated that land reform is a continuous process that is accompanied by environmental and social changes whenever new reform policies are implemented. Since land reform related problems are a global phenomenon, lessons and inferences on the issue can be learned from other countries, such as Zimbabwe wherein an extreme case of land reform occurred 20 years after gaining its independence. Moreover, the survey on literature also indicated that remote sensing technologies could provide efficient tools in solving some of the issues related to the adoption and implementation of the land

reform policy. The next chapter will provide the methods used in the application of digital satellite imagery in order to achieve the main objective of this study which is to investigate the effects of the South African land reform policy on land use and land cover change on restituted land in Makotopong, Limpopo province, South Africa.

3. RESEARCH METHODOLOGY

This section focuses on the presentation of the data sources and approaches taken in solving the problem at hand.

3.1. Data Sources

The images were classified using computer software ERDAS Imagine which is widely used to process satellite images at different levels and GIS package (Arc-Map 9.3) for mapping purposes, visualising on the computer screen and on paper. A GPS with 5m accuracy level was used during field work

3.1.1. Satellite data – Landsat Images

Landsat images, level 1G, were obtained from Council for Scientific and Industrial Research (CSIR) South Africa. The images (July 1994 and 2007) with 30m spatial resolution and 185km swath width were selected for use in this study (Table 1). The Landsat TM images offers a high spectral resolution as the image is taken using seven bands, with three TM bands (TM3, TM4, and TM5) regarded as useful in vegetation studies. A good case in vegetation mapping using remotely sensed images is the spectral radiance in the red (TM4), near infrared (TM4) and mid-infrared (TM5) regions (Xie *et al.*, 2008).

Table 1: Characteristics of the images

Acquired Date	Satellite	Sensor	Path	Row	Resolution	Spectral Range
24 July 1994	Landsat	TM	169	76	30m	TM3, TM4 & TM5
20 July 2007	Landsat	TM	169	76	30m	TM3, TM4 & TM5

July was selected because during this time in the study area little rain or no rain is expected and this reduces the occurrence of clouds during image acquisition. Hence, all the images for this study were cloud free. Again, the near anniversary dates of 24 July 1994 and 20 July 2007 were selected to ensure the accurate detection of land cover types in the study area. Kesgin and Nurlu (2009) indicated that to ensure the accurate detection of land cover change and to minimise the influence of temporal effects (effects of seasonal phonological

differences of vegetation) on the spectral response pattern of vegetation (land cover types), it is important and advisable to compare images acquired from the same date, month or season. Moreover, Landsat images were used for this study as they provide cost-effective and most applicable source of data for a comprehensive array of applications, including land cover change mapping (Rogan, 2009).

In addition, selection of images was governed by when land restitution occurred in the study area. McCusker (2004) argued that one method to determine the nature of change in a restituted land is to examine the type of activity on the farm before and after transfer. Therefore, the 1994 image were selected to show land cover type before land restitution, while the 2007 image were selected to indicate the change in land cover type after land restitution.

3.1.2. Topographic maps

The Chief Directorate Surveys and Mapping (Department of Land Affairs 2007) 1:50 000 topographic maps of 1994 and 2002 were used as base land cover maps for interpreting the location of the project area and the land cover types for the two images. High resolution Google Earth images compiled (Compiled from AfriGIS) from a July 23 2007 high resolution GeoEye imagery were also used as base land cover maps in the classification process.

3.2. Image Processing

Landsat TM images were first imported from the Landsat TM FST file into Erdas Imagine image format. This process enabled the selection of Landsat TM3, TM4 and TM5 bands, and the final output image composed of the selected TM bands for further analysis. In this study, only three TM bands (TM3, TM4 and TM5) were used to discriminate land use and land cover change. Munyati and Kabanda (2009) dropped all the other TM bands and used only TM3, TM4 and TM5 bands with an argument that the spectral signatures of land cover classes are least separable in the visible bands TM1 and TM2.

3.2.1. Geometric correction

Geometric correction of the imagery resamples or changes the pixel grid to fit that of a map projection or another reference image. The main aim of geometric corrections is to compensate for the distortions introduced by various factors (such factors as; velocity, altitude and attitude of the sensor platform, and atmospheric refraction, as well as relief

displacement) so that the corrected image will have the highest practical integrity (Lillesand *et al.*, 2004). Geometric registration was done in order to correct distorted or degraded image data to create a more faithful representation of the original scene of the study site (Lillesand *et al.*, 2004). Google Earth was used to generate 22 geographic coordinate points collected from roads, rivers and other linear intersection zones. These ground control points were then utilised to geometrically register the 2007 image to a UTM projection, Zone 35S, WGS 84 coordinate system used in South Africa. The 1994 image was geometrically registered to the 2007 image and transformed to a UTM projection, Zone 35S, WGS 84 through image-to-image registration with sub-pixel root mean square error (RMSE) of 2.59.

3.2.2. Delineating the study area from the Landsat images

From each Landsat TM image date, two subset images of the study area were extracted with one subset image encompassing the Makotopong CPA (the land under land restitution) [Fig. 2(a) and (b)] and the other one covered the Makotopong village [Fig. 2(a) and (c)].

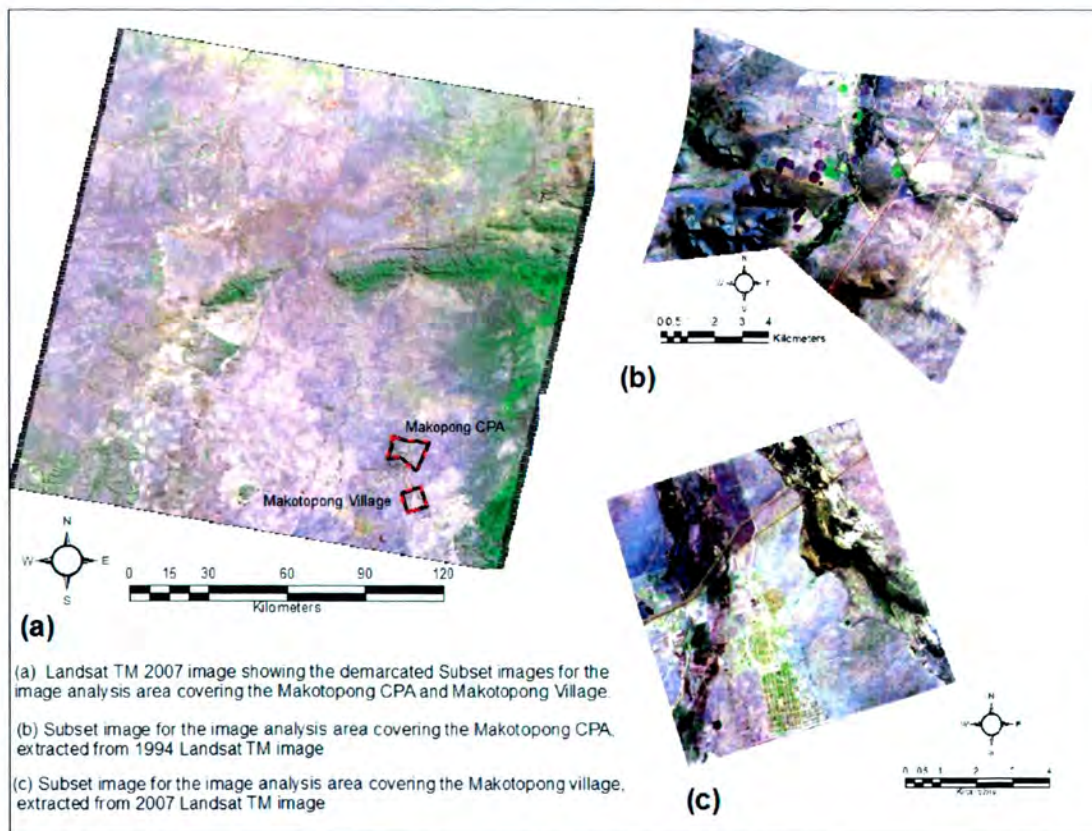


Figure 2: A 2007 Landsat TM image showing the demarcated Subset images for the image analysis area covering the Makotopong CPA and Makotopong Village.

In total, four subset images were delineated based on the 1:50 000 topographic maps. The four subset images were extracted covering Makotopong CPA (there originally place of the Makotopong people) 30-35km north of Polokwane (in the land comprised of farms Roodewal 808 LS, Ruigedraai 809 LS, and Salamis 807 LS) along the N1 road [Figure 1; and Figure 2(b)]. Under the apartheid regime laws, the community of Makotopong were forcibly relocated from their land to Makotopong village (relocated place of the Makotopong people) comprised of farm Nooitgedacht 913 LS east of Onverwacht 914 LS north east of Polokwane along the R81 road [Figure 1; and Figure 2(c)] (Moabelo, 2007). For this reason, it was comprehended that to satisfactorily analyse the consequences of the land reform programme in land use and land cover changes in Makotopong, it is important to analyse the changes occurring within the Makotopong village and the Makotopong CPA. Comparing the land cover and land use change between the Makotopong CPA and the Makotopong village ensures a clear interpretation of the drivers of change within the land under restitution (Makotopong CPA).

3.2.3. Image enhancement

Each image subset was enhanced using histogram equalisation as to obtain high quality image visualisation and to adequately distinguish the land use and land cover features. Krishnakumar *et al.* (2011) argued that image enhancement through histogram equalisation method enhances the distinction between land-use and/or land-cover features. The objective of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features in the scene (Lillesand *et al.*, 2004).

3.3. Image Classification

The aim of image classification is to replace visual analysis of the image with quantitative techniques for automating the identification of land cover types in a scene (Lillesand *et al.*, 2004). Traditionally, image classification comprises of two main classification types which are supervised and unsupervised classification (Awotwi, 2009). Unsupervised classification is a type of image classification procedure in which algorithms are used to examine the unknown pixels in an image and aggregate them into a number of classes based on the natural grouping or clusters present in the image values, without utilising training data as the basis for classification. Whereas supervised classification is a type of image classification process in which the image analyst compile a numerical interpretation key that describes the spectral

attributes for each feature type of interest, in the pixel categorisation process by making use of representative sample sites of known cover type. Hybrid classifications are image classification types that use both techniques (supervised and unsupervised) to make the classification process more efficient and accurate. According to Lillesand *et al.* (2004), various forms of hybrid classification have been developed to either simplify or improve the precision of purely supervised and unsupervised procedures.

3.3.1. Hybrid classification process

Hybrid classification was employed in this study because of its ability to analyse composite variability in the spectral response patterns for distinct cover types such as in vegetation mapping (Witt, 2001) as was the case in this study. Moreover, it advances the precision of purely supervised or unsupervised classification (Lillesand *et al.*, 2004).

In this study, a maximum of 15 spectral signature clusters were selected using the unsupervised iterative self-organising data analysis (ISODATA) algorithm. The signature clusters containing a small number of pixels were deleted while the most dominant signature classes that occur within each image were extracted. The spectral signatures resulting from ISODATA algorithm were then edited and named. The signatures were named based on the comparison with Google earth imagery and the topographic maps. This was achieved by checking that the specific clusters coincide with the information on the reference data. The signature file after the unsupervised ISODATA algorithm was composed mainly of woody, shrubs, grasslands and agricultural fallow land for all subset images. These signature files were further edited, adding the signature cluster for agricultural crop land and built-up land for both the 2007 and 1994 Makotopong CPA subset images.

The signature clusters for agricultural crop land and built-up land were added on the signature file using elements of supervised classification as outlined by Yang (2010). This was achieved through digitising polygons representing the features from the respective subset images and adding their spectral signatures to the signature file generated through the ISODATA clustering. Yang (2010) noted that in the pixel categorisation process of supervised classification, different numbers of areas or region of interest with known cover types that were ground verified in advance, are selected and digitised on each image as the training sample to represent respective sub-classes. The final output signature file composed of six signature clusters (woody, shrubs, grasslands, agricultural fallow land, agricultural crop

land and build-up land) for both the 2007 and 1994 Makotopong CPA subset images and five signature clusters (woody, shrubs, grasslands, agricultural fallow, and build-up land) for both the 2007 and 1994 Makotopong village subset images. This was due to the fact that there were no agricultural crop land cover class within the Makotopong village and therefore its omission from the classification process.

The spectral signatures file generated were then comprehensively utilized in a supervised maximum likelihood classification. According to Lillesand *et al.* (2004), maximum likelihood is a type of classification process that assumes that the data for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Maximum likelihood classification was utilised for this study because it yields the best overall accuracy (Yang, 2010).

3.3.2. Development of classification scheme

The classification of the four subset images was aimed at making distinction between major land cover classes (Figure 3). The names for major land cover types followed the standard land cover classification scheme for remote sensing in South Africa (Thompson, 1996). The classes shown in (Table 2) were extracted as thematic classes from the images and for which area statistics were generated.

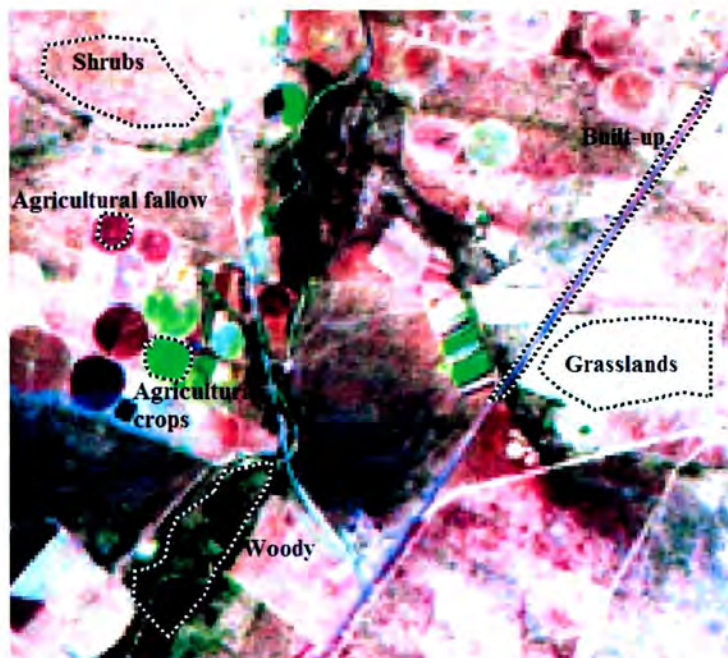


Figure 3: Spectral differences of the different land cover types-Makotopong CPA.

Table 2: Description of land cover classes

Land cover	Description
Woody	Plant community characterised by vegetation dominated by plants that use wood as its structural tissue, usually either trees shrubs, or lianas
Shrubs	Plant community characterised by vegetation dominated by shrubs (Drought resistant small thorns usually under 5m in height) often including grasses, herbs and geophytes
Grasslands	These are areas where the vegetation is dominated by grasses and other herbaceous (none woody) plants
Built-up	These are developed areas consisting of buildings such as houses, shops and tarred roads with very little open space
Agricultural crops	The land that is cultivated with crops that occupy the area
Agricultural fallow	The category include area under fallow land and land being prepared for planting

The identification of the land cover classes was based on comparison with Google Earth imagery and topographic maps as well as field work. Field survey was undertaken on 16 July 2011 in and around the village of Makotopong to verify the land cover types in the study area. This involved the use of a GPS with 5m accuracy level, a note book and a camera to identify and spatially locate land cover types within the study area. Once a land cover type was identified, a GPS point was taken while standing in the centre of the land cover type and detailed notes and a photo of this land cover type was taken. This was also the case with Wilson and Schroder (2007) study wherein field work was undertaken for the sole purpose of land cover class identification, from 1 to 5 April 2007, six years after image acquisition (April 2001). Field survey for accuracy assessment would be deemed inappropriate because historic images yield less reliable assessment from field visits due to the large time difference since imaging dates, given the possibility of vegetation change Munyati and Kabanda (2009). However, the changes in vegetation cover only result in an increase or decrease in the amount of vegetation cover while classes can still be identified (Munyati and Kabanda, 2009). Hence, field survey in this study was conducted with the sole purpose of gaining prior knowledge about the landscape within the study area that assisted in land cover class identification.

The final thematic maps produced through supervised maximum likelihood classification composed of six land cover classes (woody, shrubs, grasslands, agricultural fallow land, agricultural crop land and built-up land) for both the 2007 and 1994 Makotopong CPA subset images and five land cover classes (woody, shrubs, grasslands, agricultural fallow, and built-up land) for both the 2007 and 1994 Makotopong village subset images. The resulting thematic maps are presented in Chapter four.

3.3.3. Post-classification filtering

Classification of digital images can result in rather speckled images with unnaturally inhomogeneous areas. Using a mode filter, computation involves the most frequently occurring DN-value within the filter window surrounding each pixel. In this study, a 3*3 pixel mode filter was used to clean the classified images to the generalisation of the study area maps.

3.4. Classification Accuracy Assessment

According to Wilson and Schroder (2007), no classification is complete without an accuracy assessment. It was argued that, as image classification is based on class samples, it is therefore important to check and qualify the actual quality of the classification process (Kerle *et al.*, 2004). On the other hand, Awotwi (2009), argued that as there are always classification errors, the accuracy of the maps produced should always be questioned as to how accurate the maps are and whether the level of accuracy is sufficient for the ways in which the map information is to be used.

To assess the performance of the classification process in terms of accuracy, that is, the extent to which the land classes reflect those in reality, high resolution Google Earth image and 1:50 000 topographic maps of 1994 and 2007 were used as reference data. Other studies have used this approach (Vancutsen *et al.*, 2009). Erdas Imagine generated 194 and 190 random points for assessment for the 2007 Makotopong CPA and 2007 Makotopong village subset image respectively, while 200 Erdas Imagine generated random points were assessed for both the 1994 Makotopong CPA and 1994 Makotopong village subset image.

The result of an accuracy assessment provided with the overall accuracy of each classified image based on an average of the accuracies for each land cover class in that classified image. Additionally, this study acknowledges that one of the most common techniques of

articulating classification accuracy is through the preparation of classification error matrix (Lillesand *et al.*, 2004). In this study, the reference data and the classified image data were tabulated to form an error matrix. This was achieved by comparing on a category-by-category basis the relationship between known reference data and the corresponding results from the classified images for each land cover class. The most common elements used for assessing classification accuracy include overall accuracy, producer's accuracy, user's accuracy and Kappa statistics. Overall accuracy was calculated by dividing the number of correctly classified pixels in each category (the sum of the elements along the major diagonal) by the total number of reference pixels. Producer's accuracy was calculated by dividing the number of correctly classified pixels in each category (on the major diagonals) by the number of training set pixels used for the category (column total). Dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (row totals) resulted in the user's accuracy. The KHAT or kappa statistic is also calculated as it gives an indication of the extent to which the producer's accuracy, user's accuracy and overall accuracy are due to "true agreement versus "chance" agreement (Lillesand *et al.*, 2004). The kappa statistic is given by the formula:

$$\hat{K} = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \cdot x_{+i})}$$

Where

r = number of rows in the error matrix, x_{ii} = number of observation in row i (on the major diagonals), x_{i+} = total of observation in row i (shown as marginal total to right of the matrix), x_{+i} = total of observation in column i (shown as marginal total at bottom of the matrix), N = total number of observations included in matrix (Lillesand *et al.*, 2004).

Kappa statistic is advantageous because unlike overall accuracy, it considers omission and commission errors, thereby giving a less biased accuracy. In addition, it can be used as a basis for determining the statistical significance of any given matrix (Jensen, 2008). The resulting classification error matrix for the subset images are presented in chapter 4.

3.5. Change Detection

The process of creating land cover maps and or deriving land use and land cover change statistics involved the application of change detection techniques. Singh (1989) defined change detection as a technique used in remote sensing to determine the changes in a

particular research object between two or more time periods. The process involves the use of multitemporal data sets to discriminate areas of land cover change between dates of imaging (Lillesand *et al.*, 2004). During the process, various time-series classification and clustering methods are used to detect change whenever pixel spectral-temporal characteristics change to a different land cover type.

In this study, post classification comparison was employed from the 1994 and 2007 images that were independently classified and registered in order to employ the algorithm to determine those pixels with a change after image classification (Lillesand *et al.*, 2004). The classification allows the analyst to know the extent and nature of changes observed, i.e. the transition between different land cover classes and the correspondent area of change. This was developed using a change detection matrix with each land cover class having a unique code. This matrix was used to distinguish the entire change analysis in one view and is thus a powerful tool for examining landscape change. In addition, by applying the change detection codes to the comparison of two classified images, “from-to” change information and the kind of landscape transformations that have occurred can be easily calculated and mapped. In addition, land cover change areal statistics were summarised to express the net land cover lost and gained by each class. This was accomplished by subtracting the total amount of land cover gain from the total amount of loss. Statistics were compiled in the Microsoft Excel program to determine the specific nature of changes between dates of imagery, i.e. the size of the differences between the dates and the direction (positive and negative) in each land cover type. The results in the form of statistic tables, land cover maps and the nature of the change detected are presented in Chapter 4.

4. RESULTS AND DISCUSSION

This chapter presents the results of the analysis of data in the form of land cover maps, classification error matrix tables, land cover change tables and land cover change graphs. It also discusses the possible reasons for the observed land use and land cover changes.

4.1. Classification Accuracy Assessment

An error matrix was generated for the 1994 and 2007 land cover maps and the results presented in the form of error matrix tables. The error matrix tables (Table 3, Table 4, Table 5, and Table 6) produced for each classified land cover map present a measure of how many ground truth pixels were classified correctly.

4.1.1. Classification accuracy assessment for Makotopong CPA land-cover maps

The resulting accuracy reports present classification assessment by providing the overall accuracy of each classified image for Makotopong CPA based on an average of the accuracies for each land cover class in that classified image (Table 3, Table 4).

Table 3: Error matrix of land cover classes for 1994 Makotopong CPA

Classification Data	Reference Data							
Class	Shrubs	Built-up	Agricultural Fallow	Agricultural Crops	Grasslands	Woody	Row Total	User's Accuracy (%)
Shrubs	69	0	0	1	0	6	75	92
Built-up	0	6	0	0	0	2	8	75
Agricultural Fallow	1	0	6	0	0	1	8	75
Agricultural Crops	0	0	1	6	0	0	7	100
Grasslands	4	0	3	0	40	0	47	87.3
Woody	2	0	0	1	0	52	55	94.6
Column Total	76	6	10	8	40	61	200	
Producer's Accuracy (%)	90.8	88.9	75	87.5	100	85.3		

Overall classification accuracy = 90.5%; kappa statistics = 0.86

Table 4: Error matrix of land cover classes for 2007 Makotopong CPA

Classification Data	Reference Data							
Class	Shrubs	Built-up	Grasslands	Agricultural Fallow	Woody	Agricultural Crops	Row Total	User's Accuracy (%)
Shrubs	74	0	1	1	6	0	82	90.3
Built-up	0	8	0	0	3	0	11	72.7
Grasslands	1	0	23	3	0	0	27	85.2
Agricultural Fallow	0	0	0	7	0	0	7	100
Woody	6	1	1	0	56	0	64	87.5
Agricultural Crops	0	0	0	0	0	3	3	100
Column Total	81	9	25	11	65	3	194	
Producer's Accuracy (%)	91.4	88.9	92	63.6	86.2	100		

Overall classification accuracy = 88.1 % and kappa statistics = 0.83

In evaluating classification accuracy for the 1994 Makotopong CPA land cover map, a total of 200 randomly sampled points were used for the calculation of error matrix (Table 3), whereas a total of 194 randomly sampled points were used for the calculation of error matrix for the 2007 Makotopong CPA land cover map (Table 4). The overall classification accuracy for all land cover classes was 90.5% and 88.1% while the overall kappa statistics was 0.86 and 0.83 for the 1994 Makotopong CPA land cover map (Table 3) and for the 2007 Makotopong CPA land cover map (Table 4) respectively. Within all the land cover classes for the 2007 Makotopong CPA land cover map (Table 4), the poorest classification accuracy was achieved for agricultural fallow with producer accuracy at 63.6% and user's accuracy at 100% (Table 4). These results generally suggest that even though 63.6% of the agricultural fallow land has been correctly classified as agricultural fallow, 100% of the areas classified as agricultural fallow within the classification actually represent that category on the ground. However 63.6% producer's accuracy and 100% user's accuracy was achieved for Agricultural fallow because of spectral confusion between agricultural fallow and grasslands land cover classes (Table 4). The observed spectral confusion between agricultural fallow and grasslands land cover classes can be best explained by comparison with reference data which showed that the land classified as agricultural fallow in 2007 was actually abandoned agricultural land (that is including grasses, small shrubs and exposed soil).

However, in exception of agricultural fallow, all producer's accuracy and user's accuracy for all the other classes are above 72.7% for the 2007 Makotopong CPA land cover map (Table 4), while all producer's accuracy and user's accuracy across all categories for the 1994 Makotopong CPA land cover map were above 75% (Table 3). These results generally mean that the overall classification accuracy is good and that there is an acceptable agreement that exist between the classification and the actual land cover categories.

4.1.2. Classification accuracy assessment for Makotopong village land-cover maps

The accuracy reports presents the classification results for the supervised images based on the calculations of the most common elements used for assessing classification accuracy that include overall accuracy, producer's accuracy, user's accuracy and Kappa statistics (Tables 5, and 6). In evaluating classification accuracy for the 1994 Makotopong village land cover map, 200 randomly sampled points were used for the calculation of error matrix (Table 5).

Table 5: Error matrix of land cover classes for 1994 Makotopong village

Classification Data	Reference Data						
Class	Built-up	Grasslands	Woody	Agricultural Fallow	Shrubs	Row Total	User's Accuracy (%)
Built-up	8	0	1	0	2	11	72.7
Grasslands	1	22	0	1	3	27	81.5
Woody	0	1	49	0	0	50	94.3
Agricultural Fallow	0	0	3	14	1	18	77.8
Shrubs	3	3	4	2	82	94	83.3
Column Total	12	26	57	17	88	200	
Producer's Accuracy (%)	66.7	84.6	85.9	82.4	93.2		

Overall classification accuracy = 86.2 %; and kappa statistics = 0.80%

Within all the land cover classes, the greatest classification accuracy was achieved for shrub with producer's accuracy and user's accuracy of 93.2% and 83.3% respectively, and woody with producer's accuracy and user's accuracy of 85.9% and 94% respectively. High accuracy values were achieved for woody owing to that winter images were selected for this area as it is mainly trees (and little to no grass) that are in leafy and thus reducing the spectral confusion between woody and grasslands. Additionally, the error matrix indicates that the land class that showed the smallest classification accuracy was built-up with producer's

accuracy and user's accuracy of 66.7% and 72.7% respectively. The most significant confusion was between built-up areas and shrubs. Built-up areas and shrubs occur in similar environments, often in adjacent or mixed stands and have similar spectral signatures. The decrease could be an aspect of misclassification due to similarity between roofing materials and the surrounding pixels dominated by shallow soils and rock outcrops. During dry periods when there is little chlorophyll in the vegetation, grazing causes exposure of soil between remaining vegetation resulting into similar spectral values making it difficult to distinguish the two classes. In addition, most rural homes are built using materials such as concrete, asphalt, trees, grass, water, soil, and all kinds of roofing materials, which have different radiometric characteristics (Zhang *et al.*, 2001). Nonetheless, the overall producer's and user's accuracy for all classes except built up areas are above 77.8% (Table 5).

Table 6: Error matrix of land cover classes for 2007 Makotopong village

Classification Data	Reference Data						
	Built-up	Agricultural Fallow	Grasslands	Woody	Shrubs	Row Total	Users Accuracy (%)
Built-up	18	0	1	3	1	24	75
Agricultural Fallow	0	9	0	0	2	11	81.8
Grasslands	3	0	16	0	0	19	84.2
Woody	2	0	0	60	0	62	100
Shrubs	2	3	0	2	68	75	86.8
Column Total	25	12	17	65	71	191	
Producers Accuracy (%)	72	75	94.1	92.3	95		

Overall classification accuracy = 89.5 % and kappa statistics = 0.85

In assessing classification accuracies for the 2007 Makotopong village land cover map, 191 randomly sampled points were used for the calculation of error matrix (Table 6). Within all land cover classes, the greatest classification accuracy was achieved for shrubs (95%) and grasslands (94.1%), while the land class that showed the smallest classification accuracy were built-up at 72% and (Table 6). The low accuracies achieved for built-up can be attributed to the observed spectral confusion between built-up and shrub classes as a result of heterogeneous nature of built-up areas. The producer's accuracy and user's accuracy across all categories were above 72% (Table 6). The overall classification accuracy for all land cover classes was 89.5% and the overall kappa statistics was 0.85.

Despite the observed misclassifications that occurred across nearly all categories, the overall classification accuracy for all land cover classes was 86.2% and 89.5% while the overall kappa statistics was 0.80 and 0.85 for the 1994 Makotopong village land cover map (Table 5) and for the 2007 Makotopong village land cover map (Table 6) respectively. These results generally suggest that the overall classification accuracy for both maps is acceptable and that the percentages of the correct values of an error matrix are due to true agreement between the classification and the actual land cover categories rather than chance agreement.

4.2. Land Cover Distribution

The total area of Makotopong CPA covered by each subset image for both 1994 and 2007 was 11283.75 ha while the total area of Makotopong village covered for both imagery dates was 5824.8 ha.

4.2.1. Spatial distribution of land cover classes in Makotopong CPA

Classification of land cover in the Makotopong CPA produced six major classes namely; woody, shrubs, grasslands, agricultural fallow, agricultural crops and built-up (Figure 4).

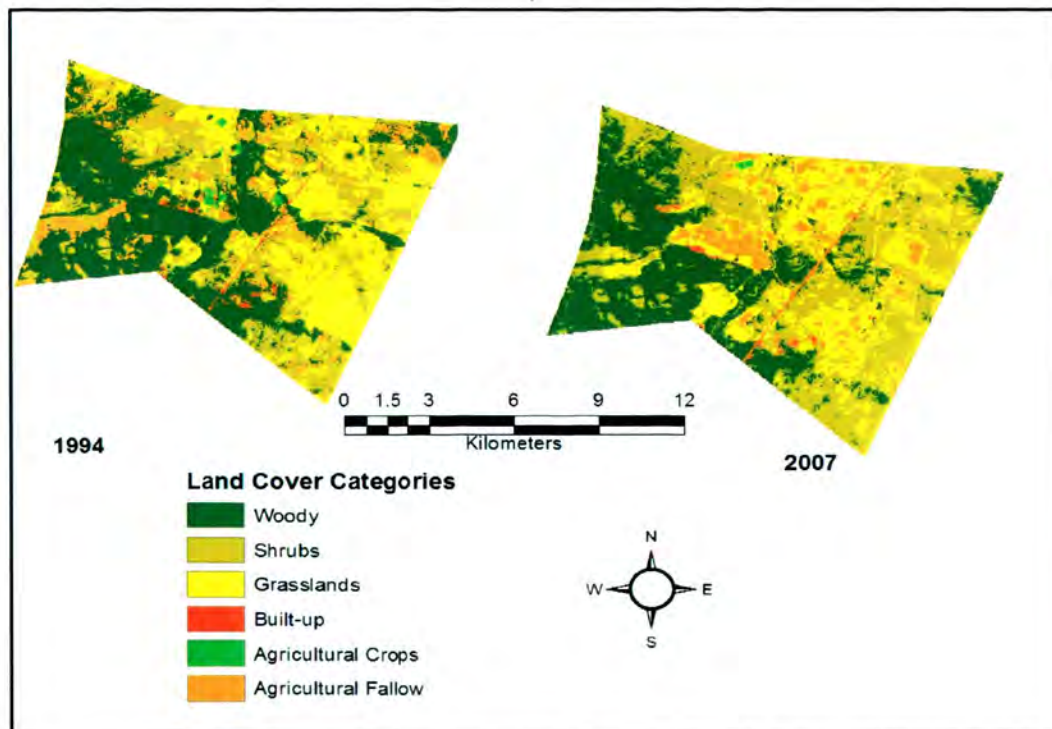


Figure 4: Land cover map for Makotopong CPA from 1994-2007

The classification indicates large areas of woody mainly located along the west part of the study area occupying 3994.83 ha (35.4%) and shrubs that spread out within the Makotopong CPA occupying 3863.91 ha (34.24%). Grasslands, which are simultaneously used as grazing areas after crop harvest, formed the next dominant land cover type - covering 2408.13 ha of the total study area representing 21.34% (Figure 4 and Table 7). Agricultural fallow class formed another class with up to 836.1 ha amounting to 7.41%. Built-up areas, mainly in the form transport routes and settlements represent a minor extension of about 102.69 ha covering about 0.91% of the study area. The smallest category was occupied by agricultural crops with 78.03 ha and 0.70% representation (Figure 4 and Table 7).

4.2.2. Spatial distribution of land cover classes in Makotopong village

Classification of land cover in the village of Makotopong derived five major classes namely; woody, shrubs, grasslands, agricultural fallow, and built-up (Figure 5).

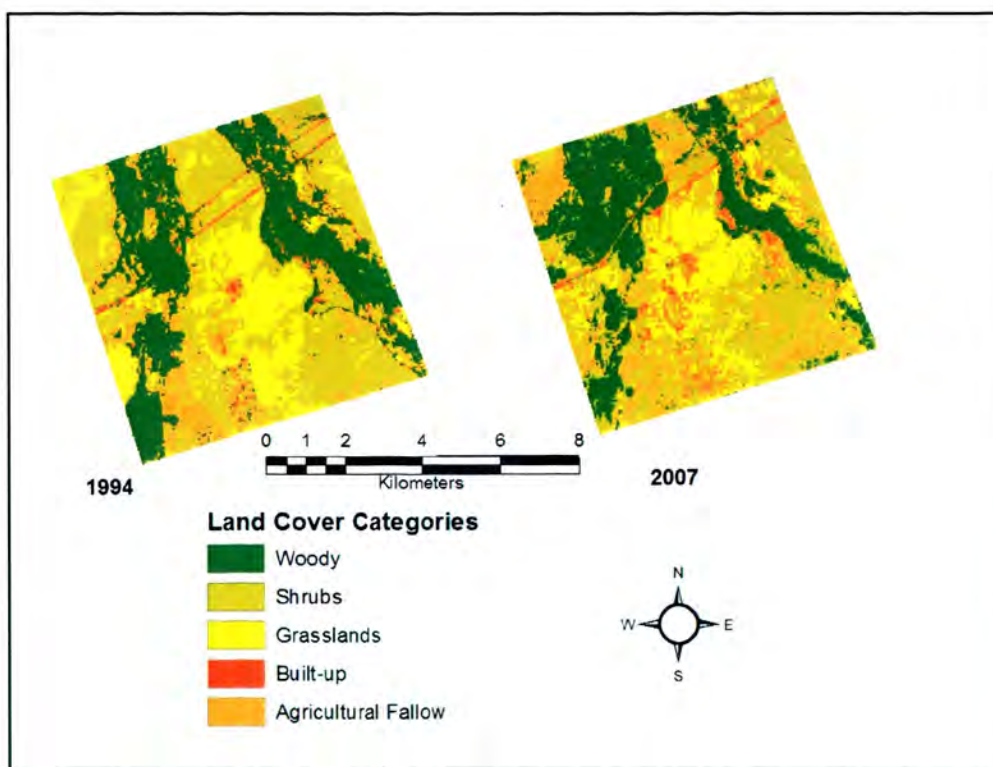


Figure 5: Land cover maps for Makotopong village from 1994-2007

The land cover distribution for Makotopong village indicates large areas of shrubs that are spread out across the study area occupying 2730.15 ha (47%) and woody land cover class that is located mainly on both the eastern and western sides of the study area and occupies 1629.27 ha (28%) of the total area. The next land cover is grasslands mainly located in the

most central part of the study area, occupying 818.91 ha of the study area representing 14%. Agricultural fallow, which are simultaneously used as grazing areas after crop harvest, formed one of the minor land cover category covering 477.54 ha of the total study area representing 8%. Built-up areas formed the next minor class occupying 168.93 ha demonstrating an extent of 3% of the total land surface in the Makotopong village.

4.3. Land Cover Change: Trend, Rate and Magnitude

4.3.1. Makotopong CPA

Table 7 and Figure 6 present the quantified results in terms of area covered per each land cover class and the nature of the detected change within Makotopong CPA. Results show that there has been a great decline in area covered by agricultural crops from 1994 to 2007 as well as a loss in area covered by grasslands. Agricultural crops declined from 78.03 ha in 1994 to 20.43 ha in 2007 while grasslands showed a decline from 2408.13 ha in 1994 to 2027.97 ha in 2007. The year 2007 depicts an increase in agricultural fallow land from 836.1 ha in 1994 to 886.05 ha in 2007 within Makotopong CPA. The decline in agricultural productivity can be attributed to the change of land ownership and its management because of the land restitution policy. Change of ownership results in lack of managerial skills through restitution of commercial agricultural farms from the hands of the experienced commercial farmers to the inexperienced land claimants (McCusker, 2004; Moabelo, 2007).

Table 7: Land cover change for Makotopong CPA 1994-2007

Class	1994		2007		Change 1994-2007	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Shrubs	3863.97	34.24	5009.49	44.4	+1145.52	+30
Built-up	102.69	0.91	120.33	1.07	+17.64	+17
Grasslands	2408.13	21.34	2027.97	17.97	-380.16	-15
Agricultural Fallow	836.1	7.41	886.05	7.85	+49.88	+6
Woody	3994.83	35.4	3219.48	28.53	-775.35	-19
Agricultural Crops	78.03	0.70	20.43	0.18	-57.6	-74
Total	11283.75	100	11283.75	100		

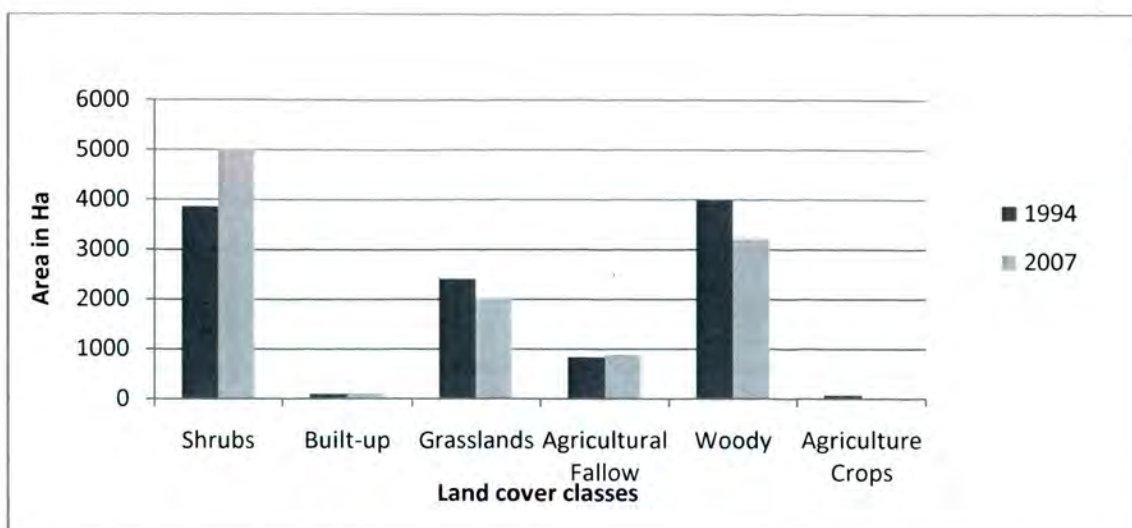


Figure 6: Land cover change graph for Makotopong CPA 1994-2007

The results indicate that the decline in agricultural crops was enormous, while shrubs had shown a marked increase. Agricultural crops decreased by about 74% from 78.03 ha in 1994 to 20.43 ha in 2007, while shrubs have shown an increase of about 30%, that is from 3863.97 ha in 1994 to 5009.49 ha in 2007 (Table 7). There have also been a decrease in area covered by grasslands and woody, while there is an increase in built-up and agricultural fallow (Table 7). Although agricultural crops covered a small portion of the image analysis area as compared to shrubs, woody and grasslands (Figures 4 and 6), agricultural crops has showed a markedly change of about 74% decrease from 1994 to 2007 (Table 7). The decline in agricultural crops is a clear indication of the lack of post transfer activities because of land restitution. However, the results show a slight increase in agricultural fallow from about 7.41% of the total image analysis area in 1994 to 7.85% in 2007 (Table 7).

4.3.2. Makotopong village

By comparing the two images (Figure 5), it can be detected that some of the area covered by woody land cover class in 1994 has been replaced by shrubs in 2007.

Table 8: Land cover changes for Makotopong village from 1994-2007

Class	1994		2007		Change 1994-2007	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Shrubs	2730.15	47	2688.03	46	-42.12	-2
Built-up	168.93	3	289.08	6	+160.11	+95
Grasslands	818.91	14	764.28	13	-54.63	-7
Agricultural Fallow	477.54	8	532.08	9	+54.54	+11
Woody	1629.27	28	1551.33	26	-77.94	-5
Total	5824.8	100	5824.8	100		

The results presented in Table 8 indicate that built-up areas had the greatest amount of land cover change observed (+95 percentage of change) even though built-up areas makes up the smallest percentages of the total image analysis area (Table 8 and Figure 7) for both dates of imagery.

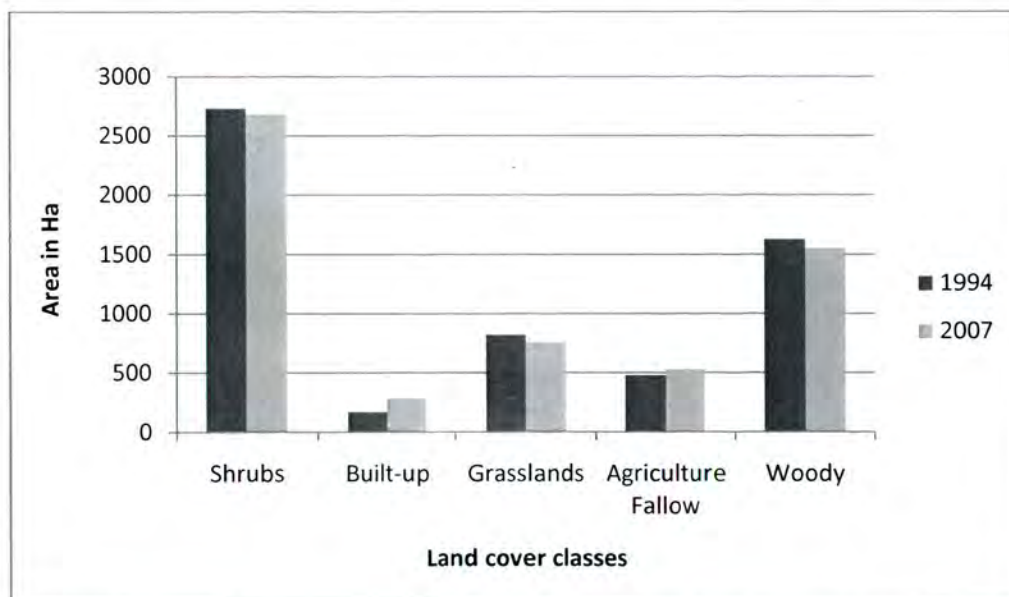


Figure 7: Land cover change graph for Makotopong village from 1994-2007

The 1994 and 2007 land cover types clearly indicate that there have been a significant increase in built-up land-cover type as well as an increase in agricultural fallow and a notable decrease in shrubs, grasslands, and woody land-cover types between dates of imagery (Figure 7 and Table 8). The agricultural land on the other hand showed an increase of about 11% between dates of imagery, from a total area covering about 8% (477.54 ha) of the image analysis area (5824.8 ha) in 1994 to about 9% (532.08 ha) in 2007 (Table 8). The area covered by built-up showed an increase of about 95%, from 168.93 ha in 1994 to 2989.08 ha

in 2007 (Table 8). Even though in comparison, built-up land makes up a small proportion of the total image analysis area (5824.8 ha) for both the 1994 and 2007 image (Fig. 7), built up land has shown the greatest percentages of change between imagery dates. There has been an increase in built-up land, from 3% of the total analysis area in 1994 to 6% in 2007 showing an overall change of 95% of change between 1994 and 2007 (Table 8). The expansion in residential areas within Makotopong village can be attributed to population growth that showed an increase from 7593 in 2001 to 8775 in 2007 (Stats South Africa, 2012).

4.4. Post Classification Analysis for Makotopong CPA

Post classification analysis enables assessment of the “from” “to” land cover change that occurred within the study sites between imagery dates. The nature of change is presented in (Figure 8) (the figures zoom in some sections within the study area to emphasise land cover that has changed), and (Table 9). The “from” “to” land cover changes and the plausible reasons for the change are further discussed.

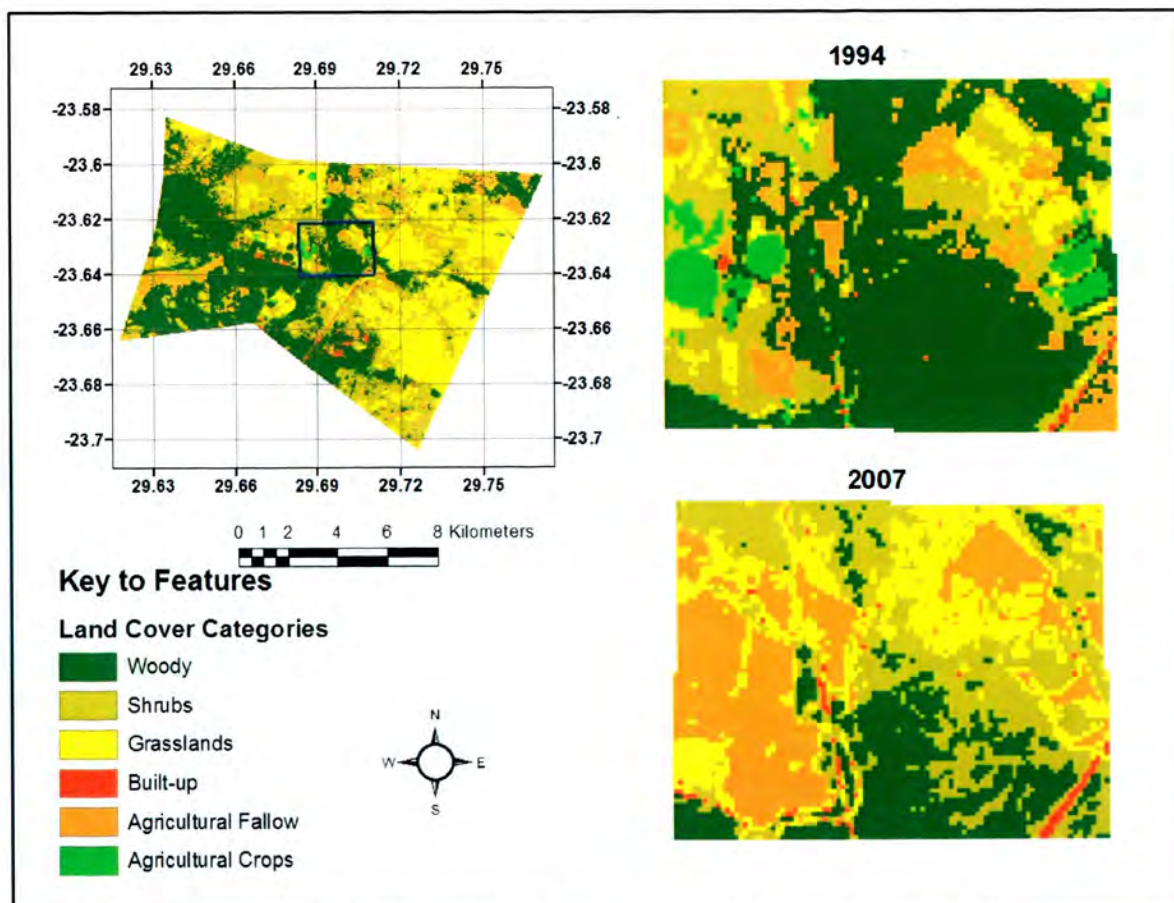


Figure 8: Post classification map for Makotopong CPA from 1994-2007

Table 9: Post classification Land cover changes for Makotopong CPA 1994-2007

	Class converted to (ha)						
Class	Shrubs	Built-up	Agricultural Fallow	Agricultural Crops	Grasslands	Woody	Area decreased (ha)
Shrubs	2311.56	28.44	290.34	3.96	902.7	301.95	1527.3 (-40%)
Built-up	36.36	38.7	1.71	0	11.7	13.77	63.54 (-62%)
Agricultural Fallow	426.33	1.8	94.86	0	135.27	175.77	739.17 (-88%)
Agricultural Crops	15.39	1.08	37.62	0.72	18.27	4.86	77.22 (-98%)
Grasslands	1236.51	0	375.57	13.05	726.66	46.98	1672.1 (-69%)
Woody	959.94	42.12	82.8	2.61	226.62	2670.75	1314.09 (-33%)
Area increased (ha)	2674.53 (69%)	73.44 (72%)	788.04 (94%)	19.62 (25%)	1294.56 (54%)	543.33 (14%)	

(A) *Shrubs*

The total land area within the Makotopong CPA that was converted from various classes to shrubs land amounted to 2674.53 ha (69%), with 2311.56 ha of shrubs area remaining unchanged, though 1527.3 ha (-40%) of shrubs converted to various classes (Table 9). The increase in shrubs area was at the expense of agricultural fallow, agricultural crops, grasslands, woody and built-up areas (Figure 8). Shrubs area expanded by 1236.51 ha from previously grasslands region; 959.94 ha from previously woody areas; 426.33 ha from previously agricultural fallow areas. Surprisingly, there is an observed change from built-up areas (36.36 ha) to shrubs. Overall, this represents a net gain of 2674.53 ha (69%) from other land cover categories. The increase in shrubs from woody, agricultural crop, agricultural fallow and grasslands areas can be attributed to increasing demands for food (vegetation clearing for cultivated lands) and vegetation succession. The practice in the area is that woody areas are initially cleared for agricultural crops area. However, due to the change of land ownership and its management because of the land restitution policy, agricultural crops area became abandoned yielding to agricultural fallow. With prolonged fallow, grasslands encroached the areas which eventually developed to shrub areas, given the 13 years between imagery dates. There is always a closed canopy of tree saplings after 10 to 15 years following many other secondary plant successions in case of prolonged fallow (Pidwirny, 2011).

(B) Built-up

The results have indicated that a total of 73.44 ha of land area within the study area were converted from various classes to built-up land, with 38.7 ha remaining as built-up land (Table 9). Moreover, the increase in built-up land took place largely at the decline of shrubs, woody, agricultural fallow, and agricultural crops areas (Figure 8). Built-up land cover type increased by 28.44 ha from previously shrubs region; 42.12 ha from previously woody areas; 1.8 ha from previously agricultural fallow areas; and 1.08 ha from formerly agricultural crops areas. Overall, this represents a net gain of 73.44 ha (72%) from other land cover categories. The increase in built-up areas from woody and shrubs area can be attributed to vegetation clearing for transport routes, and houses construction. Noticeable are the changes from build-up area (1527.3ha) to agricultural crops and agricultural fallow. The increase can be attributed to the observed general misclassification as indicated on (Tables 3 and 4).

(C) Grasslands

Within the Makotopong CPA a total of 1294.56 ha of land area were converted from various classes to grasslands, while 726.66 ha of grassland area remained unchanged and 1672.1 ha of grassland area were converted to various classes (Table 9). Decrease in grasslands resulted mostly due to expansion of shrubs (1236.51 ha), agricultural fallow (375.57 ha), woody (46.98 ha), and agricultural crops (13.05 ha) areas (Table 9 and Figure 8). Overall, this represents a net loss of 1672.1 ha (-69%) to other land cover categories. The decrease from grasslands to shrubs and woody can also be attributed to vegetation succession from grasslands to shrubs and subsequently to woody areas given the 13 years' time difference between imagery dates (Pidwirny, 2011). The initial secondary succession stage begins with communities of perennials and grasses, shrubs, softwood trees and shrubs, and finally hardwood trees and shrubs (Pidwirny, 2011).

(D) Agricultural fallow

By analysing the changes that occurred to the landscape, a total of 788.04 ha were converted to agricultural fallow from various classes. The transformation occurred mainly at the expense of shrubs (290.34 ha), agricultural crops (37.62 ha), woody (82.8 ha), and surprisingly built-up areas (1.71 ha). Overall, this represents a net gain of 788.04 ha (94%) from other land cover categories. The indiscriminate cutting of trees by villagers for domestic uses such as construction of structures, fence lines, and for firewood accounts for the change

in land-use/land-cover. However, most of the land meant for agriculture was observed to have been left fallow in the 2007 image. Increase of fallow areas could be attributed to the land restitution programme resulting in the change in the management of land where the new farmers do not have enough resources to sustain agricultural productivity.

(E) *Woody*

The results have indicated that 543.33 ha within the study site were converted from various classes to woody areas. This does not compensate for the loss of 1314.09 ha of woody areas to various classes (Table 9). The decrease in woody land occurred mainly at the expansion of shrubs, grasslands, agricultural fallow, built-up, and agricultural crops areas (Figure 8). Woody areas decreased by 959.94 ha from to shrubs; 226.62 ha to grasslands; 82.8 ha to agricultural fallow areas; 42.12 ha to built-up and 2.61 ha to agricultural crops areas. Overall, this represents a net loss of 1314.09 ha (-33%) to other land cover categories. The decrease in woody areas within the study site can be attributed to plant succession after rapid demands for agricultural lands that later became abandoned to grasslands and grasslands later developed to shrubs area given the time differences between imagery dates. In some cases, woody areas were cleared due to rapid demands of land for houses and transport routes.

(F) *Agricultural crops*

With regards to agricultural crops area, the results have indicated that a total of 19.62 ha within the Makotopong CPA was converted from various classes to agricultural crops land, with just 0.72 ha that remained unchanged as agricultural crops areas, whereas 77.22 ha of agricultural crops land converted to various classes (Table 9). These results generally indicate a decrease in agricultural crops areas. The decrease in agricultural crops land occurred primarily as agricultural fallow (37.62 ha), grasslands (18.27 ha), shrubs (15.39 ha), woody (4.86 ha), and built-up (1.08 ha) areas increased (Table 9 and Figure 8). Overall, this represents a net loss of 77.22 ha (-98%) to other land cover categories. Given the 13 years time difference between imagery dates, and the fact that there is always a closed canopy of tree saplings after 10 to 15 years during many other secondary plant successions (Tilman, 1987), the decrease in agricultural crops as an expansion of agricultural fallow, grasslands, shrubs and woody areas after abandonment can be attributed to plant succession. Moreover, according to Keeton (1986), secondary succession initial stages often proceed relatively quickly in abandoned croplands since the effects of previous communities are usually not wholly eroded. The first stage of succession on abandoned agricultural fields is usually

characterised by the pioneering colonisation of annual plant species. The following year, the annuals were quickly replaced by biennial plants and grasses, and then, about three to four years, the biennial and grass species gave way to perennial herbs and shrubs. After about five to 15 years, a number of different softwood tree species then colonised the sites (Pidwirny, 2011). However, the surprising decrease in agricultural crops to built-up areas can be attributed to the general misclassification as indicated in Tables 3 and 4.

4.5. Post Classification Analysis for Makotopong Village

Post classification analysis enables assessment of the “from” “to” land cover change that occurred within the study sites between imagery dates. The nature of change is presented in Table 10 and Figure 9 (the figures zoom in some sections within the study area to emphasise land cover that has changed from 1994 to 2007).

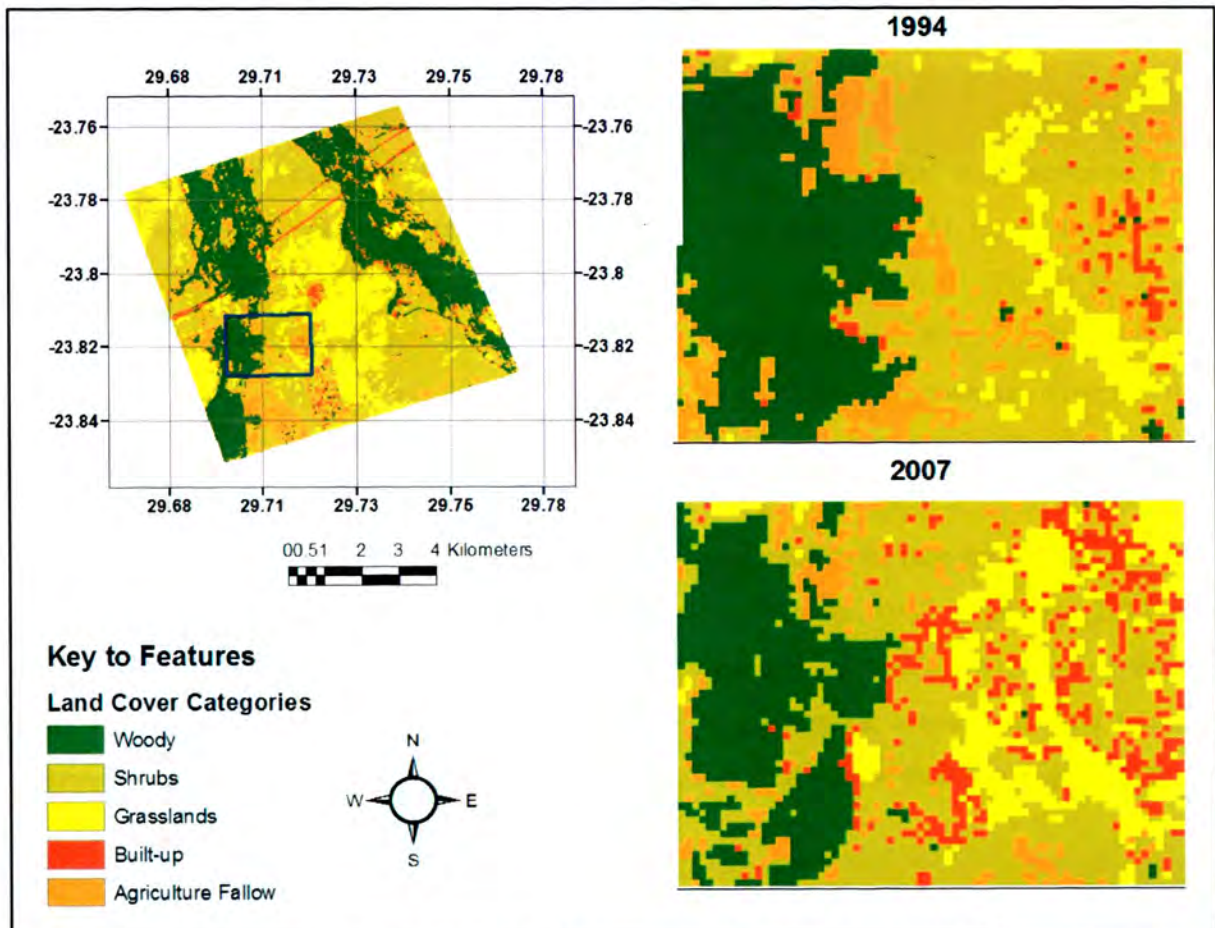


Figure 9: Post classification map for Makotopong village from 1994-2007

Table 10: Post classification Land cover changes for Makotopong village 1994-2007

	Class converted to (ha)					
Class	Shrubs	Built-up	Agricultural Fallow	Grasslands	Woody	Area decreased (ha)
Shrubs	1552.41	139.59	371.16	30.73	293.22	1154.7 (-42%)
Built-up	93.06	45.54	1.26	3.78	24.75	122.85 (-73%)
Agricultural Fallow	272.16	24.3	66.33	30.06	83.07	409.59 (-86%)
Grasslands	346.14	15.66	64.17	369.09	20.34	446.31 (-55%)
Woody	402.75	63	25.38	6.12	1124.55	497.25 (-31%)
Area increased (ha)	1114.11 (41%)	242.55 (144%)	461.97 (97%)	390.69 (48%)	421.38 (26%)	

(A) *Shrubs*

Table 10 shows the total land area within the Makotopong village that was converted from various classes to shrubs land amounted to 1114.11 ha, with 1552.41 ha of shrubs area unchanged, though 1154.7 ha of shrubs was converted to various classes (Figure 9). These results generally indicate a decrease in shrubs as agricultural fallow (371.16 ha), grasslands (350.73 ha), woody (293.22 ha) and built-up areas by (139.59 ha) expanded. Overall, this represents a net loss of 1154.7 ha (-42%) to other land cover categories. The decrease in shrubs at the expansion of wood areas can be attributed to plant succession given the 13 years period between imagery dates as there is always a closed canopy of tree saplings after 10 to 15 years during many other secondary plant successions (Tilman, 1987; Pidwirny, 2011). In addition, the expansion of agricultural fallow and grasslands areas at the expense of shrubs could be attributed to increasing demands for shelter (residential areas) and food (shrubs clearing for cultivated lands) and later cultivated areas are left fallow yielding to grasslands.

(B) *Built-up*

The results from Table 10 indicate that a total of 242.55 ha within the study site was converted from various classes to built-up land, with 45.54 ha that remained as built-up areas, whereas 122.85 ha were converted to various classes (Figure 9). Moreover, the increase in built-up land occurred mainly at the expense of shrubs, woody, and agricultural fallow areas. Built-up areas increased by 139.59 ha from previously shrubs region, 63 ha from woody

areas, 24.3 ha from agricultural fallow areas and 15.66 ha from grasslands areas. Overall, this represents a net gain of 242.55 ha (144%) from other land cover categories. The rapid increase in built-up areas as a result from expansion in residential areas within Makotopong village can be attributed to increasing demands for shelter as a result of population growth within Makotopong village that showed an increase from 7593 in 2001 to 8775 in 2007 (Statistics South Africa, 2012).

(C) Grasslands

Within the Makotopong village, a total of 390.69 ha of land area were converted from various classes to grasslands land, with 369.09 ha of grasslands areas unchanged, while 446.31 ha were converted to various classes (Table 10). This indicated a decrease in grasslands areas that resulted mostly to the expansion of shrubs (346.14 ha), woody (46.98 ha), agricultural fallow (64.17 ha), woody (20.34 ha) and built-up (15.66 ha) areas from previously grasslands areas (Figure 9). Overall, this represents a net loss of 446.31 ha (-55%) to other land cover categories. However, the decrease in grasslands at the expansion of agricultural fallow areas can be attributed to land use change because of an increasing demand for food leading to the conversion of grasslands to cultivated areas. In addition, decrease in grasslands at the expansion of shrubs and woody areas can be attributed to plant succession from grasslands to shrubs and from shrubs to woody areas, given the 13 years period difference between imagery dates. According to Bureau of Forestry (2003), trends in ecological succession begin with the low growing annual grasses from the 1st year. Perennial grasses and forbs stem from the 2nd to the 5th year, from the 3rd to the 10th year woody shrubs and shade intolerance trees seedlings invades perennial herbs and grasses. From the 10th to the 20th year pioneer trees form thicket and canopy dominates from the 20th to the 70th year depending on location, site history, soil moisture, topography and circumstance.

(D) Agricultural fallow

According to the post-classification analysis, 461.97 ha of land area within the Makotopong village were converted from various classes to agricultural fallow land, with 66.33 ha that was unchanged, whereas 409.59 ha of agricultural fallow land were converted to various classes (Table 10). This increase in agricultural fallow land occurred mainly at the decline of shrubs (371.16 ha), woody (25.38 ha), grasslands (64.17 ha) and built-up areas (1.26 ha) (Figure 9). Overall, this represents a net gain of 461.97 ha (41%) from other land cover

categories. The surprising increase in agricultural fallow at the expense of built-up areas can be attributed to general misclassification that occurred during the classification process as indicated in (Tables 5 and 6). Given that the images used in this study were taken during dry season (July), the general increase in agricultural fallow areas can be attributed to the common practice associated with subsistence farming in which there is an abandonment of cultivated area into grazing land during dry seasons.

(E) Woody

The total land area within the Makotopong village that was converted from various classes to woody areas amounted to 421.38 ha while 497.25 ha of woody areas converted to various classes (Table 10). Woody areas decreased by 402.75 ha to shrubs; 63 ha to built-up; 25.38 ha to agricultural fallow areas and 6.12 ha to grasslands areas (Figure 9). Overall, this represents a net loss of 497.25 ha (-31%) to other land cover categories. The decline in woody areas can be attributed to rapid demands for food (cultivated land), energy (fuel wood), construction material (wood), and shelter (housing).

Consequently, it was noted that the decline in woody areas can also be attributed to clear cutting and wood collection for fuel wood purposes as this is a common practice within rural areas. On the other hand it was also noted that some of the areas covered by grasslands in 1994 were transformed to shrubs in 2007 while the most noticeable transformation was an increase in the built-up areas from 1994 to 2007.

4.6. Implications of Land Restitution on Land Use/Land Cover Change in Makotopong Village and Makotopong CPA

Based on the research assumptions outlined in Section 1.5.2 of Chapter 1, the results of the study have indicated that within Makotopong CPA, agricultural productivity declined considerably from 1994 to 2007 as indicated by the decline in agricultural crops land cover type. Agricultural crops within the study area declined by 74%, from 78.03 ha of the total area within the study site in 1994 to 20.43 ha in 2007. Moreover, the results of the study also indicated that almost all total area of land within the Makotopong CPA that was classified as agricultural fallow in 1994 was being prepared for planting while the land classified as agricultural fallow in 2007 were actually abandoned agricultural areas. This was indicated during classification accuracy assessment and observed by the analysis of the error matrix in Table 4 which showed that there was a huge spectral confusion between agricultural fallow

and grasslands land cover classes. The observed spectral confusion between agricultural fallow and grasslands land cover classes were examined further through comparison with reference data, which showed that the land classified as agricultural fallow in 2007, was actually abandoned agricultural land (including grass, small shrubs and exposed soil). These findings concur with the observations by Moabelo (2007) which indicated that farming activities within the Makopong CPA came to a standstill after the land was restituted to the Makotopong Communal Property Association. The lack of farm managerial skills from the Makotopong CPA management committee was argued as the main reason behind the decline in post-transfer farming activities within the land restitution project (Moabelo, 2007).

The results showed that after land restitution there was a change in agricultural crops as the land ownership and management shifted from the hands of experienced commercial farmers to those of the inexperienced Makotopong community property association in 2002. Therefore, the major land use and land cover change, noticeably within the study area that can clearly be attributed to the unintended consequences of the implemented land restitution program in Makotopong CPA, was the decline agricultural crops and agricultural productivity. This was also observed in Kuemmale *et al.* (2006) wherein after the implementation of the land reform policy in the border triangle of Poland, Slovakia and Ukraine, there was a breakup of the agricultural sector in which large commercial farms were split-up into small holders' farms. Consequently, the disintegration of farmlands negatively affected agricultural productivity. This is an indication that land restitution significantly alters land use and land cover types. According to McCusker (2004) rural livelihoods, can be determined from spatially data analysis through lack of increase in productive land use, such a decrease in agricultural productivity as indicated by a decrease in agricultural land use on the CPA's. The observed decline in post-transfer activities, agricultural crops land cover type and abandonment that took place within the study area (Makotopong CPA) is a clear indication that the CPA after land transfer have failed to help create sustainable livelihoods. Similarly, Swinnen *et al.* (2009) documented the changes in agricultural output and productivity in the central and eastern European countries where agricultural output and productivity declined drastically since the implementation of the market reform policies. Furthermore, the study indicated that in the first year of policy transformation, gross agricultural output decreased in all countries by at least 20%, whereas the figure further plunged down to about 50% to 60% of the pre-reform output in certain countries throughout the 18 years study period.

Moreover, the underlying causes of the decline in agricultural productivity and a decline in the general status of the restituted land can be attributed to the actual management of the farm by the CPA's membership that was inconsistent, difficult, and ineffective and therefore the farm as a unit of production failed to materialise largely (McCusker, 2004). Daudi (2009) explains that the underlying causes of low agricultural productivity in Malawi could be closely linked to inadequate access to agricultural inputs as a result of widespread poverty that constrains farmers to access productivity enhancing inputs such as fertilisers, hybrid seeds and improved livestock breeds. Besides, Du Toit (2009) further highlighted that with regard to agricultural productivity within the Zebediela Citrus Estate in Limpopo province (South Africa) agricultural productivity declined considerably after the administration of the Estate came under the control of the newly formed Agricultural and Rural Development Corporative after the African National Congress (ANC) led government gained power in 1994. Du Toit (2009) further argued that before the takeover, the Estate covered 2260 ha of land and by the year 2001, the Estate was drastically reduced to only 800 ha of land. The reduction in the Estate extensive range was argued as because no fertilisers and pesticides were used and thus resulted in a fatality of more than half of the citrus trees. As such, one can argue that the CPA members in Makotopong after land restitution they not only lack practical knowledge and experience towards farm operation and management McCusker (2004) but they also lack the capital (Daudi, 2009; Du Toit, 2009).

The results of the study indicated that after land restitution, agricultural productivity within the Makotopong CPA almost came to a standstill as was indicated by the observed decline in agricultural crops area. According to PLAAS (2011) ever since the adaptation of the land reform policy, many land reform projects have failed to help create sustainable livelihoods, rural employment has tumbled and evictions have rocketed, and rural areas became more polarised than before, generating fewer livelihoods. Nonetheless, Tjale (2012) argued that commercial farming in South Africa had declined from 120 000 in 1994 to 37 000 commercial farmers currently in South Africa putting a threat on the countries food supply. Tjale (2012) further argued that farmers point to unreasonable laws, expensive water, electricity and other necessities, a shrinking supply of arable land and the countries land reform policies amongst other reasons for farming becoming unsustainable. Therefore, this is a clear indication that the current land restitution policy in South Africa has negative impacts on sustainable land utilisation.

5. CONCLUSION AND RECOMMENDATIONS

In this chapter a summary of the whole research study as well as suggestions on sustainable land management is given.

5.1. Conclusion

The principal aim of this study was to investigate the effects of the South African land reform policy on land use and land cover change on restituted land in Makotopong, Limpopo province, South Africa. The study objectives however was, to map land use and land cover types between dates of imagery (before, and after land restitution), to detect and quantify changes in land use and land cover between dates of imagery, and to develop strategies that will ensure sustainable land utilisation in the study area.

The results of the study however, indicated that there were observed land cover changes within all land cover classes for both study sites during the years under investigation. Moreover with the exception of agricultural land cover classes for Makotopong CPA, land cover changes within all other land cover classes for both study sites were solely due to environmental changes/ecological succession (woody, shrubs, and grasslands land cover types) and population growth (increase in built-up and a decrease in woody for Makotopong village). The major land use and land cover change, noticeable within the study area that can clearly be attributed to the unintended consequences of the implementation of the land restitution programme in Makotopong CPA, was the decline in agricultural crops and agricultural productivity. The results of the study indicated that after land restitution, agricultural productivity within the Makotopong CPA came to a standstill.

The study has highlighted the importance of utilising historic records in the form of satellite images analysed through remote sensing techniques, in order to investigate the historical changes in land use and land cover patterns so as to have a clear understanding of the nature of changes and to effectively identify the factors behind the detected changes. The study also provided methods that proved to be valuable in investigating the kind of landscape transformation that has taken place after the land had been restituted. Remote sensing approaches, through change detection procedures, proved to be effective technique in analysing the two dates of imagery (1994 and 2007 Landsat TM), distinguishing the 'from-to'

change information and easily calculating and mapping the kind of landscape transformation that had occurred after land restitution. However, in order to achieve the principal goal of the study, remotely sensed data were analysed guided by the specific objectives as indicated in section 1.5.1 of Chapter one.

Given the most dominant land cover type (vegetation) under investigation in this study, Landsat TM3, TM4, and TM5 band combination were utilised for this study as this band combination was argued to be the most useful combination in studies of this nature (Xie *et al.*, 2008). July satellite images (1994 and 2007 Landsat TM) were selected for the study area because during this time, there is little or no rain within the study area and thus the images are clouds free. In addition, there are only trees and little to no grass in leaf and thus reducing spectral confusion between these vegetation types. From each Landsat TM image, two subsets images of the study sites covering Makotopong CPA (restituted land) and Makotopong village were delineated. The hybrid classification method was employed for this study as it was argued that it is advantageous for analysing composite variability in the spectral response pattern for distinct cover types such as in vegetation mapping (Munyati and Kabanda, 2009). Six major land cover types were mapped for Makotopong CPA and five major land cover types were mapped for Makotopong village through hybrid classification techniques. Moreover, statistics determining the total area in hectares for each land cover type were compiled, while land cover classes showing either a decline or increase in total area from 1994 to 2007 were identified and their specific nature of changes determined through change detection procedures. Furthermore, the possible reasons behind the observed changes were discussed and possible mitigation methods outlined.

This study therefore, with the use of remote sensing techniques, through the analysis of digital satellite images had successfully produced accurate landscape maps and statistics deriving the nature of the decline in the general condition of the restituted land and thus bridging the gap left by the previous study. The study also gave insights into the kind of landscape transformations that have taken place before and after the land restitution through investigating the effects of the South African land reform policy on land use and land cover change on a restituted land. The results from the study demonstrated the usefulness of remote sensing in providing estimates of land use and land cover changes. These findings complement other studies that have shown a lack of improvement in post transfer farming activities. Results depict a decline in post transfer agricultural activities on

the land transferred. Consequently, implementation of the South African land reform policy results in land use and land cover change and a continuing decrease in agricultural land use and abandonment.

5.2. Recommendations

The following recommendations are recommended as strategies that will ensure sustainable land utilisation in the study area and beyond.

- The adoption of the land reform was to ensure sustainable agricultural practice and utilisation of resources. In order to achieve the goals set for the land reform policy in South Africa, a sustainable land reform policy should develop policies that will counteract the effects of changes that took place after the implementation of the land reform policy. It must create an environment conducive to the promotion of sustainability of commercial farming in South Africa.
- The community should be given special training concerning agricultural productivity and management, and should be expected to provide a fully-fledged business plan, clearly stipulating the long term and short term goals regarding the use of the claimed land.
- The government should ensure that the plan of action is viable and sustainable and relates to the objectives and principles of the land reform policy, which is to create development and sustainable environmental management.
- This study recommends a monitoring and evaluating committee that will oversee that after land restitution the land is not abandoned as monitoring the progress of land reform projects can help to avoid the misuse of land and can lead to sustainable land use management.
- Spatial data analysis through remote sensing procedures should form the information base in monitoring and evaluating the land reform projects, as the results of this study have indicated that the quantification of the changes in land use and land cover types can be very useful in deriving the nature of the general condition of the land reform project.

5.3. Further study

There is a need for further study primarily towards the fundamental causes and reasons behind the decline in post transfer activities on restitution projects after land transfer. The study methodology should incorporate both qualitative and quantitative approaches with questionnaires administered and interviews conducted with the affected parties (for example; the land claimants as well as the department of rural development and land reform: spatial planning and information together with the land reform office). Further studies should also select a second study area in close proximity, with similar environmental characteristics (agricultural areas) that has not undergone reform under the years of investigation, to be used as a control in the experiment.

5.4. Limitations of the study

In this section, certain limitations of the study are outlined with possible solutions provided for each limitation.

- The years under investigation and the images used are both historic and does not reflect on the current status of the restituted land given that the most recent image used was taken in 2007 (over 5 years ago). This was due to the unavailability of the 2002 and 2010 Landsat image as initially the study proposed to investigate land use and land cover changes from 1994 (before restitution), 2002 (During the time of restitution), and 2010 (after restitution). The study had to utilise the available 1994 and 2007 Landsat images were used.
- Another limitation of the study was the unavailability of enough aerial photographs covering the study site from the same period as the satellite images acquisition date. The study utilised only the available data with some reference to the study drawn from the Google earth imageries.

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