QUANTIFYING INDIGENOUS FOREST CHANGE IN DUKUDUKU FROM 1960 TO 2008 USING GIS AND REMOTE SENSING TECHNIQUES TO SUPPORT SUSTAINABLE FOREST MANAGEMENT PLANNING

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DECLARATION

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SUMMARY

This study aimed to understand how Dukuduku Forest in Kwa-Zulu Natal has changed from 1960 to 2008 and whether the change in political regimes, during and post apartheid eras might have contributed to changes in forest extent.

To achieve the aims, the following analyses were made:

- Qualitative and quantitative spatial analyses of forest change;
- Analyses of the correspondence of change with political changes in the country;
- Assessment of perception of people living in the Dukuduku forest area.

The Dukuduku land cover was mapped from aerial photos using ArcGIS 9.3 to determine whether or not there has been a significant change in the area from 1960-2008, in response to resource use pressures and to come up with the strategic sustainable management plan from the results found. Five aerial photographs were used to determine the changes in land cover from the year: 1960, 1970, 1992, 2005 and 2008. The Land cover types were classified into four classes, Indigenous Forests, Plantation Forests, Water Bodies and Other (open areas, cultivated land, and all the human disturbed and transformed land). The percentage of cover per class was compared across the years to determine overall change in land cover and the rate of change per year was also calculated.

The results from the study showed that:

- Natural Forest increased by 11% (700 ha), at the rate of 20.56 hectares per year between 1960 and 1992, which is the apartheid era. Between 1992 and 2008, the democratic era, the forest decreased by 34.4% (2472.31ha), at the rate of 168 hectares per year.
- The Dukuduku forest community gains resources (timber and grass for construction, art, firewood, medicinal plants, grazing of livestock and food) from the forest. The people are willing to contribute in protecting the forest only if the governing authorities would include

them in decisions made, as the NFA demands Participatory Forest Management, but which does not currently exist in Dukuduku.

OPSOMMING

Hierdie studie ondersoek die verandering van die Dukuduku woud in Kwa-Zulu Natal vanaf 1960 tot 2008, en vernaamlik of die verandering in politieke regimes tydens en in die post-apartheid eras tot verandering bygedra het in die woud se vorm.

Om hierdie doelwitte te breik is die volgende analises gedoen:

- Kwalitatiewe en kwantitatiewe ruimtelike analises van woudverandering;
- Analises van die korrelasie tussen hierdie fisiese omgewingsverandering en politieke verandering in die land;
- Analise van die persepsie van mense wat in die Dukuduku woudgebied woon.

Die Dukuduku gronddekking is gekarteer met behulp van lugfotos, waarvoor ArcGIS 9.3 gebruik is om te bepaal of daar noemenswaardige verandering in die gebied plaasgevind het van 1960 tot 2008, in reaksie op hulpbrongebruike, en om ‘n volhoubare bestuursplan gestel voor wat op die bevindinge gebaseer is. Vyf lugfotos is gebruik om verandering in gronddekking te bepaal vir die jare: 1960, 1970, 1992, 2005 en 2008. Die Gronddekking tipes is geklassifiseer in vier klasse naamlik Inheemse Woude, Plantasiebosse, Waterliggame en Ander (oop gebiede, landerye en al die mens-versteurde en getransfomeerde gebiede). Die persentasie van elke dekkingsklas is oor die jare vergelyk om die verandering in algehele grond-dekking te bepaal, en die tempo van verandering is ook bepaal, asook die tempo van verandering.

Die resultate van die studie wys dat:

- Die natuurlike woud toegeneem het met 11% (700 ha), teen 'n tempo van 20.56 hektaar per jaar tussen 1960 en 1992, tgedurende die apartheidsera. Tussen 1992 en 2008, die demokratiese era, het die woude verminder met 34.4% (2472.31 ha), teen 'n tempo van 168 hektaar per jaar.

- Die gemeenskap wat in die Dukuduku woud woon verkry hulpbronne van die woud (hout en gras vir konstruksie, kuns, brandhout, medisinale plante, weiding vir vee, en voedsel). Die mense is gewillig om by te dra tot beskerming van die woud indien die owerhede hulle sou betrek in besluite wat geneem word, veral omdat die nasionale Wet op Bosse voorsiening maak vir Deelnemende Bosbestuur, wat tans nie by Dukuduku gebeur nie.

KEY WORDS

Indigenous Forest, Land cover change, Land cover use, Apartheid era, Post-Apartheid era, Geographical Information Systems and Remote Sensing, and Dukuduku.

ACRONYMS

AFRA: Association for Rural Development

DAFF: Department of Agriculture, Forestry and Fisheries

DWAF: Department of Water Affairs and Forestry

FAO: Food and Agricultural Organisation

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DEDICATION

This Dissertation is dedicated to my parents, Mr. Simiso and Mrs. Tholakele Ndlovu**.**

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CHAPTER I: INTRODUCTION

1.1 Background

Natural evergreen forest in South Africa is the smallest and also the most widely dispersed biome. Natural forests occur as a series of scattered patches along the eastern and southern margins (escarpment, mountain ranges and coastal lowlands) of South Africa, from the Soutpansberg (inland, 22°40'S) and Tongaland (coast, 27°S) to the Cape Peninsula (34°S) (Cooper 1985; Von Breitenbach 1990, Von Maltitz *et al*., 2003). Natural evergreen forests typically occur in the moist areas of the country, but specialised forest types are also found fringing rivers or within protected kloofs and within some arid areas.

Less than 2% of South Africa today is covered with indigenous forests (Rutherford *et al.,* 2006). Other contemporary sources put this figure at between 0.5% (DWAF, 2009) and 0.56% (Lawes *et al.,* 2004b). These forests have the second highest average plant biodiversity per unit area of all the biomes in the country (Geldenhuys 1992), and are therefore very important to meet the South African national biodiversity conservation targets. However, natural forests have been fragmented mainly by fires in the landscape (Geldenhuys 1994), but to some extent also by unsustainable land use practices (Cooper 1985; Geldenhuys and MacDevette 1989; Geldenhuys 1991; Von Maltitz *et al,* 2003).

In KwaZulu-Natal (KZN), South Africa, coastal forests occur in small patches (of which Dukuduku Forest is the largest one) on the rolling plains of the landward side of the dune cordon along the KZN coast, from Southern Natal to beyond the Mozambican border. Gradually shifting towards more communities of a stronger tropical nature they extend north along the coastline of the Indian Ocean as far as the coast of Tanzania (Mucina *et al,* 2006). All the patches are embedded within a narrow strip of the so-called Indian Ocean Coastal Belt (extending 30 km inland in the

North, but limited to 3-4 km from the coast in the South) and form the major vegetation element of the newly distinguished Northern Coastal Forest Group (Mucina *et al,* 2006). The sustainability of natural forest is seriously threatened by uncontrolled settlement development. This has resulted in massive forest loss with dire consequences to the local economy.

The Coastal Forest in the Dukuduku region in KZN is highly threatened by rapid growth of informal settlements and agriculture. The demand on available resources has significantly altered the environment. Human impact on the environment (particularly land cover change) in the Dukuduku area shows that there is a need for sustainable development awareness for the surrounding communities and a new strategic approach on how to protect this indigenous forest.

GIS and remote sensing are important tools that can assist in analyzing, interpreting, extrapolating and forecasting the spatial data to assist in planning for the present and future. Multispectral remote sensing data has proven to be useful for forest inventory and monitoring purposes.

1.2 Problem statement

The broader geographical area in which Dukuduku forest is located, has for a number of years been a key area for commercial and state forestry, due to the suitability of the environment and the financial viability of the timber produced (AFRA 2002b). Human settlement increased in the area during the post-apartheid era (1992-2008) because of various socio-economic and political factors and which had a major impact on a large part of the Dukuduku natural forest (AFRA 2002b).

There are many privately owned and communal forests outside of proclaimed areas that are conserved but which have insecure conservation status or management. Ownership largely determines the type and quality of forest management and possible impacts on the natural vegetation. The Dukuduku forest in KwaZulu-Natal is owned by the state (Mucina *et al*., 2006). However, the state does not have the capacity to adequately manage all its forests, especially the numerous small forest patches that were demarcated in the previous homelands and independent states.

The undisturbed part of the Dukuduku indigenous forest is in the most pristine state and is thus of special importance for the conservation of biodiversity and coastal forest ecosystems. However, the human population in that region is increasing. This implies a growing pressure on the forest in terms of forest clearing for subsistence farming, building material, selective logging for timber, fuel wood and wood craft and other impacts such as livestock grazing. So the dilemma is between nature conservation and securing the livelihood of the growing local population. On the other hand, limited (controlled) disturbance of the Dukuduku forest is also necessary for the regeneration of some important canopy tree species as indicated by Everard *et al.,* (1995).

However, limited data on the degradation trends and causes impede the proper development of suitable sustainable management plans for Dukuduku Forest. Access and harvesting of products was typically restricted for decades, until significant policy shifts in the mid-1990s, when more participatory policies and programmes came into effect (NFAP 1997; Mayers *et al.,* 2001). This study will assess and quantify to what extent change in the political regimes, therefore the apartheid (1960-1992) and post apartheid (1992-2008) eras, affected the forest extent, and quantify if remote sensing data can be used to assess long-term changes in forest degradation in the Dukuduku forest.

1.3 Key questions

The key research question of this study is to identify whether the changes in Dukuduku forest extent are related to changes in political regimes from the pre-apartheid to post apartheid eras. Sub-questions include:

i. How has the vegetation cover changed in the Dukuduku area in the past 48 years?

ii. Could the continued decline of Dukuduku natural forest be due to lack of awareness about sustainable management practices on the part of communities living within and adjacent to the indigenous forest?

1.4 Objectives

The main objectives of the study were:

i. To quantify the forest change over time, analyze the rate of forest change during the apartheid era and in the post apartheid era and identify factors that shaped the forest extent over time.

ii. To determine the impact of natural forest on the community and people’s perceptions on forest change and management.

1.5 Implications of the study

Knowledge of historical vegetation cover may provide a basis for determining reference conditions. Results of the study can be used to formulate a strategic management plan for the sustainable resource use of the forest.

1.6 Study Area

Dukuduku state forest (South West: 32˚16'84"E; 28˚24'14"S, South East: 32˚17'23"E; 28˚52'25"S, North West: 32˚17'24"E; 28˚21'11"S and North East: 32˚22’16"E; 28˚23'8"S) is located between Mtubatuba and St Lucia in Northern KwaZulu-Natal (KZN), and is part of Mtubatuba Local Municipality (see Figure 1-1 and Figure 1-2). It forms part of the Isimangaliso Wetland Ecosystem. It is rich in biodiversity and is one of the last remnants of lowland forest in South Africa. Surrounding land use consists of mainly sugarcane and private commercial forest plantation. The coastal KwaZulu-Natal climate is characterized by all year round rainfall with summer maxima. The total rainfall is relatively moderate with about 1200 mm annual mean precipitation.

The tropical influence ensures that temperatures are never below 10 C˚ even in winter (von Maltitz *et al.,* 2003). The substrates are sandy, originating primarily from recent sandy dystrophic soils of the Mozambique coastal plain and Port Durnford red sands (which contain more clay). Occasional soils derived from Cretaceous siltstones occur in this area as well (von Maltitz *et al.,* 2003).

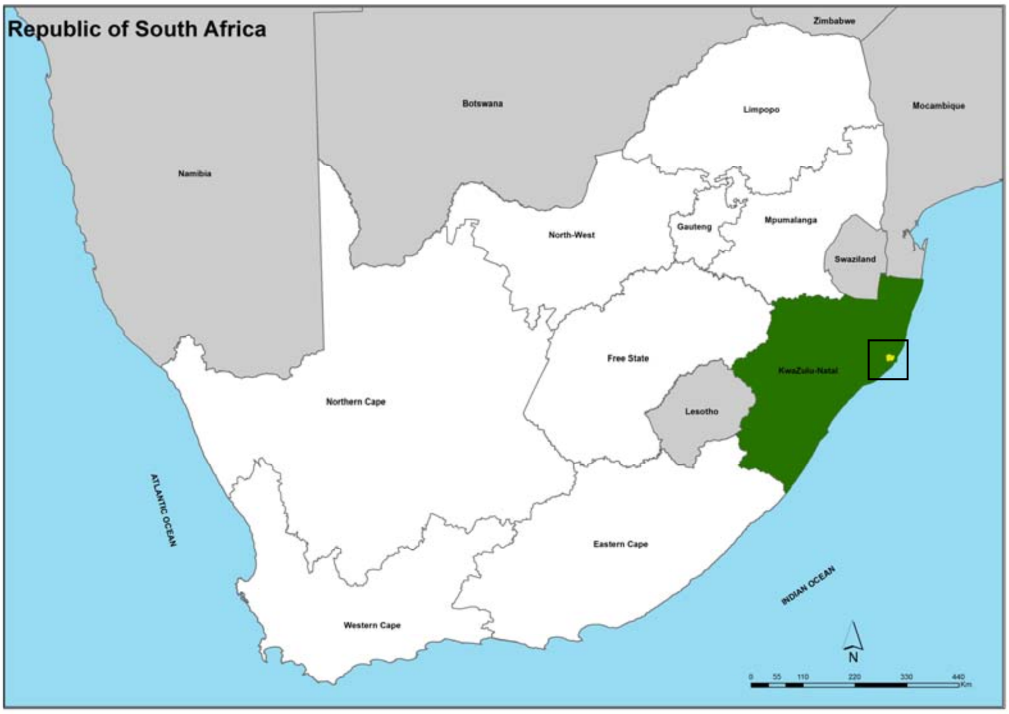

Figure 1-1: Location of the Dukuduku Forest in South Africa (Green-Province and Yellow-Dukuduku Forest).

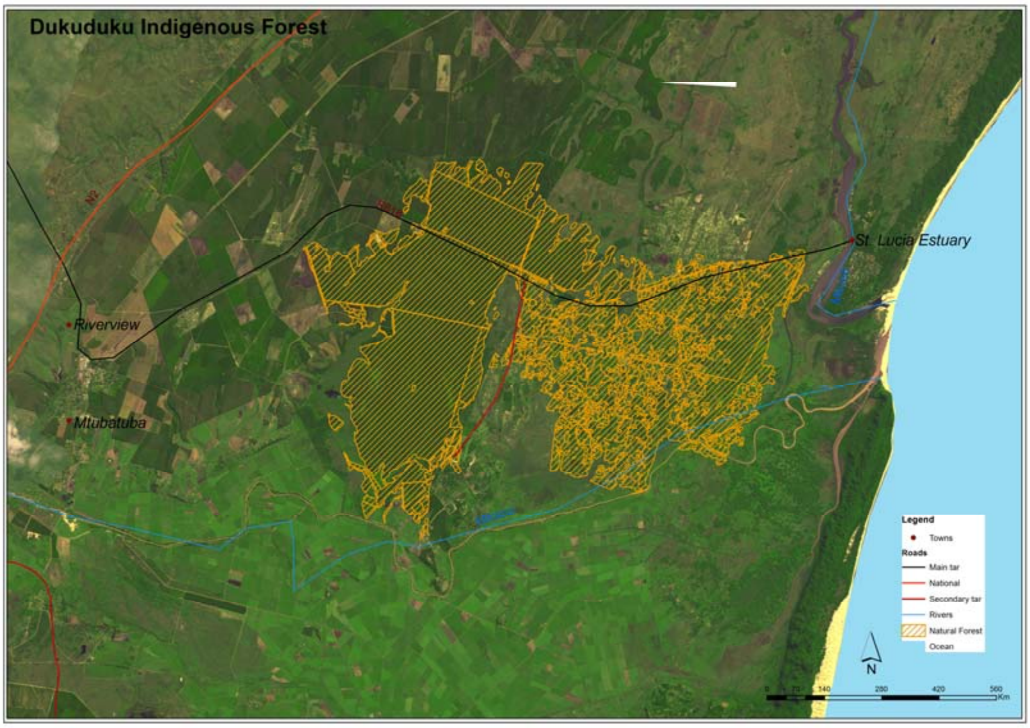

Figure 1-2: Location of the Dukuduku Forest (Yellow).

1.7 General methodology

The analysis of aerial photographs or remotely-sensed images with Geographic Information Systems has proved to be an effective method of displaying and analysing spatial and temporal data at different scales (Wilson & Berard, 1952; Mladenoff *et al.*, 1993; Hudak & Wessman, 1998; Taylor *et al.*, 2000; Bowman *et al.*, 2001; Endress & Chinea, 2001; Lawes *et al.*, 2004a; Kätsch & Kunneke, 2006, Corrigan, 2009). Aerial photographs from 1960 to 2005, KZN Landcover 2005 and Spot5 2008 were used, in time intervals of approximately 10 years: depending on data availability. In this case, it was conducted for the years 1960, 1970, 1992, 2005, 2008. Field work, data verification and capturing of new information in terms of land cover by means of ground sampling with a GPS were conducted.

People who have lived more than 8 years in the local community were interviewed to assess the impact of forest change on the livelihood of the human population using socio-economic data collected through the field survey and economical evaluations of the community using structured questionnaires.

The ERDAS 9.3 software package was used to classify different land uses and changes and further used to undertake other analyses, such as post classification matrix. Accuracy assessment and verification were conducted following the method described by Lillesand *et al.,* (2004). Field data verification was conducted using GPS-referenced field observations, where 20 points per class were selected randomly and controlled by using the 2008 SPOT5 image as reference.

1.8 Thesis outline

The main body of this thesis starts with chapter II, entirely focused on the literature review of the natural forest importance and threat with specific relevance to the Dukuduku forest, Chapter III describes the materials and methods used to respond to the various research objectives, Chapter IV reports the results of land cover change in the Dukuduku forest between 1960 and 2008 and the people's perception on forest change and management and Chapter V presents results analyses and interpretation of the study, as well as synthesis of the chapter.

CHAPTER II: LITERATURE REVIEW

This chapter reviews the importance of natural or indigenous forest and policies that guide management of natural forest in South Africa with particular reference to the Dukuduku forest patch in KwaZulu-Natal. It further provides information on how Remote Sensing has been used to assess forest change and monitoring.

2.1 Introduction

The World Food and Agricultural Organisation (FAO, 2000) defines forest as land with tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.5 hectares (ha). The trees should be able to reach a minimum height of 5 meters (m) at maturity *in situ*. Furthermore, according to the FAO definition, forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10%. Also included under forest are young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10% or tree height of 5 m. Areas normally forming part of the forest area which are temporarily un-stocked as a result of human intervention or natural causes but which are expected to revert to forest are also considered as forest (FAO, 2000).

Natural or indigenous forest can be defined as forests that are native to a given area. According to the South African National Forest Act 84 of 1998, natural or indigenous forests are defined as a multilayered vegetation unit dominated by trees (largely evergreen or semi-deciduous), whose combined strata have overlapping crowns (i.e. the crown cover is 75% or more), and where grasses in the herbaceous stratum (if present) are generally rare (National Forest Act 84 of 1998).

2.1.1 Natural forests in general

Globally, forests comprise approximately 30.3% of the earth's terrestrial surface (FAO, 2008) and play a fundamental role in regulating climate (Brown, 1996). Natural forests play a significant role in ecosystem processes such as soil erosion control, carbon sequestration, biodiversity production and functioning of water catchments. Indigenous forests contain the highest species diversity and endemism of any ecosystem type (World Commission on Forests and Sustainable Developments 1999, and Convention on Biological Diversity, 2005). Globally, natural forest biodiversity is important to human wellbeing, sustainable development and poverty alleviation.

On a global scale, natural forests are declining in quantity and quality due to a number of proximate and underlying causes, such as clearing for commercial plantations and farming, uncontrolled logging, grazing pressure and unsustainable harvesting for non-forest products (Geldenhuys, 1989; Macfarlane, 2000; Lambin *et al*., 2001; Geist and Lambin, 2002; Goodman, 2003). The effect of forest area on species richness is variable. Usually, extensive continuous forest area results in greater species richness (Wilcox and Murphy, 1985; Macfarlane, 2000; Lawes *et al.,* 2004b). Over the years, deforestation has increased the threat of global warming by reducing carbon sinks (Mthimkhulu, 2009). Natural forest deforestation and degradation account for 20-25% of total carbon emissions into the atmosphere, coming second to combustion of fossil fuels (World Commission on Forests and Sustainable Developments, 1999). Natural forest loss also affects nitrogen and sulphur cycles (Mthimkhulu, 2009; Krishna and Woodwell, 1993; Woodwell, 2001).

2.1.2 Indigenous or natural forest in South Africa

Indigenous forests constitute the smallest biome in South Africa, and almost 75% of them are conserved either as declared State forests, or within formally protected areas (National Forest Act 84 of 1998). Within South Africa, natural forests cover less than 2% (Figure 2-1) of the land area (Fairbanks *et al.,* 2000; Von Maltitz *et al.,* 2003; Geldenhuys, 2004; DWAF, 2009). Natural Forests in South Africa are widely distributed in the five coastal provinces (Limpopo, Mpumalanga, Kwa-Zulu Natal, Eastern Cape and Western Cape). Natural forests in Southern Africa are very limited in their extent. They occur in areas that receive in excess of 800 mm of rainfall annually, at altitudes below 2000 m (Schulze and McGee, 1978). Though these forests cover less than 2% of RSA land cover, they constitute the second highest plant diversity average per unit area of all the biomes in the country and are therefore very important to meet South African National Biodiversity Conservation targets.

Forests in general are vital for the well-being of the community. They provide a variety of socio-economic and ecological goods and services, including regulation of the quality and quantity of rainwater discharging into rivers, prevention of soil erosion, stopping the spread of deserts, preservation of the world's most endangered wildlife, provision of food and medicine to indigenous peoples and supporting eco-tourism (Van Cotthem, 2007).

Communities living within or adjacent to indigenous forest patches in South Africa depend on the forest for the provision of goods and services including fuelwood, water supply, fertile soils for food production, natural medicines and cultural values (von Maltitz and Grundy, 2000 and Lawes *et al.,* 2004b).

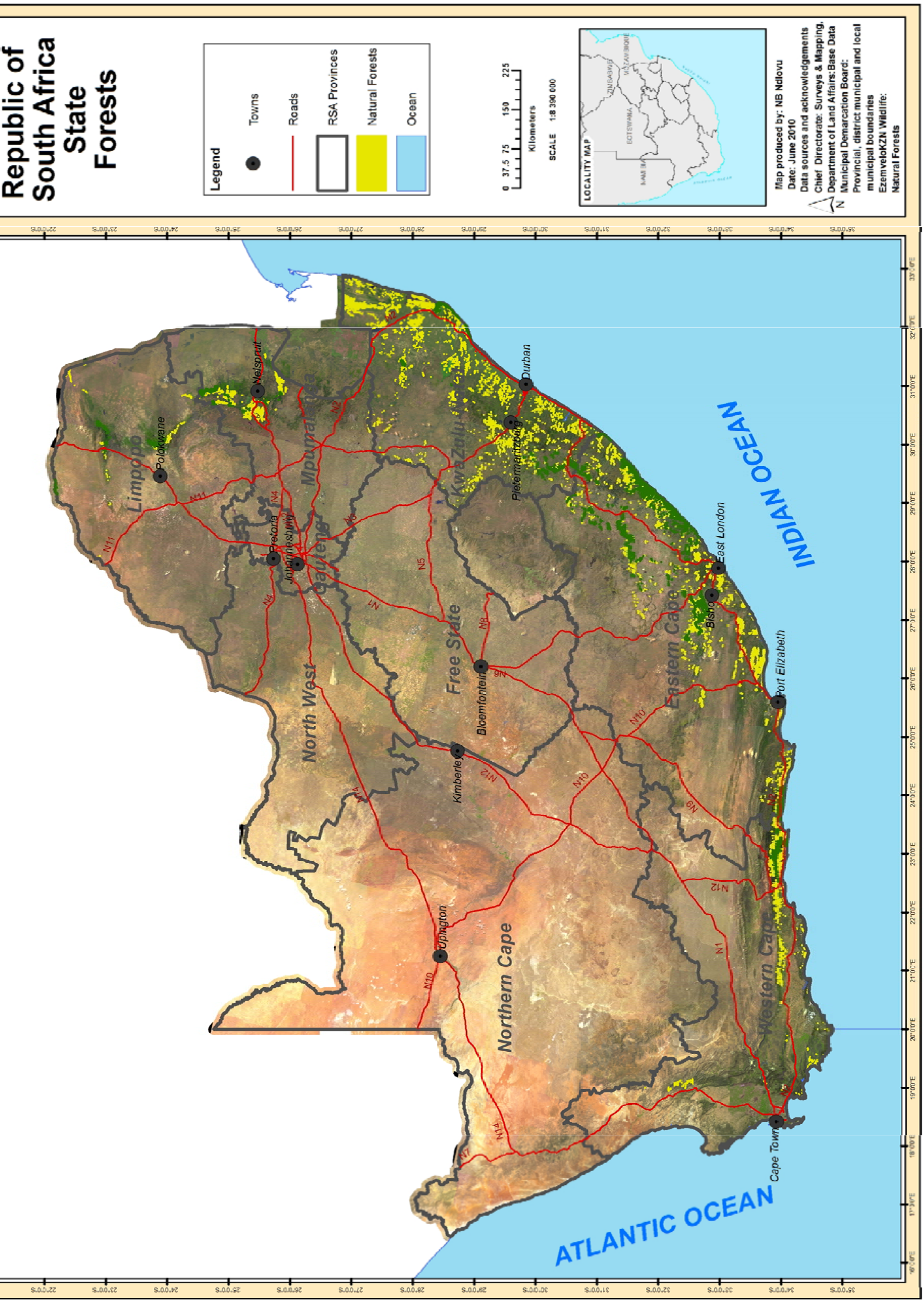
Republic of South Africa State Forests
Legend
Towns
Roads
RSA Provinces
Natural Forests
Ocean
0 37.5 75 150 225
Kilometers
SCALE 1:8 390 000
LOCALITY MAP
Map produced by: NB Ndlovu
Date: June 2010
Data sources and acknowledgements
Chief Directorate: Surveys & Mapping,
Department of Land Affairs:Base Data
Municipal Demarcation Board:
Provincial, district municipal and local
municipal boundaries
EzemveloKZN Wildlife:
Natural Forests
N
INDIAN OCEAN
ATLANTIC OCEAN
Limpopo
Mpumalanga
Gauteng
North West
Free State
KwaZulu
Northern Cape
Eastern Cape
Western Cape
Polokwane
Nelspruit
Pretoria
Johannesburg
Durban
Pietermaritzburg
Bloemfontein
Kimberley
Upington
East London
Bisho
Port Elizabeth
Cape Town

Figure 2-1: Distribution of Natural Forests in South Africa

Human activities such as coastal development and harvesting of resources for commercial and subsistence use are posing serious threat to natural forest in South Africa. According to Tinley (1985), coastal dunes are most sensitive to human interference and this includes Dukuduku coastal forest. Human activities affecting the forests such as infrastructural developments are considered to be the worst disturbances e.g. mining and holiday resort expansion; alien plant invasion e.g. through deliberate planting for dune stabilization; recreational activities e.g. unrestricted vehicle access; and inappropriate planning, zoning, and ineffective administrative control (Tinley, 1985).

According to Von Maltitz *et al.,* (2003), Dukuduku forest has had two main threats, which are commercial afforestation and sugarcane production, agriculture, woodlots, sugarcane (small growers), harvesting of non-timber forest products as well as slash-and-burn agriculture are the dominant threats to the forest. People, especially sugar cane and subsistence farmers, have a higher impact on Kwa-Zulu Natal coastal forest than they do on the Dune Forest as the underlying soil is more arable (suitable for crop production). Also, these forests occur in areas of high human population density (von Maltitz *et al.,* 2003). The increases in settlements and agricultural practices taking place in Dukuduku are unsustainable and have resulted in large-scale destruction of unique and rare biodiversity (von Maltitz *et al.,* 2003).

2.2 Indigenous forest management

Internationally, developments in forest management over the past decade have focused on progress towards sustainable forest management, an approach that balances environmental, socio-cultural and economic objectives of management in line with the Forest Principles agreed at the United Nations Conference on Environment and Development (UNCED) in 1992.

According to FAO (2000), this has led to many countries changing forest policies and management practices. Broader approaches towards forest management such as landscape management are now widely accepted and implemented. Benefits of adaptive management and the importance of collaborative decision making have been witnessed through these approaches.

2.2.1 History of forest management in South Africa

The history of Indigenous forests management indicates that these forests were heavily exploited (Owen and van der Zel, 2000), as woodlots and material for housing and wagon making in the 1700's. This resulted policies directed towards the protection of natural forest by the then government (Grundy & Wynberg, 2001). Knysna and Tsitsikamma were the first areas to be officially declared as forest reserves under the Cape Forest Act of 1888 (Rabie and Fuggle, 1992). In the past, government efforts focused on conserving the indigenous forest in both former 'White' and 'Homeland' areas whilst encouraging a thriving forest industry based on planted resources (Owen and van der Zel, 2000). However, Forest management in former homelands was not effective enough as it lacked the appreciation that indigenous communities needed the natural resources to survive (Grundy & Wynberg, 2001).

Since 1913, when the Forest Act of 1888 (Cape Colony) was revoked, the administration had been carried out under the Forest Act No. 16 of 1913 as amended by Forest Act No. 14 of 1917 and Forest Act No. 28 of 1930 (FAO, 1953). In 1941, the Forest and Veld Conservation Act (No. 13 of 1941) was passed to amend and consolidate the laws in the union relating to the tenure, demarcation, protection, management and utilization of forests and the regulation of veld-burning; to regulate trade in, and the use of, trade names in connection with forest produce; to control the exploitation and importation thereof; and to make better provision for veld, soil and water conservation. In 1946, the passing of the separate Soil Conservation Act (No. 46 of

1946) resulted in the title of Act No. 13 of 1941 being shortened to that of The Forest Act. A further brief Forest Act (No. 10 of 1948) was passed to facilitate certain aspects of the administration of land controlled by the Department and also to strengthen the position of owners of land in cases where damage resulted from the kindling of fires (FAO, 1953).

In 1998, The National Forest Act 84 was passed to manage on a sustainable basis, the State indigenous forests with the objective of conserving biodiversity and contributing to the economic, social and spiritual upliftment of South Africa's people, with a special emphasis on poor rural communities and also to promote greater participation in all aspects of forestry and the forest products industry by persons disadvantaged by unfair discrimination. The then Department of Water Affairs and Forestry which was managing forestry-related issues paved the way for the restructuring of the Forest Sector in South Africa, also with regard to indigenous forests. This resulted in the development of the National Forestry Action Programme (DWAF, 1997) and the translation of the new vision into concrete actions.

Access and harvesting of products was typically restricted for decades, until significant policy shifts were made in the mid-1990s, when more participatory policies and programmes came into being (NFAP, 1997 and Mayers *et al.,* 2001).

2.2.2 Forest management in Dukuduku

A number of indigenous forest patches in KwaZulu-Natal are considered to be conserved and yet lack proper management. This is because historical challenges still remain (Davies, 2003). Government has approved a number of management plans but due to lack of capacity and resources, these are not implemented accordingly (Davies, 2003). According to Geldenhuys (1991), forests on private land are fairly well protected, particularly those in a conservancy and natural heritage system. The application of a permit system in KwaZulu-Natal is thought to have contributed to the conservation of forests (Geldenhuys, 1991). Dukuduku is no exception to land tenure exploitation, isolation and fragmentation which influences its continued survival. The conservation authorities believe that neighbouring communities' activities are negatively affecting natural forest due to the extraction of their daily needs from the forest.

Dukuduku is a state forest as defined in section 2(1) of the National Forests Act (No 84 of 1998). It was designated as such in terms of the previous Forest Act No 16 of 1913. Although certain portions of the State Forest were excised, the Dukuduku Forest, as it is now known, remains the State Forest demarcated as such in Government Notice No 1479 dated 15 August 1930; and vests with the National Executive of RSA, represented accordingly by the Cabinet Minister responsible for Forestry.

It is a state land within the definition of the term contained in Section 1(1) of the National Forest Act of 1998. It is also part of a World Heritage Site (in terms of the World Heritage Convention Act but not part of the UNESCO listing). It may not be occupied unless a person who does occupy is licensed under the provisions of Section 23 of the National Forests Act and has thereto as required in terms of the World Heritage Convention Act 1999 (Act 49 of 1999) with the National Environmental Management: Protected Areas Act (South African Constitution, 1998) (DWAF, 2000).

Dukuduku indigenous forest falls under The Greater St Lucia Wetland Park which is seen to be a key incentive to attract large scale investment to the area. The Greater St Lucia Wetland Park Authority is authorized by national and provincial cabinet to manage the commercialisation and conservation of the system's biological diversity and to create a framework and regulations to accommodate rapid private sector investment and commercial activity together with the ongoing conservation and protection of the land (AFRA 2002a). The primary purpose of the Authority is based on the principle of sustainable management and the efficient balance of commercial development with appropriate environmental protection, thus providing a stable environment for the type of investment envisaged by the Spatial Development Initiative.

The question is (1) why is indigenous forest degradation still on the rise in South Africa, despite the various forest acts and management policies? (2) Could the continued decline of natural forest be due to a lack of awareness about sustainable management practices on the part of communities living within and adjacent to indigenous? and the lack of accurate assessment of forest loss or change? Traditional forest assessment is based mostly on laborious and expensive field survey techniques. However, remote sensing methods based on airborne or satellite images provide a rapid and cheaper means of assessing forest change over many years.

2.3 Assessing forest cover change using Remote Sensing

Change detection is the "process of identifying differences in the state of an object or phenomenon by observing it at different times" (Singh, 1989). The world is currently going through changes of land cover. Land cover change is one of the most significant disturbances to the ecosystem (Vitousek, 1992; Roberts *et al.,* 1998). Increasing effect of land cover and land use changes can impact global climate (Lean and Warilow, 1989), biogeochemical cycles (Deitweiler and Hall, 1988; Lugo and Brown, 1992), and biodiversity through habitat fragmentation (Skole and Tucker, 1993). Due to these factors, it is then important to monitor land cover and land use changes at regional and global scales. This is difficult when it is considered that in many areas, historic land cover data is either of poor quality or does not exist at all (Roberts *et al*, 1998).

Initiatives to monitor land-cover and land-use change are increasingly dependent on information derived from remotely sensed data. Such information provides the data link to other techniques designed to understand the human activities behind deforestation (Lambin, 1994; Rindfuss and Stern, 1998). A range of techniques are available to detect land cover changes from multi-temporal remote sensing data sets (Coppin and Bauer, 1996). "The objective of change detection is to compare spatial representation of two points in time by controlling all variances caused by differences in variables that are not of interest and to measure changes caused by differences in the variables of interest" (Green *et al.,*1994).

According to Lu *et al.,* (2004b) adequate change detection research should provide the following information: area change and rate of change, spatial distribution of changed types, change trajectories of land-cover types, and accuracy assessment of change detection results. Furthermore, Kaufmanna and Seto (2001) argue that time series data from high resolution satellite imagery give researchers a chance to develop sophisticated statistical models of land cover change.

According to Chambers (2002) over the past thirty years remotely sensed data have proven useful to the environmental sciences, and has been used for land cover mapping and natural resource monitoring. Remotely sensed imagery has many applications to forestry, and has been utilized for many applications including forest inventories (Bauer *et al.,* 1994), forest area estimation (Wynne *et al.,* 2000), and forest change detection (Sader, 1995; Jano *et al.,* 1998, Bauer *et al.,* 1994; Colwell and Weber, 1981; Hame *et al.,* 1998; Hayes and Sader, 2001; Malila, 1980; Muchoney and Haack, 1994; Nelson, 1983; Singh, 1986; Green and Cosentino, 1996).

Field surveys are effective but are time consuming and expensive (Green and Cosentino, 1996). Classification of medium resolution satellite imagery or aerial photography is an effective alternative to field based analysis of forest change. Lawes (2004a) conducted an analysis of a time series of aerial photos over a 50 years period from 1944 and 1996 for forest landscape pattern changes in the KwaZulu–Natal Midlands, South Africa. The study showed a decrease in forest area by 5.7%. The introduction of hyperspectral remote sensing has seen an improvement in the accurate detection and mapping of forest (e.g. Cho *et al.*, 2009). Hyperspectral data are acquired in many narrow contiguous bands, thus providing more spectral information for vegetation characterisation (Mutanga and Skidmore, 2004b; Mutanga and Skidmore, 2007; Younas *et al.*, 1998).

This study used aerial photographs to monitor the land cover change of Dukuduku indigenous forest because the available historic data found was that of aerial photographs. It allows some level of interpretation of rock types and structural geology, vegetation types and amount of cover. Aerial photographs are ideal for mapping small ecosystems and fine-scale landscape features, such as riparian areas or individual trees (Fensham and Fairfax 2002, Tuominen and Pekkarinen 2005).

2.4 Conclusion

The literature review has highlighted the importance of natural forest in South Africa and the threats facing the remaining forest patches. It further highlights the gaps in the knowledge particularly with respect to communities' attitudes towards sustainable management of forest and the need for accurate assessment of forest change using remote sensing. The study focused on using aerial photographs to assess forest change in the Dukuduku forest patch and to assess the perception of the people living with the forest patch on issues of sustainable forest management.

CHAPTER III: MATERIALS AND METHODS

This chapter describes the materials and methods used to respond to the various research objectives:

- To quantify the forest change over time, analyze the rate of forest change during the apartheid era and in the post apartheid era and identify factors that shaped the forest extent over time.
- To determine the impact of natural forest on the community and people's perceptions on forest change and management.

3.1 General methodology

Figure 3-1 shows an overview of the methods used in the study. The details of the methods for each research objective are described in the next sections.

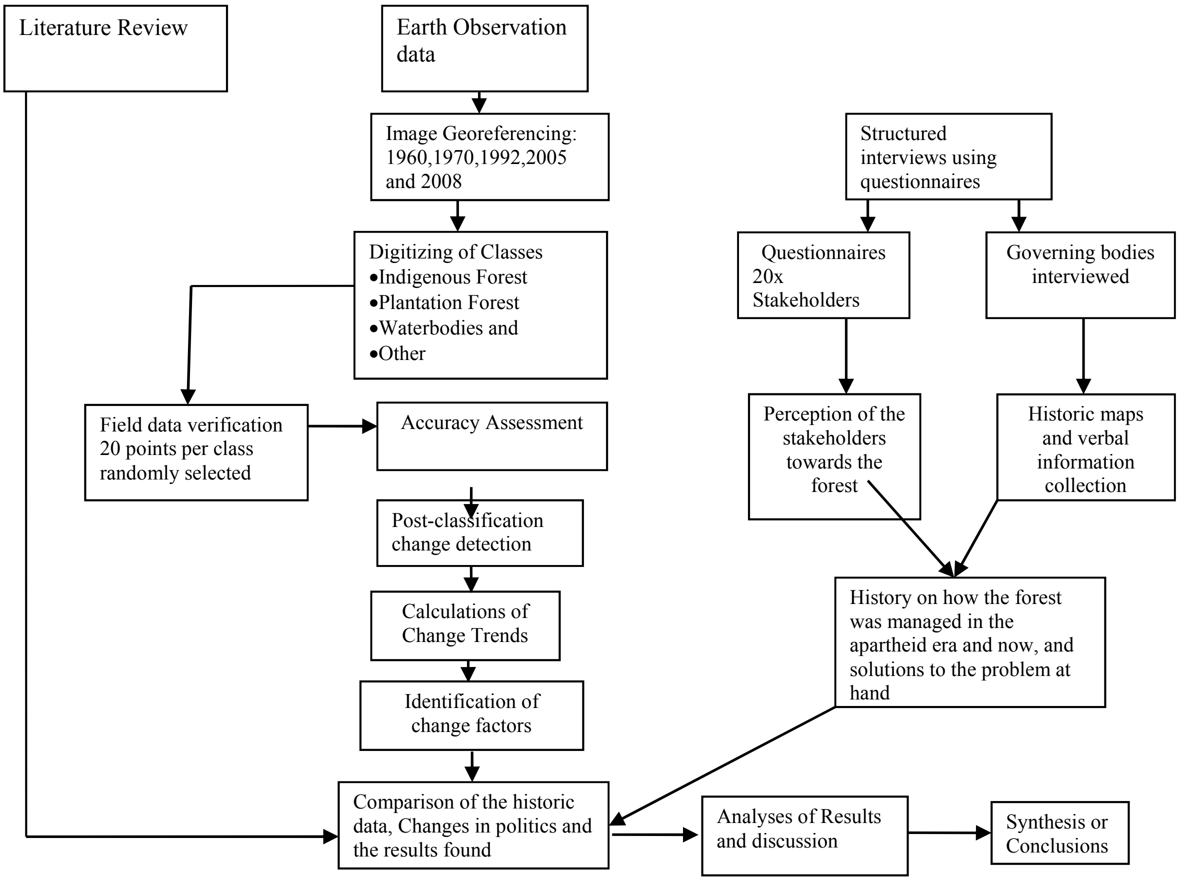

Figure 3-1: Flow diagram of the methods applied in this study.

3.2 Materials

Table 3-1: Properties of the data used in this study.

Sensor	Resolution	Acquisition Date	Sources
Aerial Photo	Scale: 1/40000 Focal length:144.20 mm Format: 7x7	July 1960	Chief Directorate for National Geo-Information
Aerial Photo	Scale: 1/20000 Focal length:152.01 mm Format: 9x9	August 1970	Chief Directorate for National Geo-Information
Aerial Photo	Scale: 1/50000. Principal distance:85.54 mm	July 1992	Chief Directorate for National Geo-Information
Aerial Photo	Scale: 1/50000. Principal distance:36 mm	2005	Chief Directorate for National Geo-Information
KZN Land Cover 2005	Scale: 1/50000. Pixel size: 20m	2005	GeoTerraImage, PTA
Spot 5	Sensor: 2 x HRG and HRS Spectral bands: Green, Red, NIR, SWIR and PAN Spatial Resolution: 10m, 5m (PAN)	April 2008	South African National Space Agency, PTA

3.2.1 Imagery

- **Aerial photography**

Digital 8-bit greyscale aerial photographs of varying scales and resolutions were obtained from the Chief Directorate for Surveys and Mapping (now: CD: NGI) in Mowbray, Cape Town. A series of photographs covering four different years were available: 1960, 1970, 1992, 2005 to document the historical state of the forest. The use of aerial photographs is considered to be a successful method to map changes in cover types in a variety of landscapes (Hudak and Wessman, 1998; Eckhardt *et al.*, 2000).

- **SPOT 5 of 2008**

Systeme Pour I' Observation de la Terre (SPOT) sensors 1 – 5 were designed and launched by the French Centre National d'Etudes Spatiales (CNES). SPOT 5 (HRG- high resolution geometric) was launched in 2002 and provides spatial resolutions in the green, red, and near-infrared bands of 10 m; the SWIR band provides at 20 m resolution. SPOT 5 is equipped with two panchromatic sensors at 5 m spatial resolution each, which allows for the calculation of a 2.5 m resolution panchromatic product through combination of the two sensors (Van Aardt, *et al.,* 2010).

Due to pointability and several satellite constellations, the SPOT sensor can obtain repetitive coverage of the globe every 1-5 days. The SPOT HRS sensor suite can provide the remote sensing analyst with increased frequency of coverage for areas with high cloud coverage, stereoscopic viewing, and DEM generation. Typical applications for SPOT multispectral imagery include precision agriculture, natural resource management, wetlands inventory, and urban planning and topographic mapping at 1:50,000 scales (Van Aardt, *et al.,* 2010).

3.2.2 GIS Datasets

- **KZN Land Cover 2005**

The KZN Landcover 2005 in ERDAS IMG raster format was acquired from GeoTerraImage (GTI) (Table 3-1). The pixel size of the data is 20 m. The projection is Universal Transverse Mercator, with a WGS 84 Datum and Spheroid. The classification, consisting of 40 classes, was done considering a 0.25 ha minimum mapping unit with a landcover scale of 1:50000 for mapping and modeling applications. The KZN Land Cover Map is a geographically combined output of the previously released 2005 KZN Coastal Landcover dataset and the follow-on KZN Interior Landcover Dataset (GeoTerraImage, 2008)

Although completed as separated contractual activities, these two land-cover datasets have been derived from equivalent SPOT2 and SPOT4 20 m imagery captured in 2005-06 and contain the same land-cover information classes and legend format. Certain edits and modifications have however been applied to the pre-existing coastal dataset in order to ensure mapping consistency with the new interior dataset. As a result the final 2005 KZN Province Land Cover dataset differs in the coastal section from that of the previously released stand-alone 2005 KZN Coastal land cover dataset (GeoTerraImage, 2008).

This dataset was used to compare the KZN LC 2005 and the 2005 aerial photographs in order to check the accuracy of the classification derived from the aerial images as a thematic reference for the classification of the old images (GeoTerraImage, 2008).

- **Digital Elevation Model (DEM)**

A 20m resolution DEM was used for orthorectification of the aerial photographs. The DEM was provided by the CSIR Satellite Applications Center, which has now changed to South African National Space Agency (SANSA) and it was generated from contour data.

3.3 Software

ArcGIS, PCI Geomatica 10.1 and ERDAS Imagine 9.3 were used for the study. PCI Geomatica version 10.1 and ERDAS Imagine version 9.3 were used for image pre-processing and change detection. ArcGIS version 9.3 was used for GIS data preparation, digitizing of land cover classes, data analysis and map production. Microsoft Excel and Word 2007 were used for report compilation and analysis.

3.4 Methods

3.4.1 Field work

Fieldwork in Dukuduku took place from 22-25/09/2010. Prior to the field trip, 20 georeferenced points per land cover class (Indigenous forest, Plantations, Waterbodies and Other) were generated using the stratified random approach in ERDAS Imagine. In the field, the points were visited using a handheld Garmin etrex GPS device and the land cover/vegetation types for the points were recorded. GPS settings were (same as random points): projection: Albers Equal Area, Datum: WGS84 and Spheroid: WGS84.

3.4.2 Pre-processing of aerial photos

Orthorectification is the process of using a rigorous physical model and a digital elevation model (DEM) to correct distortions in raw images. The aerial photograph math model provides a method to calculate the position and orientation of the camera at the time when the image was taken. Using necessary input data such as camera distortions altogether, 12 images were orthorectified in Geomatica Imagine 10.1. Six ground control points (GCPs) were taken per image. When GCPs were collected, features were chosen that can be identified accurately at the resolution of the raw image (PCI Geometrics Author, 2001). The DEM was used to orthorectify the images in order to correct for relief displacements and distortions. After orthorectification a mosaic of the images was made for the entire study area per acquisition year.

3.4.3 Classification of aerial photos

Land cover is a term which often designates vegetation, natural or man-made features on the earth's surface at a specific time of observation (Campbell, 2002). The Dukuduku area was demarcated based on the extent of aerial photograph coverage. Classification was done manually by digitizing areas considered as natural forests, forest plantations, water-bodies and others comprising of grassland/woodland, cultivated land, open area, cultivated land and settlements. This was done based on the grayscale differences, texture and shape in the aerial photographs. The 2005 KZN land cover map acquired from the GTI was used as a classification reference for the classes in the generated shapefiles.The digitizing scale was 1:3000, and features smaller than 10m were not considered.

Each photograph was digitized in ArcGIS to enable the author to calculate and analyse the changes. The area was calculated in hectares for each land cover type per year for each of the five maps derived from the aerial photos (Table 4.1).

All datasets were projected in Albers Equal Area with the following specifications:

- Projection: Albers Equal Area
- Datum: WGS 84
- Spheroid: WGS 84
- Central Meridian: 24
- Standard Parallel_1: -18°
- Standard Parallel_2: -32°
- Units : Meters

3.4.4 Accuracy assessment

Accuracy assessment for remote sensing classification is commonly based on an error matrix, or confusion table, which needs reference or 'ground truthing' data (Lillesand & Kiefer, 2004). When undertaking change detection using numerous multi-temporal images, it is often difficult to make the accuracy assessment by the 'traditional' method, which typically requires simultaneous collection of reference data. The validation of classification accuracy was done only for year 2008 because of the availability of ground thruthing information; it was then assumed that the same accuracies will apply for classification of other years as the same classification approach was used.

3.4.5 Post-Classification change detection

The study used a Post Classification method to analyse the inter-conversion between land cover types over the years. Post-classification requires independently produced spectral classification results from each time interval of interest (Coppin *et al.,* 2004; Mas, 1999; Alphan *et al.,* 2009). The classified maps of 1960 to 2008 were used for post classification analysis. The Matrix analysis in ERDAS Imagine was used to run post-classification. The matrix analysis uses two input thematic layers to produce a thematic layer that contains a separate class for every coincidence of classes in two layers (ERDAS, 2003), together with the area of change (Ramoelo, 2007).

The proportions of each land cover class were derived and reported in relation to the total area of the study. The resulting class values of a matrix operation are unique for each coincidence of two input class values by rows (input layer 1) and columns (input layer 2) as well as the land cover change map (ERDAS, 2003). Therefore, land cover change maps derived from the change detection matrix were used for the analysis (Congalton & Green; 1993, Ramoelo, 2007) and were compared to determine how the land cover types have changed over time in relation to each other. Graphs and tables were prepared in Microsoft Excel where hectares changes and percentages were calculated.

3.4.6 Analysis of the rate of forest change during and post apartheid era

Third order polynomial fits were applied to the graphs in terms of the changes of coverage of forest area over time (in years) in order to visualise the trends from 1960 to 2008 (Figure 4-6) and rate of change during the apartheid and post-apartheid eras. The R^2 value shows how good the line fits on the points on the map.

A change trend per class was calculated using this formula:

$$\text{The rate of change} = \frac{\Delta \text{ area}}{\Delta \text{ time}}$$

$$\text{e.g. 1970 to 1992} = \frac{7182.17 - 6468.68}{22}$$

$$= 32.43 \text{ hectares per year on average}$$

3.5 Structured interviews at local community

Using questionnaires (Appendix 3), data were collected in order to analyze the impact of the forest on the local community's livelihood and also to assess their perceptions towards the change of the forest over the years and its management.

Interviews were conducted within villages (see Figure 3-2) adjacent to the forest. These included Khula, Monzi, Dukuduku, Zwenelisha, St. Lucia and the Department of Agriculture Forestry and Fisheries cottages in September 2010. The content of the interviews was geared towards the local community's perception of the forest and its management. Interviews depended on availability of people in their homes and encounted throughout the day.

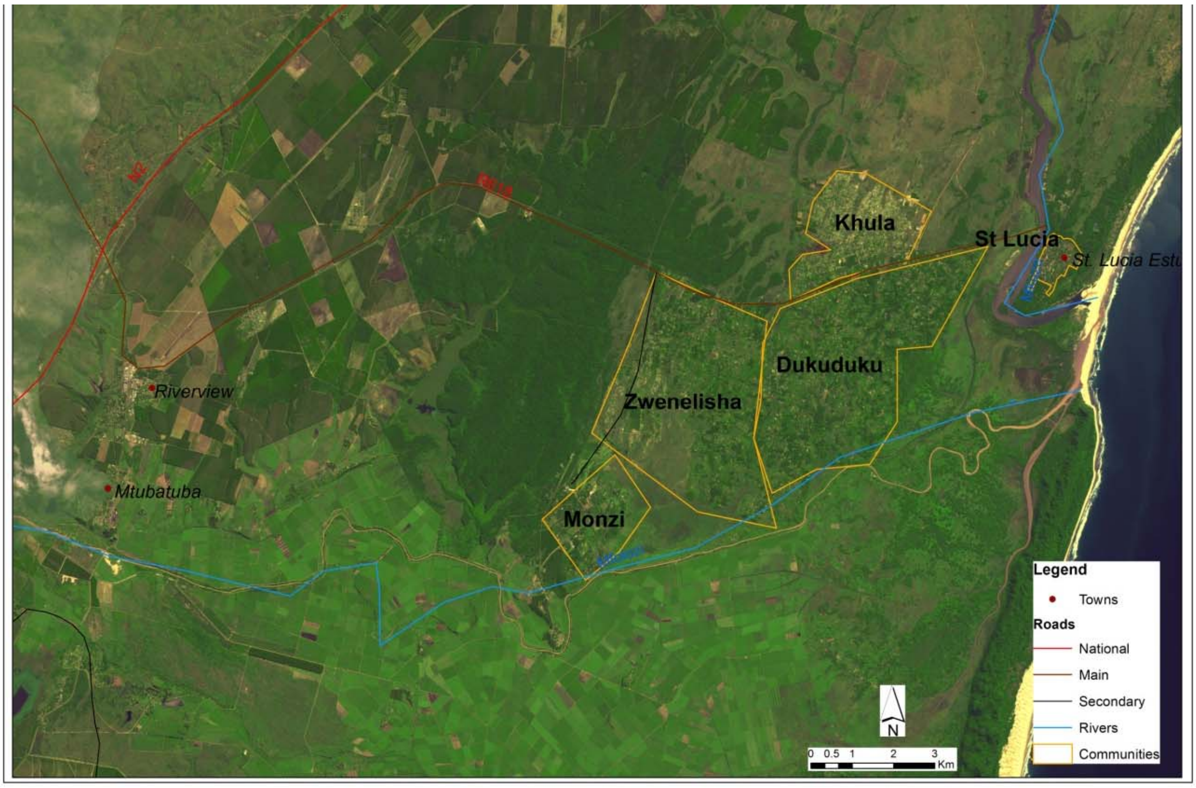

Figure 3-2: Location of communities adjacent to the Dukuduku Forest.

Structured interviews were conducted only with people who have lived in the area for more than 8 years, were interviewed as the analysis of the spatial data highlighted that the forest degradation took place mostly between 1992 and 2005. It was to be expected that people that did not live in the area during that period might not give a true reflection of what happened. In total, 20 interviews were conducted, 12 elders and 8 youth. Approximately 60 minutes per interviewee was spent.

3.6 Conclusion

This chapter described the materials and methods used throughout the study. As Dukuduku experiences degradation on a daily basis, control and monitoring mechanisms that may be effective are needed. Answers to whether RS data and techniques could be applied to address this problem and methodologies followed in this study are described in this chapter. The changes in the distribution of the land-cover, with core forest expanding and open areas contracting over the years and social and economical dynamics of the communities surrounding Dukuduku are discussed in Chapter 4.

CHAPTER IV: RESULTS

The chapter reports the results of (i) land cover change in the Dukuduku forest between 1960 and 2008 and (ii) the people's perception on forest change and management.

4.1 Single classification results

Over the 48 years for which remote sensing data were available, land cover in the area of interest (AOI) has changed considerably, as shown in Figure 4-1 to 4-3. Conversion of Dukuduku forest to other land cover classes has been the principal driver of change in the area.

Four land cover classes namely, indigenous forests, plantations, water bodies and other (open areas, cultivated land, settlements and any other activities happening in the area) were extracted from the images. Figures 4-1 to 4-3 show the land cover at the respective image acquisition date (1960, 1970, 1992, 2005, 2008).

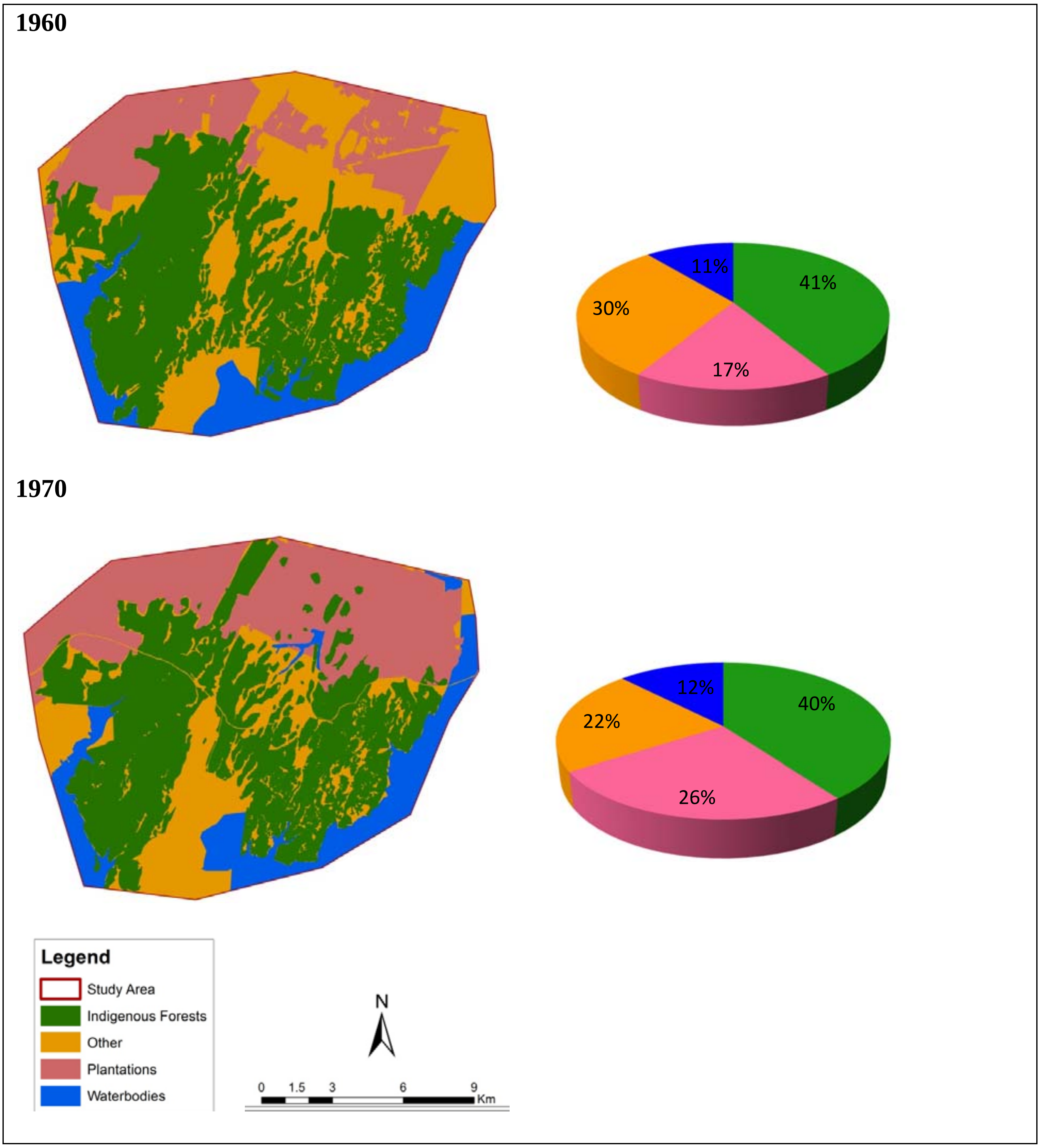

Figure 4-1: Classified maps of the AOI resulting from the Delineation of the forest extent on the aerial photo of 24 June 1960 and August 1970, accounted for by using land cover percentages to compare cover between years.

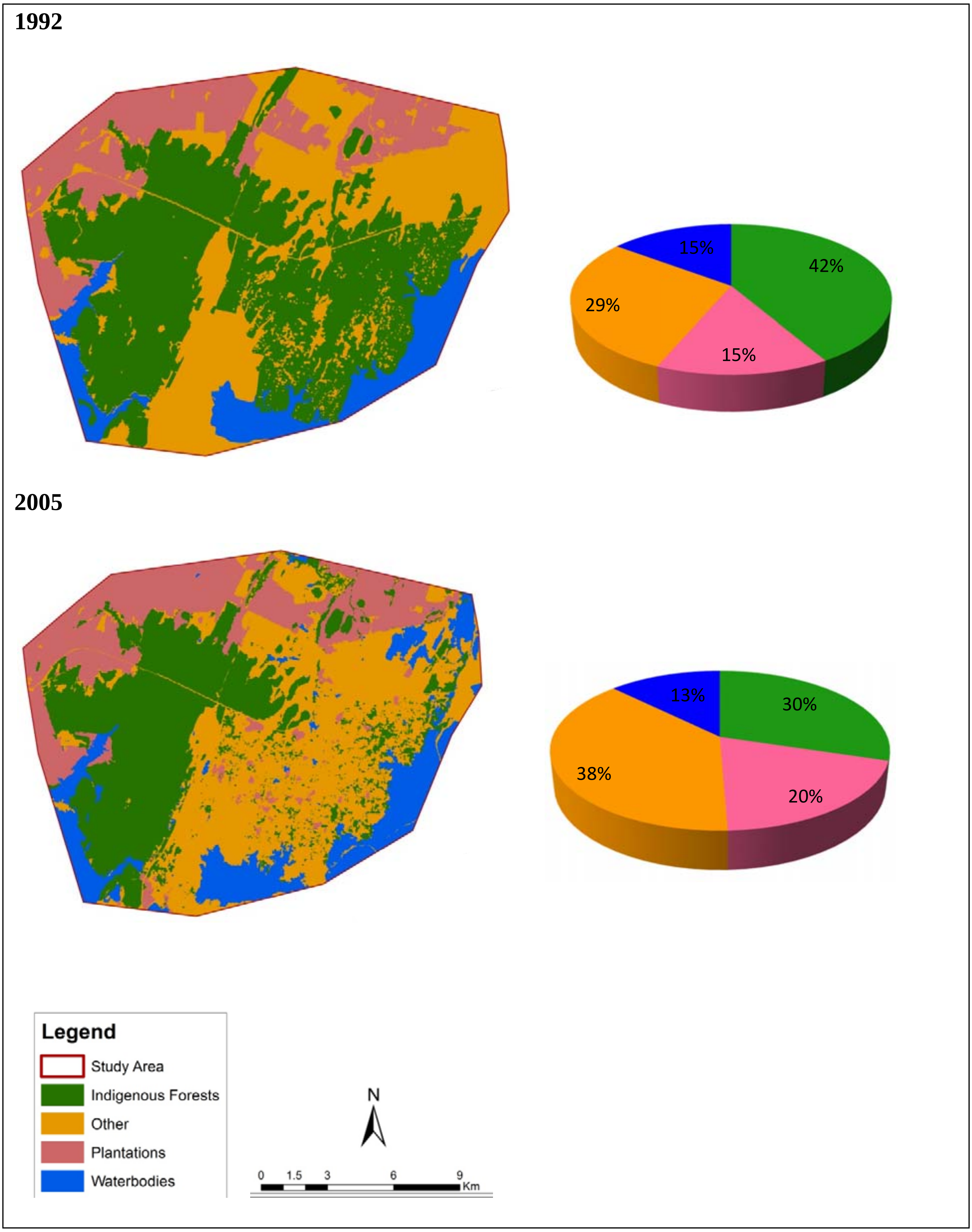

Figure 4-2: Classified maps of the AOI resulting from the Delineation of the forest extent on the aerial photo of 14 March 1992 and 2005, accounted for by using land cover percentages to compare cover between years.

2008

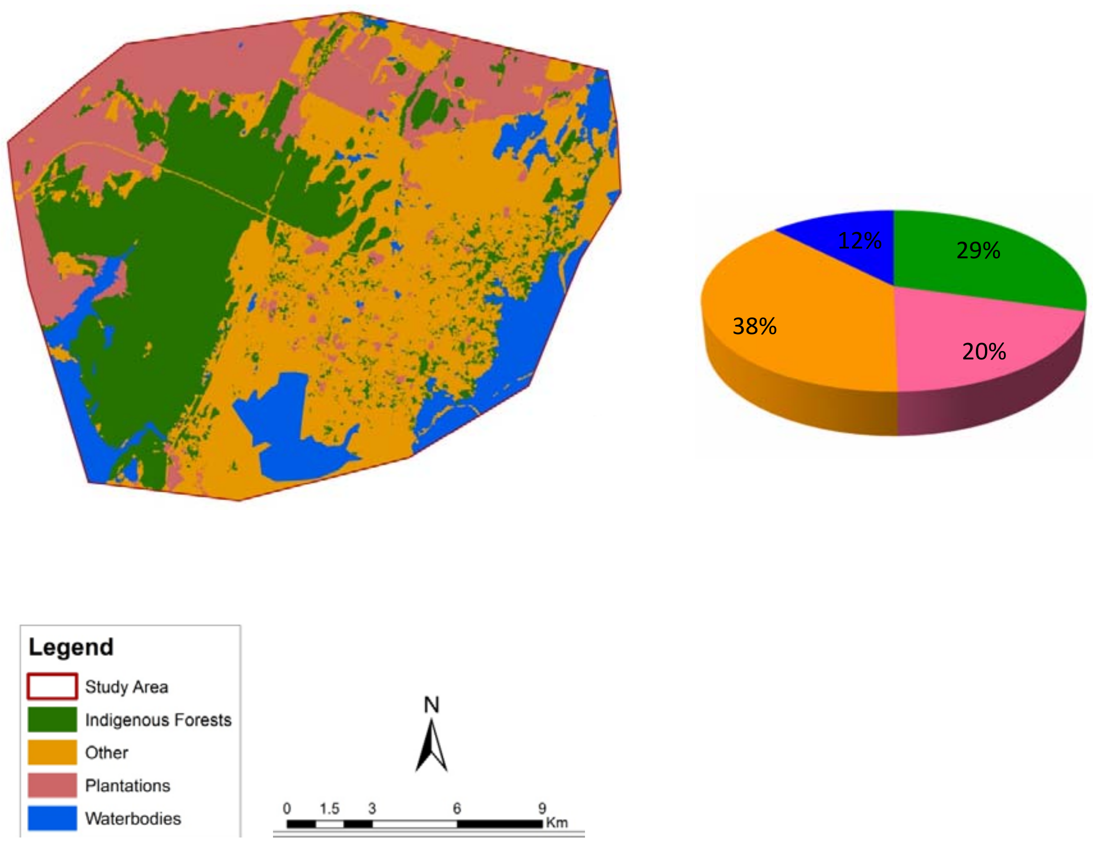

Figure 4-3: Classified maps of the AOI resulting from the Delineation of the forest extent on the Spot 5 imagery of 2008, accounted for by using land cover percentages to compare cover between years.

The maps above revealed considerable shifts in the extent of indigenous forests, plantations, waterbodies and 'other' from 1960 to 2008. During 1960 to 2008 the 'other' class was continuously growing, and indigenous forest grew between 1970 and 1992. From 1992 to 2005 Figure 4-2 shows decrease of indigenous forest whilst the 'other' class significantly increases. In 2005 signs of cultivated lands, human settlement and opens areas become apparent, particularly in the eastern and southern part of the Dukuduku area (see Appendix 1). This is where the imagery shows a high degree of fragmentation and transformation of the landscape which is totally different from 1960 and 1992.

Table 4-1: Land cover statistics of the study area from 1960 to 2008.

Land cover class	Area in Hectares									
	1960 (ha)	1960 (%)	1970 (ha)	1970(%)	1992 (ha)	1992 %)	2005(ha)	2005 (%)	2008 (ha)	2008 (%)
Indigenous Forests	6600	41.30	6500	39.93	7200	41.59	4700	29.75	4630	29.40
Plantations	2780	17.40	4230	25.98	2560	14.79	3100	19.62	3200	20.32
Other	4850	30.35	3550	21.81	5000	28.89	6000	37.97	5970	37.90
Water bodies	1750	10.95	2000	12.29	2550	14.73	2000	12.66	1950	12.38

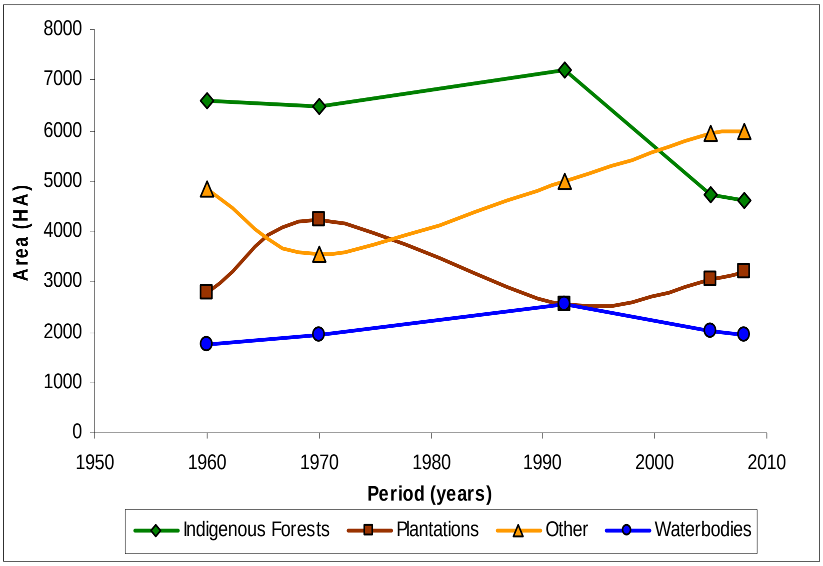

Figure 4-4: Trends in aerial coverage of land cover classes from 1960 to 2008

From the land cover maps shown in Figure 4-1 to 4-3 above, it is apparent that the ‘other’ class has been increasing since 1960 in Dukuduku forest. Table 4-1 and Figure 4-4 show that there has been a significant change over the years. Indigenous forest has greatly changed in area between 1960 and 2008. With the openings occurring along low lying (wetter) dune structures in 1960 (about 6600 ha) (see Appendix 1 and 2) and expanded in 1992 to about 7200 ha, whilst by 2005 the forests had been lost (about 4700 ha).

4.2 Accuracy assessment of single date classification

Post-classification change detection used in this research provides "from-to" information. A change verification accuracy table is shown as below. Note in the table that the pixels without change are located along the major diagonal of this matrix. Note also in the table that the producer's accuracy of indigenous forest class is 95%, the omission error is 5%. The user's accuracy of indigenous forest class is 95%, the commission error is 5%. The overall classification accuracy of this error matrix achieved was 91.25% (kappa = 0.88).

Table 4-2: Verification of Spot Image 2008 derived land cover for single classification (Calculated following Lillesand & Kiefer, 2004)

Ground truth reference							
Description	**Indigenous**	**Plantations**	**Waterbodies**	**Other**	**Total**	**Users Accur.**	**Error of commission**
Indigenous Forests	**19**	1	0	0	20	95.00	5.00
Plantations	1	**17**	0	0	18	94.44	5.56
Waterbodies	0	0	**18**	1	19	94.74	5.26
Other	0	2	2	**19**	23	82.61	17.39
Test points per class	20	20	20	20	**80**		
Prod. Accuracy	**95**	**85**	**90**	**95**		**91.25**	
Kappa total	**0.8833**					**Overall Accuracy**	
Error of omission	**5**	**15**	**10**	**5**			

4.3 Change detection

Year 1960 to 1992 was chosen as the apartheid era and 1992 to 2008 as post-apartheid era, this was due to availability of land cover data availability for the Dukuduku area.

4.3.1 Change between 1960 and 2008

Figures 4-5 to 4-6 show the land cover changes for two periods: 1970 to 1992 and 1992 to 2005. The figures show class changes. The highlighted cells (yellow) in Table 4-3 and Table 4-4 indicates the unchanged areas.

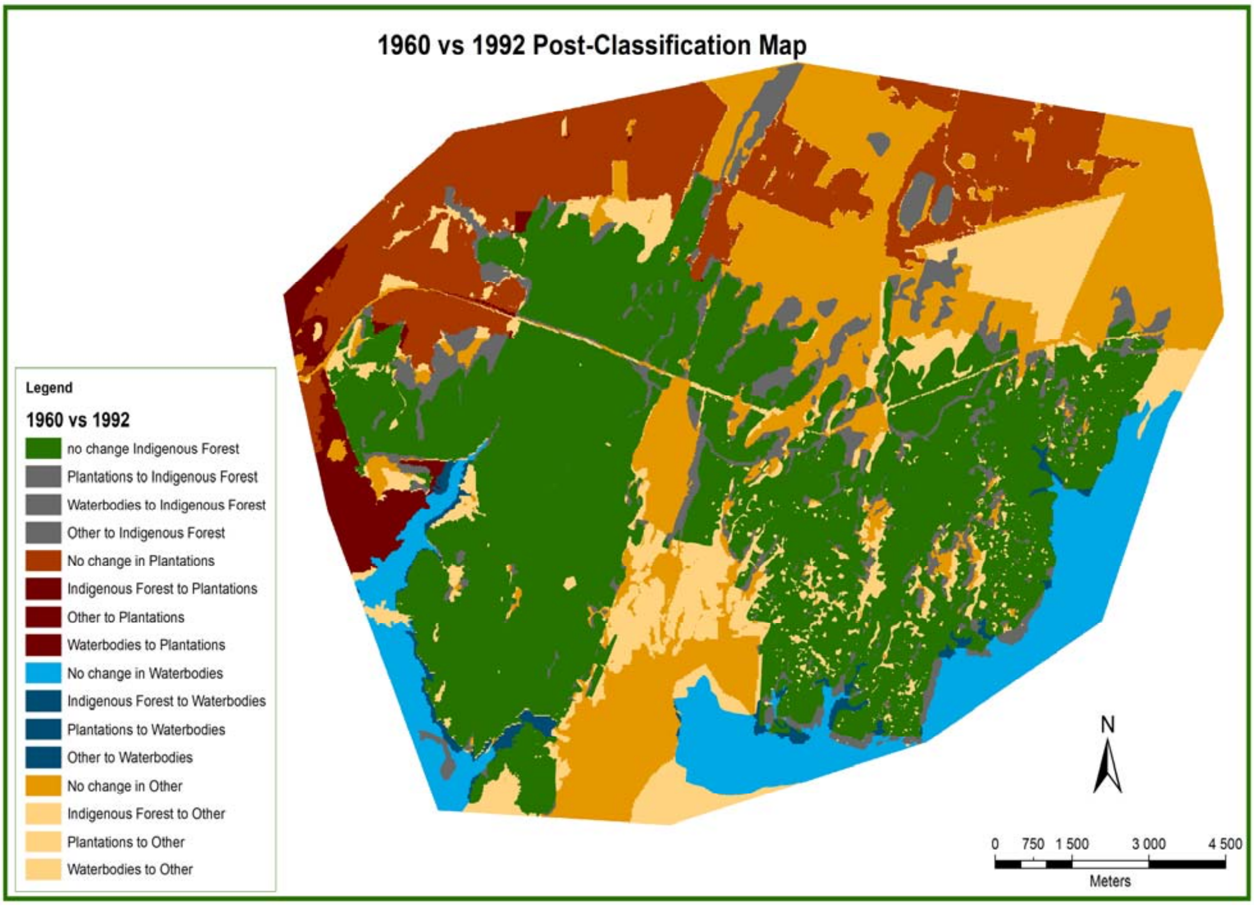

Figure 4-5: Matrix result from images of 1960 versus 1992.

Table 4-3: Changes between 1960 and 1992.

Area (ha) in1960	Post-Classification	Area (ha) changed to in 1992			
	Description	Indigenous Forest	Plantations	Other	Waterbodies
	Indigenous Forest	**5700**	120	1034	145
	Plantations	87	**2200**	560	1
	Other	920	170	**3070**	13
	Waterbodies	120	85	275	**1260**

Table 4-3 and Figure 4-6 indicates that indigenous forests (Dukuduku) changed to the 'other' class by 1034 ha. Though that transformation took place, other classes changed into indigenous forests whereby the 'other' class changed into indigenous forests by 920 ha; and plantations by 87 ha and waterbodies also changed by 120 ha in total to indigenous forests.

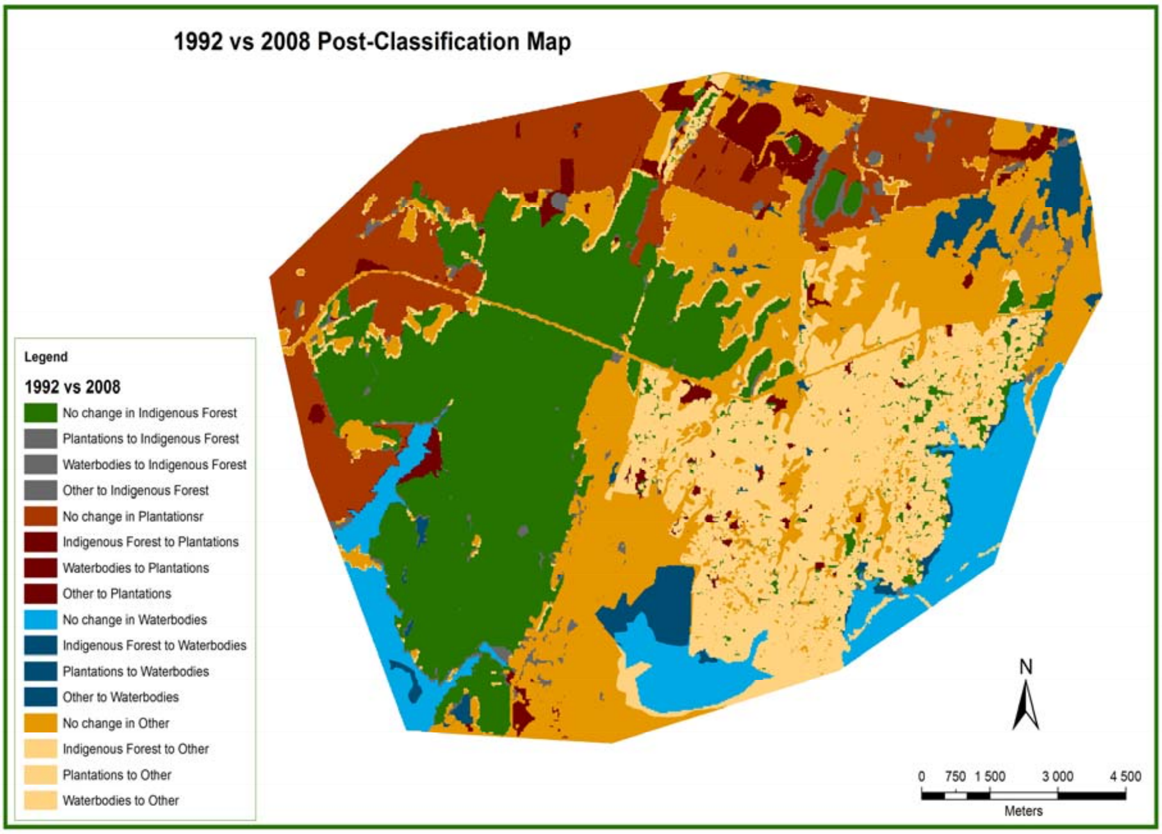

Figure 4-6: Matrix result from image of 1992 versus 2008.

Table 4-4: Changes between 1992 and 2008.

	Post-Classification	**Area (ha) changed to in 2008**			
	Description	Indigenous Forest	Plantations	Other	Waterbodies
1992	Indigenous Forest	**3800**	75	2870	79
	Plantations	54	**2405**	110	0
	Other	308	420	**3765**	445
	Waterbodies	33	11	198	**1173**

Table 4-4 and Figure 4-7 indicates that Indigenous forests (Dukuduku) changed to the 'other' class by 2870 ha whilst 'other' class only changed by about 308 ha to indigenous. This is the class ('other') that indicates how the indigenous forest changed. Though that transformation took place, other classes changed into indigenous forests whereby the plantations changed by about 75 ha.

4.3.2 Trends in land cover change during apartheid (1960-1992) and post-apartheid (1992-2008) eras

Third order polynomial fits were applied to the graphs in terms of the changes of coverage of forest area over time (in years) in order to visualise the trends from 1960 to 2008 (see Figure 4-7) and rate of change during the apartheid and post-apartheid eras. The R^2 value shows the goodness of fit of the polynomial functions. The same was done for the other 3 classes. (Figure 4-8 to 4-10).

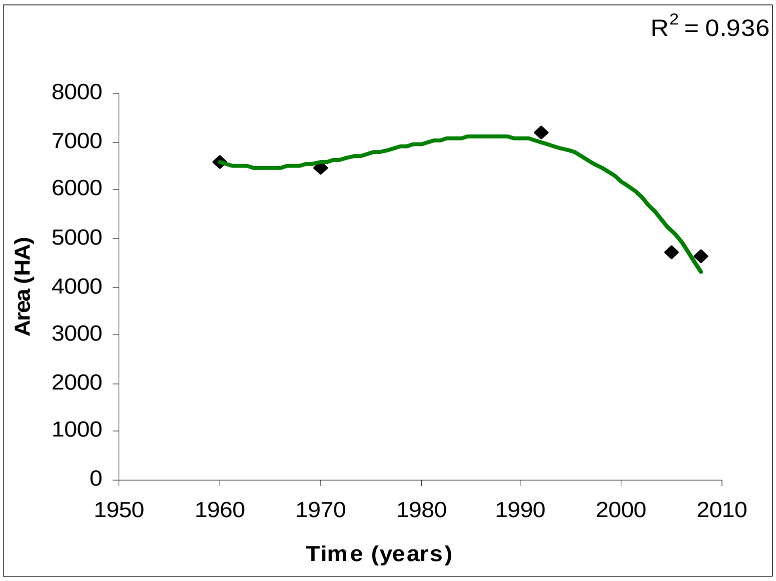

Figure 4-7: Trends of change of the Indigenous Forest between 1960 and 2008.

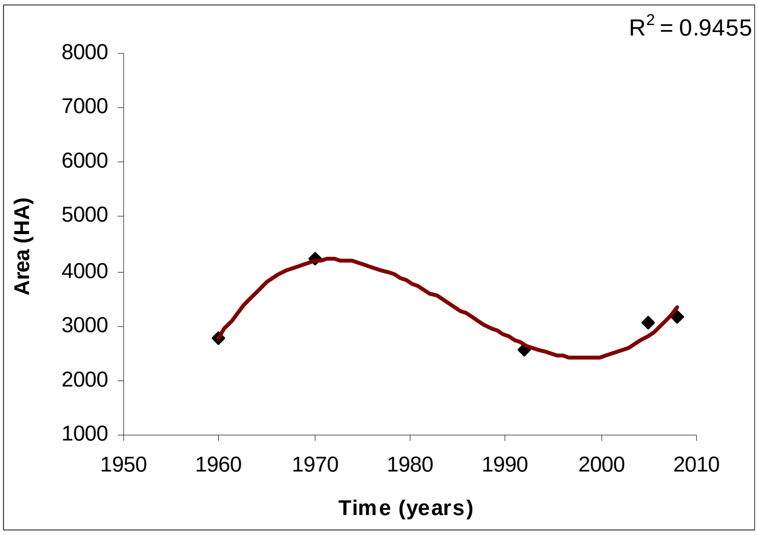

Figure 4-8: Trends of change of the Plantations between 1960 and 2008.

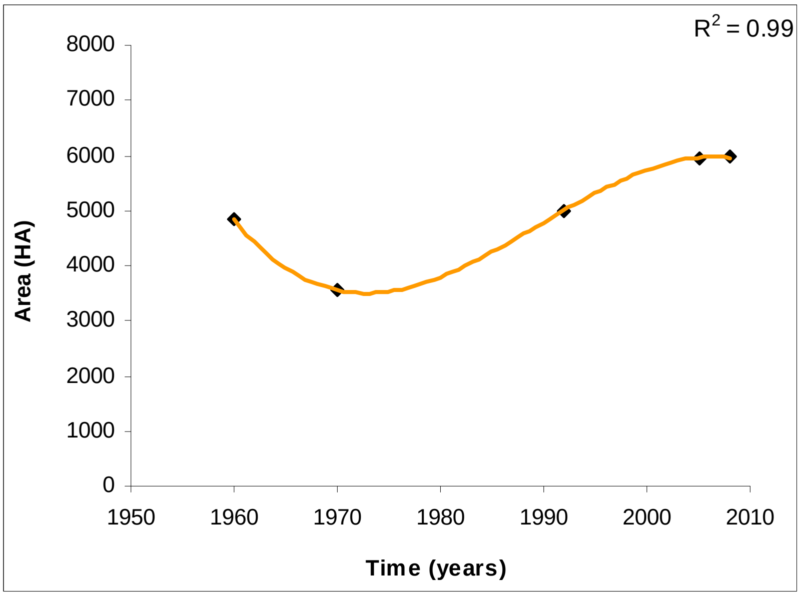

Figure 4-9: Trends of change of the category Other between 1960 and 2008.

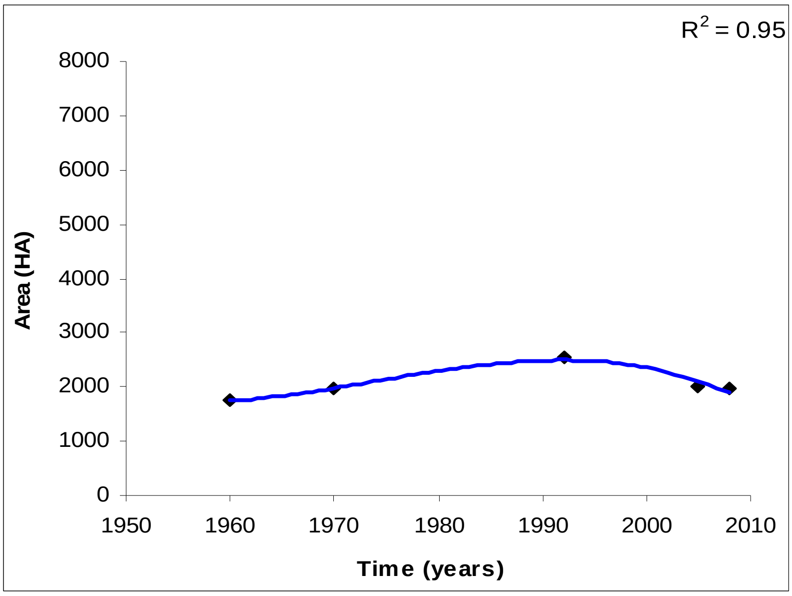

Figure 4-10: Trends of change of the Waterbodies between 1960 and 2008.

The graphs above show the trends of various land cover classes over the past 48 years. The area covered by indigenous forest changed significantly during the 48 years of observation. During the period from 1970 to 1992, indigenous forest cover increased but from 1992 to 2005 the area rather decreased (Figure 4-7). In contrast with the class 'other', from 1960 to 1970 the area mapped decreased, but increased from 1970 to 2008 (Figure 4-9).

In order to evaluate trends in the single political regimes, the graphs above were separated into apartheid and post-apartheid fractions 1960 to 1992 and 1992 to 2008, respectively. This was presented in a table format (see Table 4-5).

Table 4-5: Summary of rate of change over the years. Yellow stands for the class that decreased the most during each period and light brown for the class that increased the most.

Rate of change (ha/y)	Apartheid era			Post-Apartheid era		
	1960-1970	1970-1992	1960-1992	1992-2005	2005-2008	1992-2008
Indigenous Forests	-13	32	18	-190	-28	-160
Plantations	147	-76	-6	38	40	39
Other	-128	66	6	73	18	60
Waterbodies	20	26	25	-41	-15	-36

Table 4-5 shows that during the apartheid regime, though the indigenous forest was lost between 1960 and 1970, it somehow recovered between 1970 and 1992 where it was increasing at a rate of about 30 ha per year. Overall, indigenous forest increased at the rate of 18 ha per year between 1960 and 1992. In the post apartheid era (1992 to 2005) indigenous forest was lost at the rate of about 190 ha per year and then after 2005, the rate of degradation decreased to about 28 ha per year, this puts the total average of the indigenous forest loss to 160 ha per year in the post-apartheid era.

Table 4-5 also shows that during the apartheid era (1960-1992), plantations decreased by at the rate of about 6ha per year. During the post-apartheid era (1992-2008), the 'other' class was increasing at the rate of about 60 ha per year, compared to a rate of about 5 ha per year for the during apartheid era.

4.4 People's perception about forest change and management

John *et al.* (2002) argue that South African protected areas have been under increasing pressure to reconcile a wealth of natural resources with the acute social and economic needs of the black rural majority. Demands for land reform, poverty alleviation and job creation have had profound implications for the conservation and management of the nation's protected areas. Dukuduku is no exception to this as it provides non-consumptive and consumptive uses to the people of the area. This part of the chapter looks at how the natural forest has been managed during apartheid and post-apartheid South Africa, and how the Dukuduku community stakeholders perceive the forest and how it could be managed better.

4.4.1 Socio-economic survey results

Structured interviews were conducted with 20 people from the community in order to gather information on communities living within and adjacent to the forest in 2010/2011, their knowledge of forest and sustainable management as well as their economic status. Results are as follows:

- 60% of the stakeholders were migrants from Mozambique and surrounding towns in northern KZN and 40% were locals.
- 86% of the housing was traditional dwellings/huts/structures made of traditional materials.
- 85% of the households used candles as fuel for lighting.

80% of the households utilized local taps for water.

- 90% of the populations were Zulu speakers as it is the main language in the area of KwaZulu Natal
- 95% were Black Africans.
- 55% were self-employed and 35% were office employees, whilst 10% were unemployed

The area of Dukuduku is rural with limited infrastructure and its community derives various benefits from the forests including food and tourism which contributes to their income, medicine, building material, protection from natural disasters and other consumptive and non-consumptive uses of the forest. Figure 4-12: shows the forest's contribution to the community's livelihood consumptive and none consumptive use of the forest.

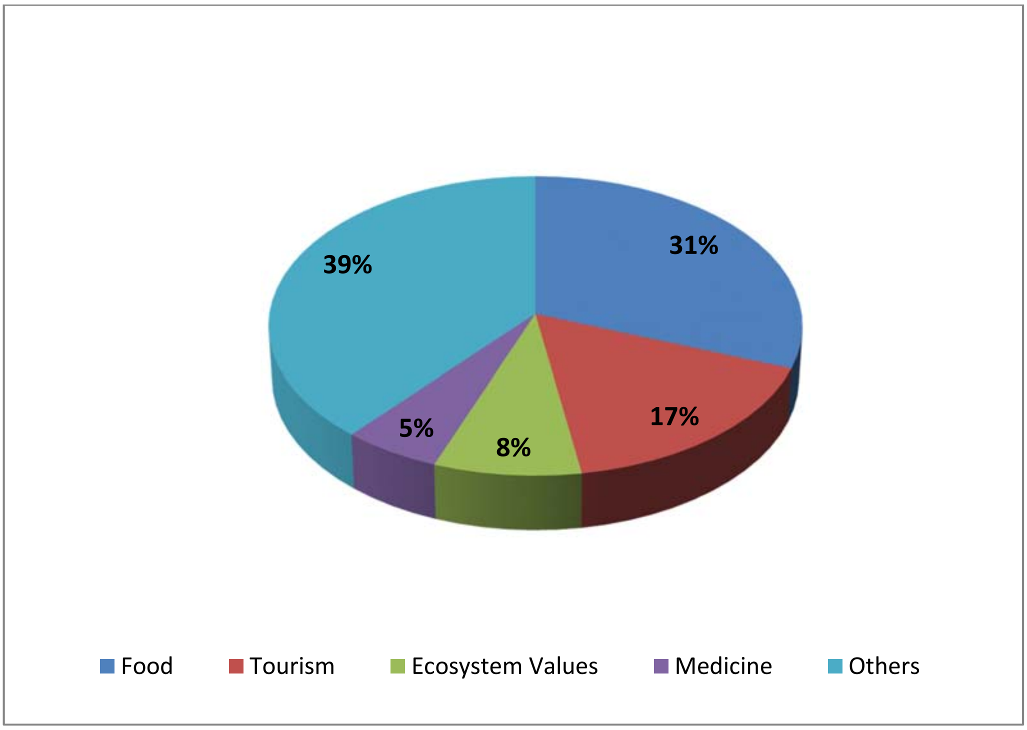

Figure 4-11: Forest provisions to the Dukuduku Community.

Figure 4-11 shows that Dukuduku community uses the forest mostly to derive resources essential to their livelihoods, 39% derives food, 31% for other uses which includes hunting, fuelwood, building material, grazing and many more benefits, whilst 17% uses it for tourism activities such as work of art and medicine has the lowest values. These results highlight the importance of the forest to the community.

4.4.2 Forest Management

The primary responsibility of the Department of Agriculture, Forestry and Fisheries (DAFF) is to manage forests in South Africa; Dukuduku is a state forest which makes DAFF responsible for the well-being of the forest. DAFF responsibility also involves the conservation and protection of present forest areas, the conservation of plant and animal diversity, soil conservation, water conservation and the retention of landscape beauty. The motivation for this is based on aesthetic and ethical considerations, the scientific and economic value of the forests and the sociological assets of a natural environment (DAFF, 2009). Kellert *et al*. (2000) asserts that social factors as well as economic factors need to be considered in conjunction with biophysical factors.

There is consistence with previous surveys by John (2000), whereby residents expressed support for the concept of conservation, but significant hostility towards local conservation authorities. Local residents expressed high expectations towards authorities governing the forests. However, according to Induna Buthelezi (pers comm.) there has not been much gain from the forest in terms of Participatory Forest Management (PFM's); especially since government's mandate is to involve the communities surrounding the forest in every decision taken (PFM's), and residents were also hoping that there will be more employment opportunities, poverty alleviation programs and tourism but have not seen any of that in the region (DWAF, 2002).

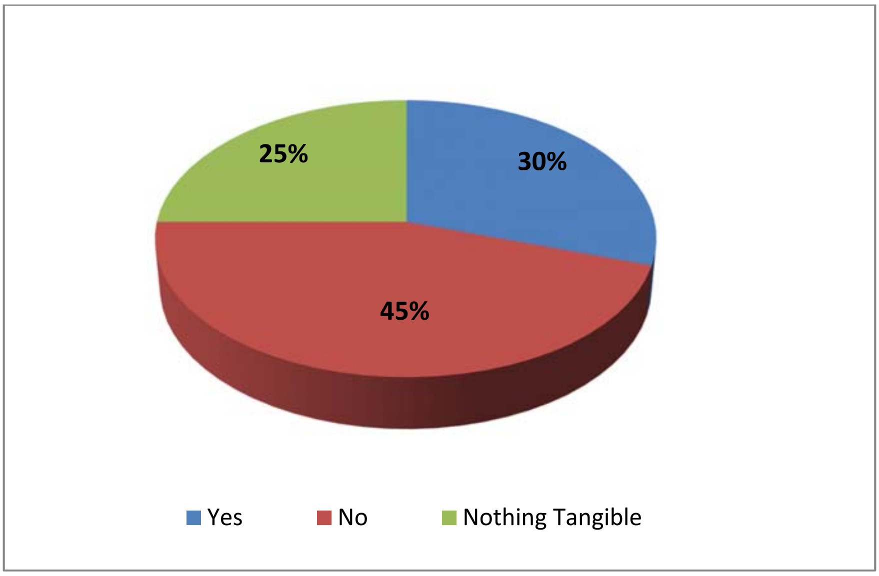

Figure 4-12: Government efforts in forest protection according to the Dukuduku residents.

Figure 4-12 illustrates the attitude of the residents towards the local authorities governing the forest. Only 30% of the residents said government has done something to protect the forest whereby they fenced the forest but ended up with some of the fence being stolen, hired guards to guard the forest but they were never enough since it is a very big forest. However 45% of the respondents said government has not done anything to protect the forest, whilst 25% said government has not done enough to protect the forest. These responses raised a question of what is it that government has not done to protect this coastal forest from being degraded even further.

4.4.3 People's perception about change of the forest and management

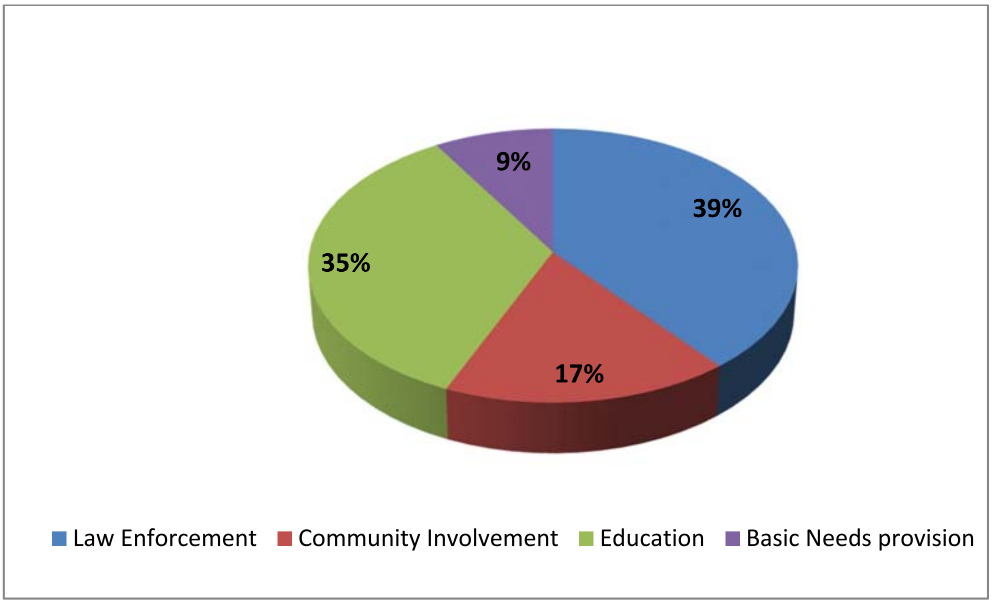

Figure 4-13: How the forest can be successfully protected according to the community

Figure 4-13 shows that if government can involve the community in whatever campaign they do (17%), raising more awareness will be educational to the people of the area and they will understand more about conservation and the need for sustainable development, of which about 75% of the respondents did not know what it means. 39% of the respondents emphasized the issue of more law enforcement. The author verified from the Dukuduku forest manager that only four security guards are employed, which probably not enough given the size of the area. 9% of the respondents emphasized the point that government can do all the above mentioned but if there is a lack of basic needs provided to them by government, the forest will continue to be under pressure as that is where they get most of their basic needs. The community of the Dukuduku sees the potential of forest protection if government can do the above mentioned.

4.5 Conclusion

Results show that the method applied allows the detection of land cover changes that shows the changes in the distribution of the natural forests, plantations, waterbodies and other land cover classes. The indigenous forests increased sharply over 22 years (1970 - 1992) and then decreased sharply in just 13 years (1992-2005), with almost half of the natural forest left in 2008.

Assessment of remotely sensed data indicates that subsistence agriculture and human settlements are the principal drivers of forest change in the region. Historically, plantations have been dominant, but with increasing poverty and population pressure, subsistence agriculture and human settlements are likely to drive land cover changes even more in the future.

Dukuduku forest provides many services and the loss of this forest may have damaging impacts to the local population and to biodiversity in the region. The forest provides economically quantifiable services such as timber, materials for traditional medicines, food and income from activities such as art for tourism. They are productive systems that provide a source of livelihood for impoverished communities. The primary land cover change in the Dukuduku forest has been the conversion of the forest to the class called ‘other’ (farmlands, human settlements, open areas). Community stakeholders believe that if the authorities governing the forest can include them in every decision taken about the forest, the forest can still be protected for future generations to benefit from it.

CHAPTER V: DISCUSSION AND CONCLUSIONS

This chapter presents discussion and synthesis of the thesis. It discusses the results and relates them to the past studies as indicated in the literature review and events that happened in South Africa from 1960 to 2008.

5.1 Introduction

Scientific, political and economical spheres of each community should form part of the basis for the management of community forests (Mitchell, 1994; Klooster, 2002). In 2008, 'participatory' and 'community-based' projects are the global trend in forest management (Corrigan, 2009; Dlamini, 2007; Dongol *et al*., 2002; Turyahabwe *et al*., 2006; Twyman, 2000). The maintenance of environmental integrity of an ecosystem involves maintaining viable populations and ecological processes, protecting evolutionary potential of species and accommodating inevitable human resource use (Corrigan, 2009; Grumbine, 1994).

South African rural communities still depend on the natural forests for various resources even if under the new National Forests Act (1998) harvesting is illegal without a license (Section 7). However the reality is that current control mechanisms are not effective and natural resources are declining (Geldenhuys, 2004). Dukuduku is the largest coastal forest in Kwa-Zulu Natal but is continuously experiencing degradation due to economical reasons facing the community living adjacent to the forest, which is pushed by the economy of the country as a whole. Demands for land reform, poverty alleviation and job creation have all had profound implications for the conservation and management of the nation's protected areas. Dukuduku is no exception to this; it provides non-consumptive and consumptive uses to the people of the area.

5.2 Forest Change

The classification of the aerial photographs and subsequent change analysis clearly showed a significant degradation in the natural forest in Dukuduku. Van Wyk (1996) urges that Dukuduku forest expansion occurred mainly after 1960 indicating that forest succession can proceed rapidly in this sub-tropical area, and this corresponds with the findings of the study. History puts the figure at 3164 hectares in 1937 (van Wyk, 1996), in 1960 it was about 6600 hectares and by 1992 it was about 7200 hectares according to the spatial analysis done in this study. There was a particularly significant natural forest loss after 1992 as the natural forest was reduced to about 4650 in 2008.

The political changes South Africa experienced decades ago (1992) are reflected in the aerial photographs used in this study by showing major land cover changes during the same period. Natural forests expanded between 1960 and 1992, and this was during the apartheid era, an opposing trend to that of the 1992 to 2008 period, whereby natural forests decreased at four times the expansion rate of the forests during the apartheid era. According to interviews conducted in the area, these changes were caused by the change in policies, leading to more open borders to Mozambique, increasing population and other developments that took place in the area. This suggests that there was no proper planning that would protect the natural resources, especially natural forests, in South Africa during the political regime changes.

The results of Remote Sensing data and the understanding of the reasons for land use change show that subsistence farming, human settlements and plantation forestry are the major or core driver of environmental changes in and around the Dukuduku forest. In the past plantation forestry and human settlement have been dominant, but due to increasing population growth, subsistence agriculture is now the most significant land-use besides human settlements and is likely to drive land changes even further in the future. For these reasons, agriculture, human settlement and plantation has been identified as key drivers of forest landscape changes.

Currently Dukuduku forest is under severe pressure from the human activities in and around Dukuduku, subsistence farming and other anthropogenic activities. It all boils back to the lack of basic needs for human living around the forest (lack of employment especially to youth in the area, lack of proper sanitation, electricity and other basic needs). Therefore the community stakeholders help themselves by using the forest for the provision food (such as mushrooms, tubercules, legumes, fruits, juice, seeds, oils and gums), medicine (leaves and bark), building and craft materials, other household needs, services and income (arts and craft). However, the dominant changes detected in the aerial photographs are the transformation to plantation forestry, agriculture and human settlement, as a selective extraction of resources, such as specific medical plants cannot be detected from aerial photographs. This is all reflected through the questionnaire used in this study.

The results in this study highlighted the role of remote sensing data and GIS as a means to monitor land cover changes in and around the indigenous forest in the Dukuduku area. The following are recommended:

- Remote sensing should be used for forestry management to monitor forest change over time as exemplified in this study and other studies such as Corrigan (2009) and Van Wyk (1996).
- It is strongly recommended that more and further studies using the same technology be conducted at field and canopy levels for other natural forest patches in South Africa.
- It is recommended that the Management Plan of Dukuduku addresses the mentioned shortcomings by developing a participatory approach, and not only Dukuduku forest, but

the South African government must monitor the implementation of these in other forests as well, as more natural forests might be saved.

5.3 Community perceptions about the sustainable forest and its management

Under apartheid, notions of race, power and privilege shaped all aspects of the South African society, including the creation and management of the nation's protected areas (PA) (John *et al.,* 2002). Relationships between neighboring communities and protected areas (PA) were typically characterized by misunderstanding, conflict and distrust. Until the early 1980s, black South Africans only had restricted access to most PAs or hunting reserves. The study results highlight how the relationship between community stakeholders of Dukuduku and authorities governing the forest has been, even though community members are in favor of forest protection, they do not approve of some measures taken by the government/authorities to protect the forest. According to the interviews conducted, it is clear that the community have little information about sustainable development and also highlighted that they are not included in the decisions made by the authorities whilst the NFA (1998), emphasizes the use of Participatory Forestry Management.

According to respondents, the Dukuduku community would benefit from the Participatory Forest Management approach as it relies on the forest for resources. As there is a lot of forest degradation taking place in the area, PFM and better strategic management plans are needed. The focus of the governing authorities should be encouraging sustainable development and promoting the alternative sources of income, in an attempt to relieve pressure on forest resources (Corrigan, 2009). The respondents say that, if government can involve the community in whatever campaign they do raising more awareness will be educational to the people of the area and they will understand more about conservation and the need for sustainable development, more law enforcement is needed. But more emphasis was that government can do all the above mentioned but if there is a lack of basic needs, the forest will continue to be under pressure. The community of the Dukuduku sees the potential of forest protection if government can do the above mentioned.

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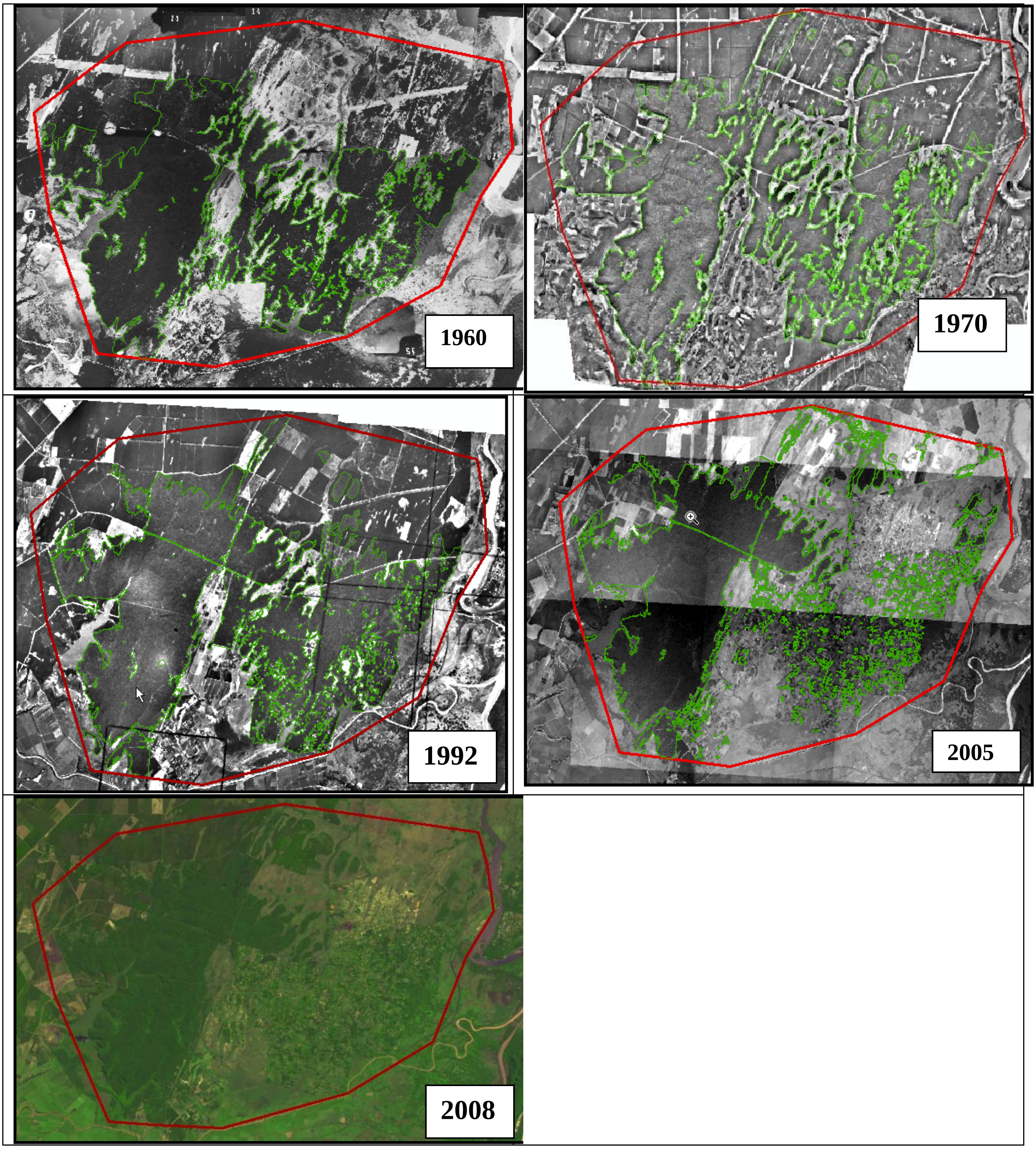
APPENDICES

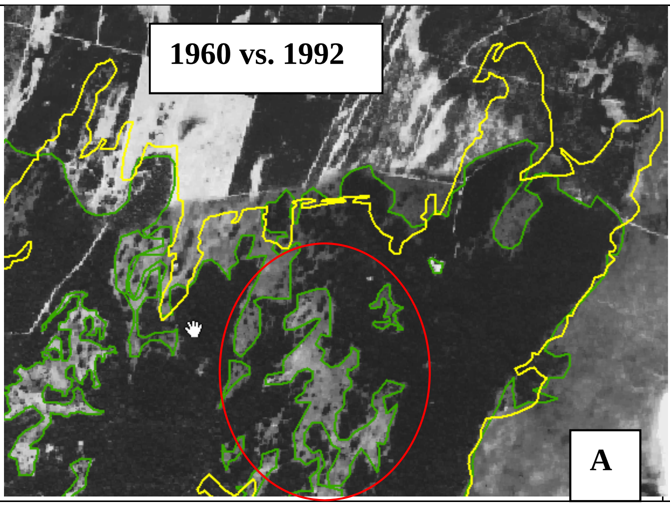
APPENDIX 1: Changes of the indigenous forest land cover over time (1960-2008) with study area
Green layer represents indigenous forest and **Red layer** represents the study area

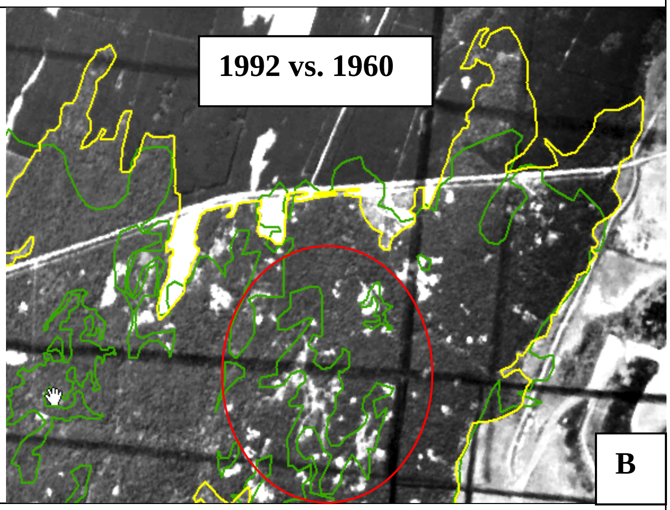


APPENDIX 2: Cropped and comparison of different areas of the imagery to reflect the changes over time.

A: Background image of the year 1960 and **B:** Background image of the year 1992

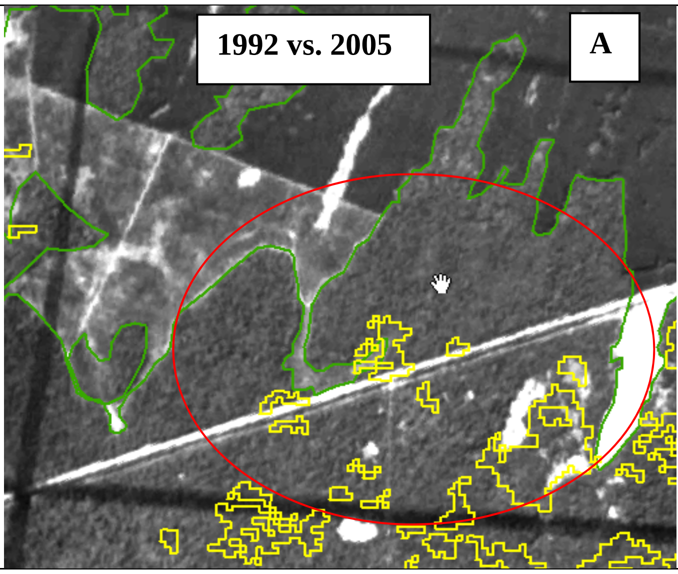
A & B: green layer represents indigenous forest in 1960 and yellow represents indigenous forest in 1992 and red circle is showing the change between the years.

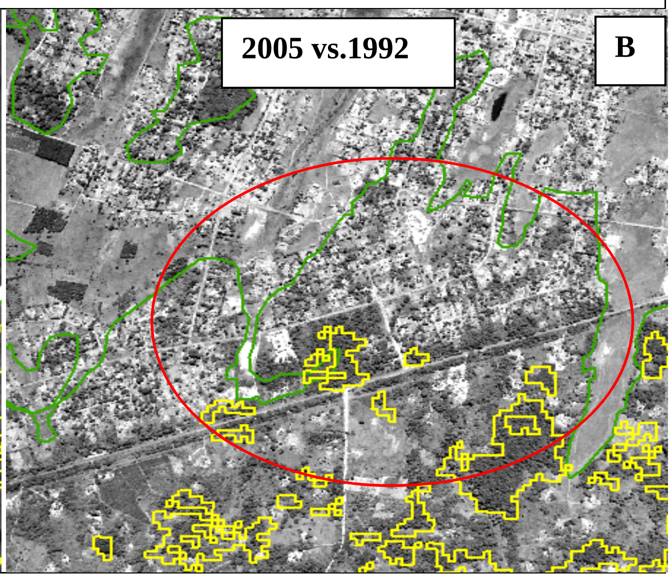




A: Background image of the year 1992 and **B:** Background image of the year 2005

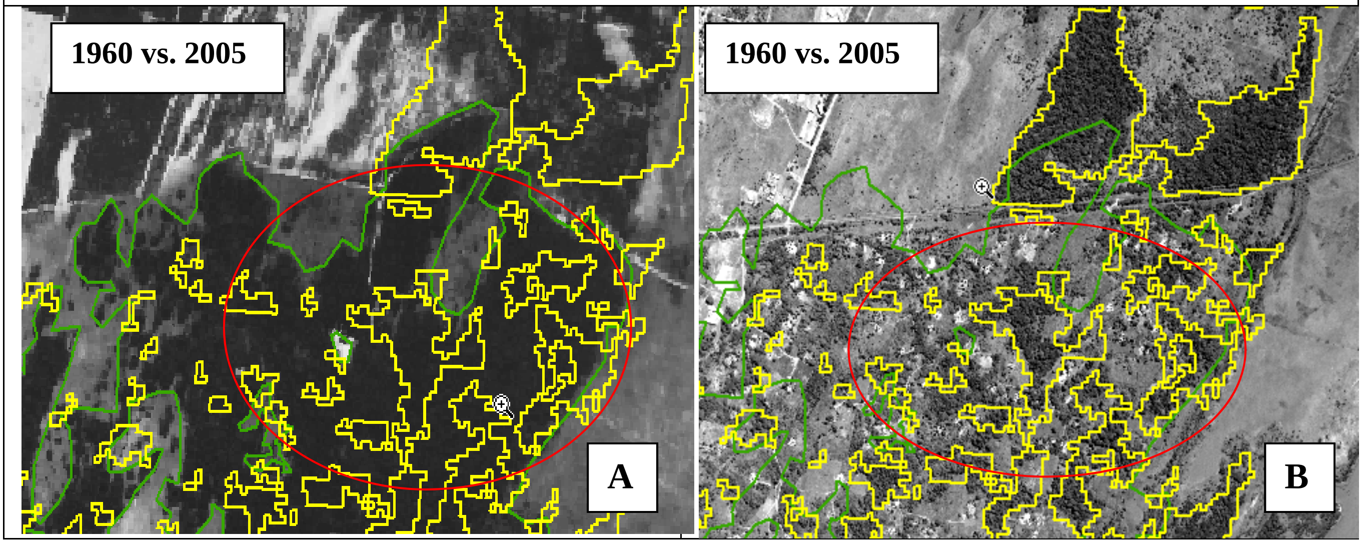
A & B: green layer represents indigenous forest in 1992 and yellow represents indigenous forest in 2005 and red circle is showing the change between the years.





A: Background image of the year 1960 and **B:** Background image of the year 2005

A & B: green layer represents indigenous forest in 1960 and yellow represents indigenous forest in 2005 and red circle is showing the change between the years.



APPENDIX 3: EXAMPLE OF THE INTERVIEW TRANSCRIPTS USED (Questionnaires used for structured interviews)

Socio-economic survey form for land use and land cover change study

Interviewer: **Date:**

Personal Details

Name and surname **Age:**

Village

Location: ____

Contacts: ---

Basic Household Information

How many people are living in your household?

Status in the village

1: Migrant 2: Local

If your answered "migrant" to the question above, how long have you been living here? /______/ and where did you live before?/______________________/ and how long do you want to stay? /______________/

Employment

What are the main sources of income in your household?

Does someone in the household have regular income? Yes No
If yes, what kind of job is it?

Code Occupation:
1. Agriculture
2. Craftman
3. Wage Laborers
4. Trade
5. Pension
6. Office Employee
7. Student
8. Other________________________

Natural Forests

1. What do you think of Natural Forests? Maybe more precise: what is your relationship to the Dukuduku forest and natural forests in general.

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2. Do you ever go into the forest and do you make any use of the forest?

We collect firewood from forest	Yes	No
We collect mushrooms, spices and herbs		
We collect for consumption		
We only graze our animals		
Others		

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3. How much does the forest contribute to your livelihood?

----

4. Would you be affected if the forest would disappear completely?

----

5. As an older person in the community, how was the forest before?

----

6. How did it all start that the forest looks like this today?

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7. Who are the worst culprits of the disappearance of the forest? More modest: In your opinion: who are the more responsible for the changes of the forest?

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8. Do you think it is important to preserve what is left of the forest? Why?

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9. Do you think there is any way we can preserve what is left of it? How?

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10. Do you know anything about Sustainable Development?

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11. What do you think of government e.g. DWAF when it comes to forest issues and why? More modest: In your perception, what is the role of government…

Interviewer Name: ________________________
Signature: _______________________

Thank you for giving me time for the interview. In case you would like to get in touch with me regarding or discussion at a later stage feel free to call the number below.

012 336 7211