A COMPARATIVE STUDY
OF LAND COVER/USE CHANGES BETWEEN
MKHUZE, AND THREE NEIGHBOURING
PRIVATE GAME RESERVES

by

Jayshree Govender

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As the candidate's supervisor I have approved this thesis/dissertation for submission.

Signed: _____________ Name: _____________ Date: ________

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ABSTRACT

In recent years several regions in South Africa including KwaZulu-Natal (KZN) have experienced a significant shift in their farming practice, moving away from conventional commercial farming to the apparently more lucrative private game farming. This is clearly evident in the northern parts of KZN, where most Private Game Reserves (PGRs) occur in semi-arid areas, which are poorly suited to agriculture or livestock farming. These conversions of land cover or change in land use (i.e. from conventional commercial farming to private game farming) is occurring fairly swiftly even though the extent (area of change), impacts and implications of this trend have not been established. Very limited scientific research has been carried out on the environmental effects, impacts and implications of these land cover/use changes related to PGRs. In an attempt to document these changes as well as the environmental implications, three PGRs i.e. Kube Yini, Thanda and Phinda and the Mkhuze Game Reserve within northern KZN were selected for in-depth study. Mkhuze, which is owned and managed by the state, was selected as the control for this study, as it has remained relatively undisturbed for a long period of time. A comparison between the PGRs and Mkhuze was carried out to compare the land cover/use changes within the study area since the establishment of the PGRs.

Remote sensing software was used to achieve the aim and objectives of this study. Using satellite images from 1990 and 2007, a change detection analysis was performed to determine the land cover/use changes that occurred within the study area during the period 1990-2007. Sixty-four land cover/use classes were generated from the analysis. These sixty-four classes were reclassified into five broad land cover/use classes which were identified as (1) water and riverine vegetation, (2) sand forest, forest and rock faces, (3) woodlands, (4) old fields and disturbed areas, (5) and grasslands. The results illustrated that during the period 1990 to 2007, the land cover/use of the entire study area changed significantly, with the overall land cover/use changes illustrating a decrease in the water bodies and riverine vegetation (6 percent to 3 percent); sand forest, forest and rock faces (19 percent to 16 percent); woodlands (26 percent to 25 percent); and old fields and disturbed areas (26 percent to 25 percent) whilst an increase in the grasslands (23 percent to 31 percent) was evident.

Within each individual PGR, significant land cover/use changes related to private game farming were evident. In Kube Yini PGR, a decrease in the water bodies and riverine vegetation (4 percent to 1 percent); old fields and disturbed areas (23 percent to 11 percent); and grasslands (6 percent to 5 percent) were observed whilst an increase in the sand forest, forest and rock faces (31 percent to 47 percent); and grasslands (6 percent to 5 percent) land covers were seen. There has been no change in the woodlands cover (i.e. remains 36 percent). Old fields and disturbed areas have decreased due to the clearing programme that was implemented by Kube Yini, which has also contributed to the increased sand forest, forest and rock faces; and grassland land covers.

At Thanda PGR, water bodies and riverine vegetation remained the same overall, while an increase in the grasslands cover (19 percent to 49 percent) was clearly evident. A decrease in the sand forest, forest and rock faces (13 percent to 4 percent); woodlands (29 percent to 18 percent); and old fields and disturbed areas (38 percent to 28 percent) was also noted. This was due to Thanda's Management Plan, whereby management had cleared the old fields and disturbed areas to accommodate the increased tourist accommodation, increased game species as well as the increased space that is required for these species. Furthermore over the recent years, Thanda has been practicing bush clearing and thinning of vegetation, which has resulted in the creation of a grassland landscape. A grassland landscape was required for viewing the

game species, which resulted in a decreased sand forest, forest and rock faces; woodlands; and old fields and disturbed areas.

In Phinda too, the water bodies and riverine vegetation remained the same (i.e. 1 percent). The sand forest, forest and rock faces (32 percent to 19 percent); and woodlands (43 percent to 41 percent) decreased whilst an increased old fields and disturbed areas (15 percent to 26 percent); and grasslands (9 percent to 13 percent) were observed. Sand forests are sensitive and decrease in extent rather easily as a result of disturbances experienced in the area. The decrease in sand forest, forest and rock faces during this period may be due to the increased wildlife and especially elephant population experienced on this reserve. The woodlands land cover decreased in size as a result of clearing to accommodate tourist infrastructure as well as creating a grassland landscape i.e. open space and clear viewing for the game species. The changes in Phinda's land cover resulted can be explained by the different management practices that were practised on the reserve.

The results from the PGRs were compared against Mkhuze so as to determine whether private game faming was in fact changing the landscape of the study area. During this period 1990 to 2007, Mkhuze experienced only slight changes within it's land cover/use classes: water and riverine vegetation (2 percent to 1 percent); sand forest, forest and rock faces (16 percent to 15 percent); and grasslands (29 percent to 26 percent) decreased whilst an increase in the woodlands (27 percent to 30 percent); and old fields and disturbed areas (26 percent to 28 percent) were noted. Since Mkhuze is managed by the state with its priority being conservation first and not increased monetary gain, competition between species and habitants occurred with the least amount of human influence. It is most likely that the water and riverine vegetation; and grasslands decreased due to the drought experienced in the area between 2001-2006, which may have led to the increased old fields and disturbed areas. In addition woodlands may have increased due to its resistance to harsh conditions. Also contributing to the increased old fields and disturbed areas could be the increased wildlife numbers experienced in the reserve. The slight drop in the sand forest, forest and rock faces land cover most likely resulted due to natural competition between the vegetation species as well as management realising the significance of the sand forest, thus assisting in the preservation of the sand forest, forest and rock faces cover.

An accuracy assessment was carried out to determine the accuracy of the image classification, and a 75 % accuracy was achieved for the overall analysis. The results illustrate that during the period 1990-2007, the study area's land cover changed significantly and that this was mostly like due to the changes within the land cover of the individual PGRs. Climatic data for this period was also taken into consideration to see whether climate variations had occurred and whether this had impacted the change in land cover/use of the study area. The results from the PGRs were compared against the state reserve results as well as the climatic data. The results suggest that the majority of the land cover/use changes within the study area had occurred largely due to private game farming rather than natural processes. The climatic variables such as temperature of the area remained fairly unchanged whilst humidity remained fairly high. With the exception of the drought experienced in the area between the period 2001-2006, it is most likely that the changes in the area are the result of the change to private game farming. Private game farming is having a significant effect on the landscape of the study area and this is largely due to the different management practices practised on each individual PGR.

It is recommended that PGRs be monitored and regulated consistently in order to prevent the degradation of the environment and its ecosystem. The study exhibits the value and usefulness of satellite imagery in detecting land cover/use changes related to private game farming. Landsat 5 TM imagery was the most suitable and accurate in identifying and mapping broad scale land cover/use changes related to private game farming. If a more detailed level of investigation is required, the use of higher resolution imagery (e.g. Spot/Landsat 7) is advised.

PREFACE

The experimental work described in this dissertation was carried out in the School of Environmental Sciences, University of KwaZulu-Natal, Durban, from April 2008 to December 2010, under the supervision of Prof Onisimo Mutanga (PMB campus) and co-supervision of Dr Shirley Brooks (formerly of the University of KwaZulu-Natal, now at University of Free State).

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.

____

Jayshree Govender

December 2010

DECLARATION 1 – PLAGIARISM

I, ………………………………………. declare that

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

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

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

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

    a. Their words have been rewritten but the general information attributed to them has been referenced
    b. Where their exact words have been used, then their writing has been placed in italics and inside quotation marks, and referenced.

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

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DECLARATION 2 – PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis (include publications in preparation, submitted, *in press* and published and give details of the contributions of each author to the experimental work and writing of each publication)

Publication 1

Publication 2

Publication 3

etc.

Signed: …………………………………………………………

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LIST OF ABBREVIATIONS

DEAT	Department of Environmental Affairs and Tourism
DOS	Dark Object Subtraction
GCPs	Ground Control Points (GCPs)
GIS	Geographical Information Systems
MSS	Multispectral Scanner
NAMC	National Agricultural Marketing Council
PGRs	Private Game Reserves
SAC	Satellite Application Centre
SANPAD	South Africa-Netherlands Research Programme on Alternatives in Development
TM	Thematic Mapper

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DEDICATION

To My Dad

To my Dad, though you are not physically here with me, your voice of wisdom and your self belief in me has carried me throughout this journey.

To My Mum

A very big thank you to you mum who is really an extraordinary person. Thank you for affording me the opportunity of doing my Masters. Mum you have always been and will continue to be my pillar of strength, my best friend and my most loyal supporter. Thank you for your never-ending love, understanding, patience, guidance, support and belief. Without your constant motivation and encouragement I would not have been able to complete this dissertation.

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CHAPTER ONE

INTRODUCTION

In recent years, several regions in South Africa have experienced a significant shift in their farming practices, as many farmers move away from conventional commercial farming to the apparently more lucrative private game farming. This change in agricultural practice is a relatively recent trend, which gathered momentum in the early 1990s just prior to the 1994 democratic elections (Brooks *et al.,* 2008). Land cover/land use changes related to private game farming are having significant yet largely undocumented impacts on the physical condition of the environment, and it is in an effort to analyse this aspect of the land use change that this study has been embarked upon.

This chapter provides a concise introduction to the significance and relevance of this trend and a brief introduction to the policies and legislation governing private game farming. The rationale behind the present study is outlined, followed by the aim and objectives of the research. Geographical Information Systems (GIS) and Remote Sensing are introduced as the methodological tools that were utilised in the identification and mapping of the spatial extent of the land cover/land use changes related to private game farming in one area of KwaZulu-Natal province. The chapter concludes with an overall view of the subsequent chapters that are to follow.

1.1 BACKGROUND

1.1.1 The growth of game farming in South Africa

Over the last decade, the conversion of many farms to game farming has progressed swiftly and this can clearly be seen in the provinces of the Eastern Cape and KwaZulu-Natal (National Agricultural Marketing Council (NAMC), 2006). In the northern parts of KwaZulu-Natal, conventional commercial farming such as cattle, cotton and pineapple farming have been in many cases completely replaced by private game farming. According to the Department of Agriculture (2006), private game farming can be defined as any farming activity involving wild animals.

The reasoning behind the change to private game farming is linked to a number of factors. In the early 1990s farm owners may have believed that this shift would prevent them from losing their land to the land reclamation process (Brooks *et al*., 2008). Other farm owners have optimistically changed to game farming as a business enterprise. A range of activities takes place on private game farms, from hunting and game meat processing to high-end ecotourism. According to Brooks *et al*. (2008), significant resources have been invested into many Private Game Reserves (PGRs), which are only accessible to the affluent individuals who can afford the price.

These land conversions are having significant yet undocumented impacts on the physical environment. Biggs and Scholes (2002) state that the changes in land cover not only impact the biogeochemical cycles, climate and hydrology directly, but may also contribute to the loss of species through habitat fragmentation and destruction. Thus changes in land cover related to private game farming may have led to significant changes in the vegetation patterns, which would result in changes within the biomes. Hence this shift in farming may not only be altering the land cover of the study area in unknown ways but it may also be impacting on agricultural productivity.

Biggs and Scholes (2002) argue that the impact of private game farming on land cover is hard to determine because of the lack of knowledge and information about the historical and chronological changes that have taken place. To date there has been very limited research carried out on land cover/land use changes related to private game farming. Academics have shown very little interest to this topic and this could be due to the fact that this change in practice is a fairly recent trend that begun in the early 1990s (Brooks *et al*., 2008). This dissertation attempts to document the land cover/land use changes related to private game farming in one part of the country, northern KwaZulu-Natal. One of the ways of obtaining this information is through the use of Geographical Information Systems (GIS) and Remote Sensing.

1.1.2 Private game farming conservation laws

At present there is no specific legislation stating the guidelines for the practice of private game farming in South Africa and the state of health of the landscape being used by PGRs is unknown. Although there are a multiplicity of laws that are from time to time used independently or in combination to protect and conserve the landscape, explicit, well-defined laws need to be created and enforced by government to determine the current state of health of the land used for private game farming (Cousins *et al*., 2010). The most significant South African conservation laws that are used to protect and conserve the landscape from further loss and degradation presently and into the future, include the Constitution of the Republic of South

Africa (Act no. 108 of 1996) and the National Environmental Management Act (NEMA): Biodiversity Act, (2004). Since there is no specific legislation with regards to PGRs, government needs to formulate and implement plans and laws including monitoring and management plans to protect the landscape from degradation and further loss currently and into the future. Geographical Information Systems (GIS) and Remote Sensing technologies, discussed below, provide a means to monitor the changes related to private game farming, thus allowing for the development of suitable and sustainable management responses.

1.2 RATIONALE BEHIND THE STUDY

As the impacts to the land cover of private game farming remain largely unknown, this study attempts to address this issue. It aims to identify and map the land cover/land use changes related to private game farming in the study area, determine the factors that have driven and are currently steering this change. It aims to document the impacts on the physical condition of the environment and suggest tools for future monitoring. As Sokolic (2006) concluded, understanding the nature, extent and impacts of land cover/use changes is the foundation for implementing better management practices.

This research is applicable to any research conservation project. Analyses, comparisons and deductions are summarised and these results can be utilised to assist landowners of the PGRs in understanding the effects of PGRs on the landscape of the study area. Researchers, students, government and non-governmental agencies will benefit from this study as it provides valuable information on how private game farming impacts the land cover/land use of the area of interest.

1.3 AIM AND OBJECTIVES

AIM

The aim of this study is to map the land cover/land use changes related to private game farming, using remotely sensed data.

In order to achieve the overall aim of this study several objectives had to be met and they are listed as follows:

OBJECTIVES

1. To determine the changes in the land cover/land use patterns using remotely sensed data between 1990 and 2007.

2. To assess the suitability and accuracy of using a medium resolution multispectral sensor such as Landsat for the purpose of identifying and mapping land cover/land use changes related to private game farming.

3. To infer changes in land cover related to private game farming over time.

1.4 REMOTELY SENSED DATA AND THE METHODOLOGY EMPLOYED

Remotely sensed data - also known as satellite imagery - has been extensively used in land cover/land use studies (Allan, 2007) as it provides an accurate and cost-effective approach for identifying and mapping land cover/land use changes. There are several reasons as to why remotely sensed data was selected for this particular study. Firstly it was possible to draw on archival satellite imagery, in this case Landsat 5 Thematic Mapper (TM), which was provided free of charge from the Satellite Application Centre (SAC). Archival imagery provides a valuable resource because it allowed the researcher to identify and classify the land cover/land use of the study area during the 1990s. The archival data was compared to the 2007 Landsat imagery so that the researcher was able to map the land cover/land use changes related to private game farming over time. Secondly, satellite data were employed in this research because it was impossible to ground truth the entire study area due to its large extent. Thirdly, several parts of the study area were inaccessible and remote due to the topography, dense vegetation cover, and the presence of "Big Five" game animals. Thus to overcome the above mentioned problems remotely sensed data was selected to map the land cover/land use changes related to private game farming.

By documenting the land cover/land use changes related to private game farming this study attempts to illustrate the link between the diverse components that make up this environment (Sokolic, 2006). The interactions between the components and the changes in land cover/land use practices from past to present must be taken into consideration holistically and understood fully when mapping the land cover/land use changes related to private game farming. This information can be used to better understand this shift in practice as well as the impacts and implications of this shift on the physical environment.

1.5 STUDY OUTLINE

This dissertation comprises of six chapters. Chapter One introduced the reader to the topic as well as the aim and objectives of the study. A detailed description of the background of the study area, which comprises selected private game reserves and a state reserve within northern KwaZulu-Natal, South Africa, is given in Chapter Two. This chapter includes the geographical location, climatology and geology of the study area.

Chapter Three presents a comprehensive literature review, clarifying theoretical concepts used in this study. The theory of private game farming, image processing together with GIS, Remote Sensing and its application, as well as the capability of Landsat 5 TM to identify and map land cover/land use changes related to private game farming, is discussed in this chapter.

An overall description of the methodology that was employed and materials that were utilised in this investigation is given in Chapter Four, while Chapter Five presents the results (i.e. maps produced which depict the land cover/land use changes related to private game farming), analysis and discussion of the research.

Chapter Six is the Conclusion. The aim and objectives of the dissertation are re-visited in order to answer the primary research question of whether land cover/land use changes have resulted due to private game farming and, if so, what the nature of the changes is. Limitations of the study are noted and recommendations for future research are suggested.

CHAPTER TWO

BACKGROUND TO THE STUDY AREA

This chapter presents an overview of the study area, which comprises of three selected Private Game Reserves (PGRs) and the Mkhuze Game Reserve (owned by the state), within northern KwaZulu-Natal. The selected PGRs include Kube Yini, Thanda and Phinda. Chapter two provides an introduction to the study area, introducing the reader inter alia to its geographical location, climatology, geology, precipitation and vegetation.

2.1 GEOGRAPHICAL LOCATION OF STUDY AREA

The study area is located between 32° 02' 21.34''E and 32° 27'33.16''E latitudes and between 27° 32' 50.77''S and 27° 54' 14.27''S longitudes and falls within the following grid references 2732 CA, 2732 CB, 2732 CC and 2732 CD. Figure 2.1 illustrates the geographical location of the study area. The general topography of the study area is relatively flat, comprising of drainage lines, valleys and gentle hills that occur here. To the east of the N2 highway is the Lebombo mountain range, which progressively rises to the height (450 meters) of the Ubombo village (van Rooyen & Morgan, 2007).

Since the study area lies just south of the 18ºC isotherm and coincides more or less with the southern boundary of the Köppen's Tropical Savanna climatic type (van Rooyen & Morgan, 2007), the area experiences a tropical to subtropical climate, with warm to hot, to very hot and humid conditions. As a result the summers are usually hot whilst winters are cool to warm. The weather can also change quickly and predictably, varying as it frequently does in summer from scorching heat and drought to tropical storms and floods (Gush, 2000). The study area is situated in a somewhat semi-arid region; there are few streams and rivers present within the study area.

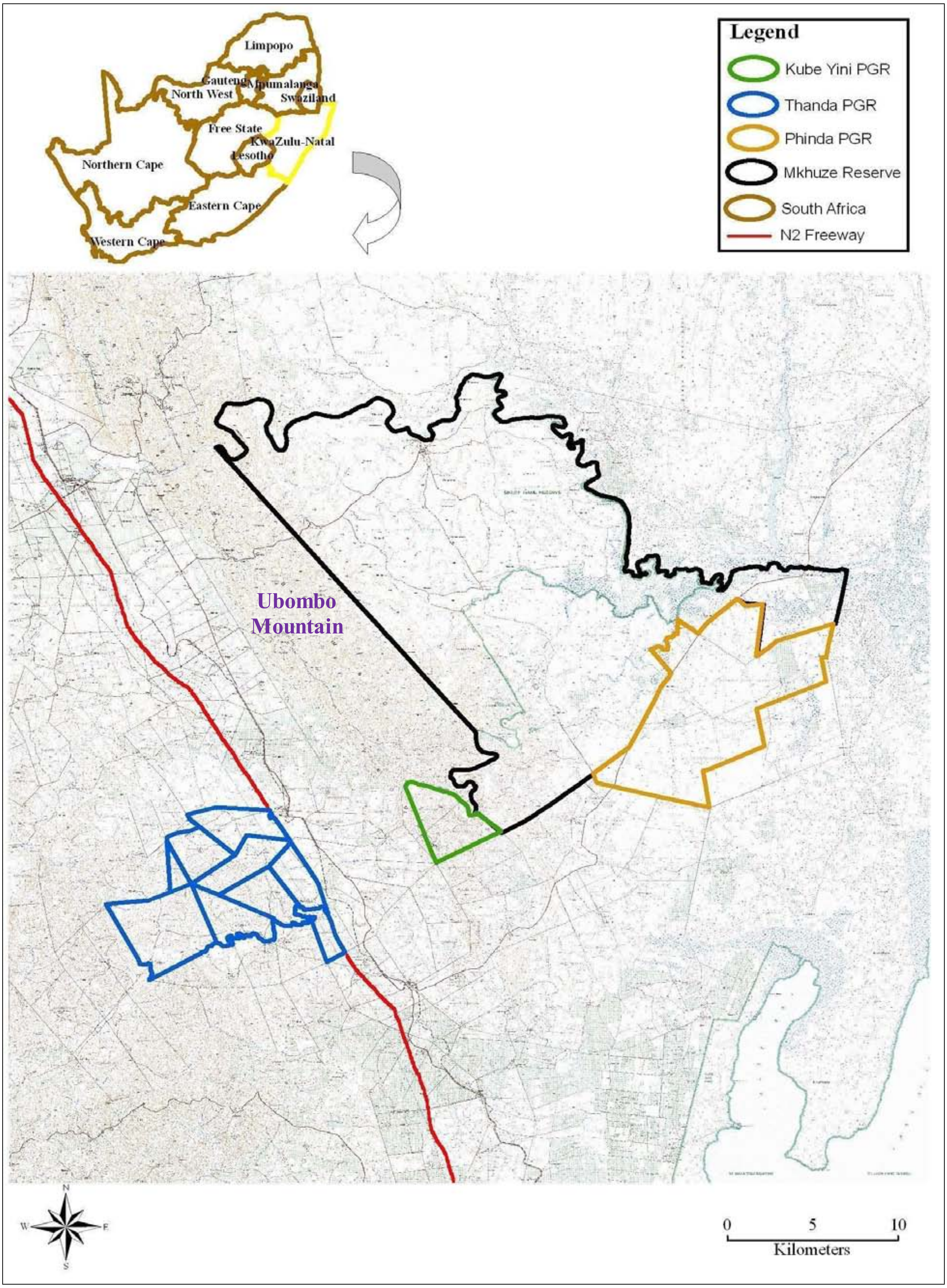

Figure2.1: Geographical location of study area

2.2 INTRODUCTION TO PRIVATE GAME RESERVES (PGRS)

Private Game Reserves (PGRs) have mushroomed rapidly within northern KwaZulu-Natal and three selected PGRs in the Mkhuze area were chosen for this study. Kube Yini PGR belongs to shareholders who bought and combined their farms. Today Kube Yini comprises of fifty private villas built for the exclusive use for the shareholders, and the land use is exclusively wildlife. Both Thanda and Phinda PGRs were created as tourist destinations for wealthy international and local tourists who can afford the expensive accommodation. In addition both these reserves comprise of “Big Five” game species as well as extra-limital species. Extra-limital animals are animals that are indigenous to southern Africa, but do not naturally occur within an area, for instance Thanda PGR stocks extra-limital species such as blesbok, gemsbok, sable and roan (Brousse-James & Associates, 2008). The following section provides a brief history into each PGR.

2.2.1 Kube Yini Private Game Reserve

Situated in northern KwaZulu-Natal on the Ubombo Mountains and at the south western end of the extensive Mozambican coastal plains lies Kube Yini PGR. To the east of Kube Yini lies the renowned Mkhuze Game Reserve. Kube Yini lies between 32° 12’ 29.34’’E and 32° 15’ 34.58’’E latitude, 27° 46’ 45.97’’S and 27° 49’ 29.81’’S longitudes, with a spatial extent of 1214 hectares (ha). Together, Kube Yini as well as the Lowane farm comprises Kube Yini PGR. This PGR was purchased in 1989 and the first phase of the game farm was developed in 1991 (P Binney, 2008, pers. comm.[1]). According to P Binney, (2008, pers. comm.[2]), the previous owners were Dr. Prigge and Andrew Montgomery and today approximately a hundred shareholders that make up the share block own this PGR.

Historically crops such as cotton and maize were cultivated on the land, but proved unsuccessful due to the rough, uneven terrain (N Hawkey, 2008, pers. comm.[3]). According to P Binney, (2008, pers. comm.[4]) for this very same reason, cattle farming were not developed on the land, giving rise to the opportunity for ecotourism. P Binney, (2008, pers. comm.[5]) added that in creating Kube Yini, vegetation as well as boulders were removed from the flat areas and private

[1]Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[2]Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[3]Interview with Neville Hawkey, Kube Yini PGR, 20 October 2008.

[4]Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[5]Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

villas were constructed. Unlike a reserve within a commercial lodge operation, Kube Yini was developed into a share block with fifty privately owned sites (C Lloyd, 2008, pers. comm.[6]). P Binney, (2008, pers. comm.[7]) further stated that presently there is "Big Five" game on the PGR, which includes white rhinos, giraffe, blue wildebeest, zebra and impala. Kube Yini's vegetation comprises of mixed bushveld, riverine and open mixed grassland. No hunting is allowed on the PGR as the majority of the shareholders voted against this practice, but the shareholders do allow game captures and sales (P Binney, 2008, pers. comm.[8]).

2.2.2 Thanda Private Game Reserve

In the early 2000s, Dan and Christin Olofsson, Swedish citizens, purchased six farms just west of the N2 in the Mkhuze area and created Thanda PGR (Brousse-James & Associates, 2008). This property was purchased as a holiday home for their family and friends. The Olofssons decided to develop Thanda into a private "Big Five" game reserve inclusive of an upmarket game lodge facility. The majority of the farms making up Thanda PGR were acquired in 2002. Previously all of the farms were utilised for cattle farming, with a restricted usage of wildlife. In creating Thanda PGR, fences that had been erected internally were taken out. New game-proof boundary fences for the restriction and containment of the "Big Five" game animals were erected. In addition all cattle infrastructure such as dip tanks, water reservoirs, scrap farming equipment and cattle pens were removed (Brousse-James & Associates, 2008).

In addition, a luxury eighteen-bed lodge, and eight-bed tented camp, Dan Oloffson's private villa and the Vula Zulu Theatre and Cultural Experience (previously called Bayete Zulu Cultural Village) were developed. To the east of the N2 highway, a separate 312 ha section, registered as Bayete, was purchased. An additional farm (Portion 1 of Bartenheim 13194) was acquired in 2004. In 2005, this farm was consolidated with Thanda PGR. Two more farm properties; the Meyersland (Sub A of Ititihoya and Unohemu and the remainder of Bartenheim were purchased in 2007 (Brousse-James & Associates, 2008). Although under the ownership of Mr. Dan Olofsson, the farm Bartenheim, which later changed its name to Intibane PGR, has been managed differently from Thanda PGR. In particular, Intibane PGR lacked the presence of "Big Five" game species (A Smith, 2008, pers. comm.[9]).

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[6] Interview with Craig Lloyd, Thanda PGR, 20 October 2008.

[7] Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[8] Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[9] Interview with Alain Smith, Intibane PGR, 8 April 2008.

In 2009, the fences between Thanda and Intibane PGRs were dropped, which resulted in a single reserve, thus extending Thanda PGR. After consolidating all farms, the total size of Thanda PGR was estimated to be approximately 7,136.5043 hectares, consisting of 6,824.5043 hectares on the west of the N2 highway and 312 ha on the east of the N2 highway (Brousse-James & Associates, 2008).

2.2.3 Phinda Private Game Reserve

Phinda Private Game Reserve, also known as Phinda Resource Reserve, is the oldest of the PGRs in the area. Phinda is situated to the west of the N2 highway, between Mkhuze Game Reserve, Sodwana State Forest and the former St. Lucia Game Reserve and covers an area of approximately 15 000 hectares. Agriculture was always problematic as the region's poor soil and unfavourable weather conditions did not support farming (van Rooyen & Morgan, 2007). As early as 1925, settler farmers farmed the land, practising cattle farming, as well as planting maize, tobacco and cotton (Varty & Buchanan, 1999). However farming operations were not successful, due to the infrequent yet heavy precipitation, drought, hailstorms as well as insects destroying the crops (Varty & Buchanan, 1999). According to Varty and Buchanan (1999), pineapple, granadilla and mango plantations have also been attempted but were unsuccessful. The failure of these farming endeavours convinced the owners that the land was never meant for agriculture farming and in 1990 Phinda PGR was established (Varty & Buchanan, 1999). (For a discussion of the failures of settler farming in Zululand in the 1920s, see Brooks 1997).

Commencing in 1991, Phinda PGR consisted of two properties: the farm Zinave (named after the Zinave National Park in Mozambique) in the north, and Zulu Nyala in the south. The Zulu Nyala farm shared a common boundary with the Mkhuze Game Reserve to the west. Later, Phinda extended its boundary from wetland to wetland: i.e. from the Mkhuze river in the north to the Mzinene river in the south (Varty & Buchanan, 1999). The most significant change to the area was the construction of a new road, which runs through Mozambique. This road provides access to the Nibela, Makasa and Mnqobokazi communities that reside east of Phinda (Varty & Buchanan, 1999).

2.3 INTRODUCTION TO STATE GAME RESERVES

In the late nineteenth century, game reserves were established in South Africa (Gush, 2000). In Zululand in particular, four protected areas for game were declared, of which the Hluhluwe and Umfolozi, which was proclaimed in 1985 – were the oldest in colonial Africa (Brooks, 2005).

These reserves were owned and managed by the government, with the main focus being conservation of biodiversity, in particular wildlife. Unlike PGRs, state game reserves prioritise conservation first rather than monetary gain.

According to Brooks (2005), it was only during the late 1930s, that game reserves took on a new cultural meaning, becoming places not only known for conserving wildlife but also as tourist places for the elite people who visited during their leisure time. As a result state game reserves had now become public reserves that were opened to the public to view the wildlife. Thus it was only in the third and fourth decades of the twentieth century that game reserves begun to be more widely thought of as places of public resort (Brooks, 2005).

2.3.1 Mkhuze Game Reserve

Mkhuze Game Reserve lies at the south western end of the extensive Mozambican coastal plains and on the eastern slopes and southern foothills of the Lebombo Mountains (van Rooyen & Morgan, 2007). This 40 000 hectare reserve situated in northern Zululand, between the Mkhuze River in the north and Phinda Game Reserve in the south, was proclaimed a protected area in 1912 (Gush, 2000).

Located approximately between 32° 08’ 35.46’’E and 32° 25’15.35’’E latitudes and between 27° 35’ 00.00’’S and 27° 44’ 00.15’’S longitudes, this reserve is historically known for its Nagana outbreak that occurred within Zululand. The outbreak of the Nagana disease, which was linked to the presence of game, made its first appearance in the 1890s. It was established that the game acted as hosts to the tsetse fly, the carrier of Nagana and in 1903 government’s decision to destroy all game in the area to ensure the survival of the game was carried out. It was only in 1912 due to Mr Oswald Fynney’s concern for the welfare of the Mkhuze area, which led him to approach the Provincial Secretary of Natal to have the area officially proclaimed as a game reserve. As a result, the official proclamation of the reserve was made on 15 February 1912. (Gush, 2000).

The Mkhuze River curves along the reserve’s northern and eastern borders with a fine stretch of fig forest along its banks. This reserve is well known for its rare sand forest type that also occurs within its boundaries.

2.4 HYDROLOGY OF THE STUDY AREA

The only rivers of note are the Msunduzi, Mzinene, Mkhuze, Mhlosinga, Pongolo, Ndlovini and Mduna, which flow through the study area. The Mkhuze, Msunduzi and Pongolo rivers flow from the north into Phinda PGR while the Mhlosinga and Mzinene rivers flow from the south into the PGR. According to Varty and Buchanan (1999), the catchment of Phinda PGR comprises mostly of the Mhlosinga River and its tributaries, which include the Munywane and Mungwana rivers.

Quite a few non-perennial rivulets, many of which arise in the hilly terrain on the western side of Thanda PGR, drain Thanda (Brousse-James & Associates 2008). Two major streams that drain Thanda PGR are the Ndlovini, which flows through the northern part of Thanda, and the larger Mduna, which flows through the southern part of Thanda. Neither of these streams holds perennial water for Thanda PGR. The Mduna stream flows through Intibane PGR while the Msunduzi River flows through Kube Yini PGR.

The Mkhuze River flows directly into the Nsumu Pan, creating a permanent water supply for Mkhuze Game Reserve. The Mkhuze River, forming Mkhuze's northern and eastern boundary, flows past the Itshanene Mountain through the impressive Mkhuze Gorge, past the Ukhombe Hill, the Lebombo Mountains and eventually flowing into the northern reaches of Lake St Lucia (Gush, 2000). The Msunduzi River forms the southern boundary of Mkhuze Game Reserve.

More often than not, narrow belts of riverine forest border the rivers. According to Brousse-James and Associates (2008), the rivers that flow through the study area are seasonal, flowing all through the wet summer months only. During winter, these rivers become dry and are sometimes reduced to pools of water (van Rooyen & Morgan, 2007).

2.5 PRECIPATION

The Private Game Reserves under consideration lack precipitation stations hence the annual and seasonal precipitation trends are extrapolated from weather stations in close proximity to the PGRs. The 2007 mean monthly and annual rainfall recorded at the weather stations in this region is summarised in Table 2.1.

When considering the precipitation statistics for the study area, it is important to keep in mind the influence of season seeing as the study area falls within the summer rainfall region. Primarily due to the rain shadow effect of the Lebombo mountain range, the mean annual precipitation is 578 mm in Mkhuze but much higher further east (1128 mm at Hlabisa). The highest precipitation recorded in 2007 was between the months October to April and it was during this period that more than 75% of the annual rainfall fell (van Rooyen & Morgan, 2007). The lowest precipitation was experienced during winter between the months June to August.

Table 2.1: Mean and annual precipitation (mm) for the year 2007 for the weather stations that are in close proximity to the study area (data provided by van Rooyen & Morgan, 2007)

Month	Makatini	Mkhuze	Hlabisa	St Lucia Lake	Mbazwana	Ndumu
January	102	64	172	153	133	151
February	112	88	142	125	140	91
March	78	30	167	124	108	70
April	42	28	61	87	76	57
May	24	31	40	60	47	22
June	14	9	16	42	40	8
July	12	16	26	41	42	19
August	15	28	28	49	40	16
September	43	50	64	69	50	54
October	59	77	120	87	83	54
November	77	80	132	114	90	93
December	83	77	160	93	86	91
Year	661	578	1128	1044	935	726

2.6 TEMPERATURE

Table 2.2 illustrates that during the year 2007, the mean annual temperature for Makatini was 22.3°C with the mean monthly temperature for January being 26.7°C and for July 17.1°C. The absolute maximum and minimum temperatures measured at Makatini in 2007 were 44.2°C and 0.1°C respectively. This is shown in Table 2.3.

Table 2.2: Mean monthly temperature (°C) for the year 2007 for the weather stations that are in close proximity to the study area (data provided by van Rooyen & Morgan, 2007)

Month	**Makatini**	**Mkhuze**	**Hlabisa**	**St Lucia Lake**	**Ndumu**
January	26.7	25.5	22.7	25.4	26.9
February	26	25.8	23.1	25.4	26.6
March	25.3	24.7	21.9	24.5	25.7
April	22.8	23	20.5	22.1	23.4
May	20	19.7	18.6	19.4	21.1
June	16.9	16.6	16.8	16.7	18.7
July	17.1	16.4	16.5	16.9	18.6
August	19	18.3	17.5	18.5	20.1
September	21.3	20.4	18.7	20.3	21.8
October	22.6	22.5	19.7	21.3	22.8
November	23.9	23.4	20.9	22.5	24.1
December	25.7	24.8	22.3	24.2	26
Year	22.3	21.8	19.9	21.4	23

Table 2.3: Maximum and minimum temperatures (°C) for the year 2007 for weather stations that are in close proximity to the study area (data provided by van Rooyen & Morgan, 2007)

Station	**Maximum**	**Minimum**
Makatini	44.2	0.1
St Lucia	43.5	1.4
Hlabisa	40.6	3.3
Ndumu	44.5	6.2

2.7 AIR HUMIDITY, DEW, EVAPORATION AND FROST

For most of the year, the air humidity is relatively high (Herbert & Kilburn, 2004). During the summer months, a high discomfort index is experienced due to the scorching summer temperatures coupled with the fairly high air humidity. Dew is experienced all year round and is particularly heavy during the winter period. The region experiences a mean annual evaporation rate of between 1660 - 1880 mm (Herbert & Kilburn, 2004).

Frost rarely occurs within this area. Depressions are present and are usually filled after the summer rainfall to become pans. The diversity of vegetation within the study area is to a great extent influenced by precipitation as well as the geological variation and its associated soils (van Rooyen & Morgan, 2007).

2.8 GEOLOGY AND TOPOGRAPHY

The geology and topography of the study is complex, involving both sedimentary and volcanic processes. The basement rocks within the region are known as the Natal Metamorphic Province. These rocks are more than 1,000 million years old, consisting of metamorphic gneisses and schists and igneous granites, and were formed at higher subterranean temperatures (Herbert & Kilburn, 2004). A series of sedimentary rocks, commonly known as basalt and which also includes the Natal Group sandstone, overlies the basement rocks. Overlying the sedimentary rocks is the famous Karoo sequence of rocks. The lowest layer of the sequence is the Dwyka Group Tillite.

The geology of the study area is typical of the southern region of the vast Makatini flats and is in many ways similar to the nearby Mhkuze Game Reserve and part of the Lebombo foothills (van Rooyen & Morgan, 2007). It comprises of the following soil types: arenite, basalt, mudstone, rhyolite, sand, siltstone and shale.

2.9 VEGETATION

The study area's vegetation is of great interest due to its diversity and richness as it ranges from dry sand forest, forest, woodland, riverine vegetation, old fields to open grassland, savanna landscape. Gush (2000) states that the sand forest in particular is of importance, as despite the indifferent soil to be found in the forest, the area contains a richness and diversity of plant species. Gush (2000) further adds that seeing as most of the existing sand forest areas in South Africa occur outside the conservation areas, they are regarded as a threatened vegetation type.

Some of the dominant tree species that characterise the area include the *Acacia nigrescens*, *A. tortillas*, *A. burkei*, *Schotia brachypetala*, *Spirostachys africana*, *Sclerocarya birra* and *Ziziphus mucronata* (Brouse-James &Associates, 2008). A number of grass species occur in the area and these include *Themeda triandra*, *Panicum coloratum*, *P. maximum*, *P. deustum*, and *Setaria incrassate*, etc (van Rooyen & Morgan, 2007). Riparian vegetation occurs along the river and is characterised by lush, dense vegetation such as huge fig and fever trees. The existence of these areas of riverine fig-forest within the reserve is especially important. Today, the total area of this type of fig-forest to be found in KwaZulu-Natal is 1800 hectares, of which 1400 hectares occur within the Mkhuze Game Reserve (Gush, 2000).

Old fields were created as a result of the historical farming techniques practised in the area (old fields prior to their conversion to PGRs), which have largely been left undisturbed to return to natural veld. Bush encroachment was also evident within the old fields within the study area.

According to Herbert and Kilburn (2004), South Africa is broadly divided into seven ecological units, commonly referred to as biomes. Each biome is subdivided into a series of vegetation types. In KwaZulu-Natal four of the seven biomes exist. They include forest, grassland, savanna and thicket. Although all four biomes occur within KwaZulu-Natal, it is the grassland and savanna that occur more extensively, followed by the thicket and lastly forest (Herbert & Kilburn, 2004).

2.9.1 Forest

Herbert and Kilburn (2004) describe the forest biome as being mostly evergreen, characterised by their closed, relatively high canopy and multi-layered under storey of bushes, shrubs, herbs and lianas. Herbert and Kilburn (2004) further state that this biome occurs where there is high rainfall; the mean annual precipitation must be greater than 725 mm, the aspect is favourable (southerly) and where there are areas of topographic change, is where forest would most likely occur.

2.9.2 Thicket

This biome is not easy to define, as there is a large variation in the density, for instance thicket can occur as an almost impenetrable low forest to a closed shrubland (Herbert & Kilburn, 2004). It is unlike true forest as it is not layered like true forests and lacks the grassy ground layer of the savanna biome. In the eastern region of South Africa, most of the thicket is valley thicket and as the name suggests, it is most often located in river valleys.

2.9.3 Savanna

Savanna is another biome that is a variable biome and which is characterised by a mixture of woody vegetation combined with a grass cover. This biome arises where the precipitation is inadequate to allow for the development of the canopy. A Savanna biome is maintained by fire and grazing and this encourages grass to grow.

2.9.4 Grassland

Grasslands are characterised by a single layer of grasses, whereby the trees are mostly absent. This biome is also maintained by fire and grazing, hence causing the grass to remain dominant (Herbert & Kilburn, 2004).

2.10 SUMMARY

Since there has been a progressive shift towards the practice of private game farming within northern KwaZulu-Natal, this research was carried out to determine whether and in what way land cover/land use changes related to private game farming are impacting the study area. The study area comprises of selected PGRs i.e. Kube Yini, Thanda and Phinda Private Game Reserves as well as the Mkhuze Game Reserve, within the Mkhuze area of northern KwaZulu-Natal. Mkhuze Game Reserve, which is owned by the State, is a reserve that is open to the public and run by the government. This reserve was used as a control, which would help to determine whether or not the land cover/land use changes within the PGRs had most likely resulted due to the different private game farm management techniques practiced within the area of interest. Satellite imagery and Remote Sensing software are used to identify the land cover/land use changes related to private game farming, illustrating how the land cover has changed over time.

Consequently, Chapter Two provided the background to the study area, focusing mainly on the physical characteristics of the region as well as giving a brief background to the history of each of the PGRs as well as the state reserve under consideration. The next chapter describes the literature on the topic of Remote Sensing, with specific reference to Landsat 5 TM imagery. Theoretical concepts such as land cover/land use are discussed as well as image processing. Literature on private game farming is also reviewed.

CHAPTER THREE
LITERATURE REVIEW

This chapter is divided into two main sections. The first section reviews developments in satellite-based remote sensing. The terminology of land cover/land-use change is discussed as well as image processing and change detection techniques that can be used to map land cover/land use change. The second section examines the evolution of private game farming in South Africa.

In recent years, the development and application of satellite-based remote sensing technologies has been momentous, generating much debate and discussion. Understanding the theory behind remote sensing is imperative, as this knowledge guides the processing of remotely sensed data within the study, the aim of which is to determine whether changes in land cover/land use related to private game farming have occurred. The first section provides a general introduction into the progress, development and advancement of remote sensing technologies, beginning with the early satellite-based remote sensing which started in the 1960s and 1970s, evolving to the present day studies i.e. data evolution to advanced spatial, temporal and spectral resolutions of data. Lastly, Landsat 5 TM is considered. This is followed by a review of literature examining the evolution of private game farming.

3.1 REMOTE SENSING

3.1.1 Early and contemporary satellite-based Remote Sensing

In the late 1950s, the launch of the first satellites commenced, signalling the dawn of satellite-based remote sensing as a reality. Even though several of the early satellites were designed for meteorological applications, scientists analysing data returned by these satellites quickly realised that remote sensing could be exploited for more than just meteorology (Sokolic, 2006). In 1967, the (American) National Aeronautics and Space Administration (NASA) initiated the first civilian programme specialising in the acquisition of digital remotely sensed satellite data (ERDAS, 2009). The first programme was called Earth Resources Technology Satellites (ERTS), and was later renamed the Landsat programme, initiating its first satellite, ERTS-1 in July 1972 (ERDAS, 2009). ERTS-1 was the first satellite designed to systematically and repeatedly measure and/or record data on the earth's resources (Sokolic, 2006). According to Kondratyev *et al*. (1973), the initial results received from satellite ERTS-1, later renamed

Landsat-1, showed promise, permitting the anthropogenic, geological, hydrogeomorphic and vegetative features to be identified - even though the imagery's resolution (of 79 metres) limited its value for the identification of small surface features. To date there have been seven Landsat missions, starting with Landsat-1 and continuing until Landsat 7 (Table 3.1).

Table 3.1: Landsat Missions

Satellite	Launched	Orbit	Status
Landsat – 1	July 1972	18 days/900 km	Decommissioned, 1978
Landsat – 2	January 1975	18 days/900 km	Decommissioned, 1982
Landsat – 3	March 1978	18 days/900 km	Decommissioned, 1983
Landsat – 4	July 1982	16 days/705 km	
Landsat – 5	March 1984	16 days/705 km	Operational
Landsat – 6	October 1993	16 days/705 km	Failed at launch
Landsat – 7	April 1999	16 days/705 km	Operational

[Landsat 5 TM, 2008] URL: http://www.geog.ucsb.edu/~jeff/115a/history/landsat5.html

3.1.2 Landsat 5 Thematic Mapper

Landsat 5 Thematic Mapper (TM) was launched in 1984 and is still operational today (Moran *et al.*, 2001). This TM scanner is a multispectral scanning system (MSS) much like Landsat 4 MSS, except that the TM sensor records reflected and emitted electromagnetic energy from the visible, reflected-infrared, middle-infrared, and thermal-infrared regions of the spectrum (ERDAS, 2009). Landsat 5 TM has a swath width of approximately 185km from a height of approximately 705km (Chander *et al.*, 2004). According to Chander *et al.* (2004), the spatial resolution of Landsat 5 TM is 28.5 x 28.5 m for all bands except the thermal (band 6) band, which has a spatial resolution of 120 x 120 m. Chander *et al.* (2004) further adds that the larger pixel size of this band is necessary for adequate signal strength and that it is then resampled to 28.5 x 28.5 m to match the other bands. The radiometric resolution is 8-bit, meaning that each pixel has a possible range of data values from 0 to 255 (Chander *et al.*, 2004). This satellite is useful for vegetation type and health determination such as soil moisture, snow and cloud differentiation, and rock type discrimination (ERDAS, 2009).

3.1.3 Mapping Land Cover and Land Use Changes using Landsat Imagery

Within the last millennium and in particular the last two centuries the earth's land cover has changed drastically as a result of man's activities (Biggs & Scholes, 2002). Brovkin *et al*. (2004), state that it is estimated that a third of the earth's surface has in some way been changed due to the action of mankind. Over the last 150 years, the transformation of the natural ecosystems and modifications in land use practices (Biggs & Scholes, 2002) have led and are currently leading to significant land cover changes. According to Biggs and Scholes (2002), the change in land cover/land use not only impacts the biogeochemical cycles, climate and hydrology directly, but also contributes to the loss of species through habitat fragmentation and destruction. In Africa particularly, there are few records of historical changes in land cover/land use.

Archived satellite imagery provides a valuable resource of information as it permits land cover/land use changes to be examined in detail. Thompson *et al*. (2001) state that Remote Sensing offers a mapping technique which is cost effective, permitting spatial and temporal characteristics of the earth's features to be examined. Sokolic (2006) adds that large parts of the earth's surface can be mapped reliably and repeatedly using remotely sensed data. In addition Allan (2007) further states that remote sensing allows for large-scale derivation of land cover/land use types and with a temporal imagery sequence, changes within the system can be calculated.

Remote Sensing can be defined as any process whereby information is gathered about an object, area or phenomenon without being in direct contact with it (ERDAS, 2009). Satellites, orbiting the earth, have sensors on board that collect information about the features on the surface of the earth without actually being in physical contact with the earth's features. Data is captured in the form of satellite images, which are then turned into information using image processing techniques. Several steps are used to process raw image data into a form that is easy to understand and interpret. In most cases the interpretation involves image comparison, either visual or automatic, to laboratory spectra or other known end-member spectra. GIS (Geographic Information Systems) is used for further analysis, dealing with geo-referenced spatial data to perform such processes as capturing, storing, retrieving, manipulating, analysing, and displaying the output of such spatial data (Burrough, 1998).

Remote Sensing is a valuable tool for mapping and analysing land cover change. According to Yemane (2003), concepts concerning land cover and land use are closely related and in many cases have been used interchangeably. There is no uniform land cover/land use classification system to date. According to Anderson *et al.* (1976), land cover/land use patterns change in keeping with the demands for natural resources, hence it is difficult to develop a standard land cover/land use system. According to Jansen and Di Gregorio (2000), the majority of land cover/land use classifications that do exist are generally developed around specific user objectives and are often influenced by geographical location and actual data capabilities.

Remote Sensing techniques provide timely, up to date and relatively accurate information for determining land cover/land use changes. The need for accurate, up-to-date information on land cover and land use is essential for strategic planning, sustainable resource management, and environmental research (Thompson *et al.*, 2001). In recent times there has been a growing interest in the utilisation of classification techniques in Remote Sensing, indicating a widespread interest in the exploration of new techniques. What is also evident is the rapid progress in the exploration of new methods (Xiuwan, 2002). Information regarding the characteristics and spatial distribution of South Africa's land cover is critical for sustainable land use planning, strategic environmental assessments, and global change research (Thompson *et al.*, 2001). According to Thompson *et al.* (2001), most classification schemes are designed to be useful for a rather narrow range of application; conversely, no single classification scheme can satisfy all or even most of the applications.

According to Thompson *et al.* (2001), the terms land cover and land use are closely related and often confused. Whilst Thompson (1996) adds that the interdependence of these two terms has often resulted in land cover being used as a major diagnostic tool in the identification of land use, leading to a common mapping association within many Remote Sensing classification schemes. Examples are the USGS land cover/land use model, and the proposed South African hydrological land cover/land use model. Thompson *et al.*, (2001) further contributes by stating that these two terms are not the same, and it is imperative to clearly distinguish between the two terms in any classification design. In its broadest sense Thompson *et al.*, (2001) assets that land cover can be defined as all natural and human features that cover the earth's surface, which includes vegetation (natural or planted), man made features (example: buildings, roads, etc), water, soil, bare rocks and/or sand surfaces. In addition Thompson *et al.*, (2001) defines land use as a human activity that is associated with a specific land unit, in terms of utilisation, impacts or management practices. Land use is therefore based upon function, where a specific use can be „defined in terms of a series of activities undertaken to produce one or more goods and services' (Thompson *et al.*, 2001). Thompson *et al.* (2001) concludes that there can only be one land cover type associated with a point on the earth's surface, even though this may be associated with several land uses (e.g. „grassland' may be utilised for communal grazing within a conservancy area).

South Africa's future depends on developing sustainable land use practices and alternatives that are ecologically suitable to the environment as well as being economically viable, and socially justifiable (Langholz & Kerley, 2006). Achieving this dynamic equilibrium is easier said than done as balancing these three components are tricky, even under perfect conditions (Langholz & Kerley, 2006).

3.2 PRIVATE GAME FARMING

According to De Alessi (2005); Krug (2001); Langholz and Lassoies (2001), privately protected areas have emerged as revolutionary as well as powerful tools for sustainable development in recent years. Mitchell, (2006) and Kramer *et al*. (2002) further add that there is an increasing amount of evidence which powerfully advocates that land owned privately can not only conserve and preserve biodiversity and wildlife, but can also succeed in terms of monetary value, and contribute to the social upliftment of a particular area. In 2003, governments from 154 countries approved the Private Protected Area Action Plan at the 5th World Parks Congress in South Africa (IUCN, 2005), in recognition of private protected areas and their distinctive and increasing contribution to the global world. According to Langholz and Krug (2004), this plan called for an increased investment from both the public and private sectors towards conserving private protected areas.

According to Pasquini (2007), it is becoming more and more difficult to manage and expand statutory conservation areas (i.e. parks and formally protected areas). Consequently alternative opportunities for land conservation need to be considered and established. Private conservation areas significantly complement statutory conservation areas in the type of biomes, elevation classes, and threat status classes conserved (Smith & Wilson, 2002). They can also provide additional resources for both research and implementation of biodiversity conservation strategies.

3.2.1 Game farming in Southern Africa

In several countries around the world wildlife is managed and owned by the State. However, in the last 30 years Zimbabwe, Namibia and South Africa have changed their legal systems to provide full control over the utilisation of wildlife to private owners of the land on which the wildlife are located. According to Muir-Leresche and Nelson (2000), Africa's wildlife is a matter of great international concern, as in several regions in Africa, the wildlife populations have declined significantly in recent years. Finding a way of slowing down this decline has been a priority for both the international and local conservation communities.

Prior to this, private landowners had limited incentives to manage for an increase in their wildlife populations as the state denied owners the chance of profiting from wildlife (Muir-Leresche & Nelson, 2000). Following the privatisation of wildlife management in southern Africa, wildlife tourism on private lands exploded. As of 1990, South Africa consisted of 78 percent private farms and ranch land, Namibia 45 percent private land and Zimbabwe 35 percent (Muir-Leresche & Nelson, 2000). No other country in southern or eastern Africa has had more than 10 percent of their land in private farm and ranch ownership (Cumming, 1990).

According to Muir-Leresche and Nelson (2000), wildlife populations on private lands in Namibia have risen by 80 percent since the creation in 1967 of a regime of private wildlife ownership. The executive director of the South African Wildlife Ranching Society, Mr. R. Holtshauzer, stated that approximately 95 percent of the South African game is owned privately by individuals (Brooks *et al*., 2008). NAMC (2006) further stated that over the last three decades, South African wildlife has proven to be the fastest growing agricultural sector. Wildlife farming is perceived as a more profitable alternative than the conventional commercial farming on the semi-arid lands of southern Africa, as it may cause less soil erosion and in general less damage to the environment (Muir-Leresche & Nelson, 2000).

In the South African province of KwaZulu-Natal, private game farming is expanding at a phenomenal rate. Private game farming, also commonly referred to as private game ranching, seems to be the newest movement towards the replacement of conventional commercial farming. While agriculture has long dominated the region of northern KwaZulu-Natal, this is changing. Privately owned farmers in northern KwaZulu-Natal focused on cotton, pineapples and cattle. According to some critics, conventional commercial farming has led to the degradation of ecosystem processes and functions as farmers continuously practised their farming methods on nutrient-poor soil. Thus conventional commercial farming not only faltered economically but was also destroying the environment (Child, 1988).

As the realisation dawned that the nature of the land was not suitable for these conventional farming practices, farm owners opted to change to the lucrative private game farming. As a result private game farming is seen as a sustainable alternative to conventional commercial farming (Kerley *et al.* 1995), particularly in the dry, semi-arid regions of South Africa where low precipitation prohibits planting of crops and where livestock production is marginal. Unfortunately, according to Smith and Wilson (2002), quantitative data on private land use trends are limited. Smith and Wilson's (2002) own study on land use trends in the thicket biome related to the change to game farming, does not use Remote Sensing to actually quantify change. This is thus an important area for further research.

While it may not have been satisfactorily quantified, there is no doubt that since the 1980s South Africa has experienced a significant shift from the conventional commercial farming to private game farming. In a number of cases the primary goal of PGR owners was to diversify their enterprises by running game-based ventures in conjunction with stock farming practices. In several cases, owners removed all stock and replaced it with game. In an Eastern Cape study, several farm owners expressed a positive outlook towards private game farming and are trying to implement conservation measures. However, as these owners have been stock farmers their entire lives, some conservationists are concerned that their approach to private game farming might be skewed too much towards the principles applied to conventional commercial farming (Sims-Castley *et al*., 2005).

Game farming is defined in terms of legislation as any farming activity involving wild animals (Department of Agriculture, 2006). It is important to note that this refers to extensive (ranching) systems as well as to systems where animals are fed (Department of Agriculture, 2006). Grossman *et al.* (1999) defines private game farming as a term that is used to describe private land from which domestic stock were removed and replaced with game. Grossman *et al.* (1999) further states that the most significant characteristic of these PGRs is the lack of internal fences and the presence of game-proof boundary fences.

The change in attitude to the utilisation of game, accompanied by the realisation of the value of game, accelerated the shift towards private game farming. Farm owners saw the benefit of game fencing as it allowed landowners to supplement their properties with a diversity of indigenous game species. Two basic trends can be identified: either the landowners themselves changing from conventional commercial farming to private game farming, or investors purchasing these conventional commercial farms and financing their conversion to PGRs. By fencing the farms, landowners have managed their game populations, i.e. prevented the movement of their game into adjacent farms.

According to Gallo *et al*. (2009), PGRs are more profitable than conventional commercial farming practices. It is estimated that about seventy percentage of South Africa's total area of about 1.2 million km^2 is suitable for livestock production, of which the local game industry now forms an integral part (Taljaard, 2003). Bothma (2005) believes that almost one third of the country's potential grazing land is utilised by game and game-related activities. These days, there seems to be an increase in the number of private game farmers who are interested in the relative profitability of game (Grove *et al*., 2007).

Legislation for wildlife is established at both the national and provincial level in South Africa. At the provincial level it is similar but not identical across all provinces. According to Muir-Leresche and Nelson (2000), a private landowner can apply to register as a wildlife operator as long as the farm meets certain criteria in terms of size and perimeter fencing. Cumming (1990) noted that a small number of studies had been done on the cumulative statistics, which existed for wildlife farming in South Africa. For example, in 1990 it was estimated that more than 19 percent of South African farm land, which involved more than 160000 square kilometres, was in one or another way utilised for private wildlife use. This involved more than 8000 farms and ranches, about 17 percent of the more profitable farming operations in South Africa (Cumming, 1990). Farmers and ranchers earned on average about 14 percent of their gross revenues from wildlife. The figure would certainly be higher now.

In more recent estimates, Child (1995) characterised the status of South Africa's wildlife industry in 1997, based on data from the Centre for Wildlife Economics at the University of Potchefstroom. Child (1995) estimated that there were approximately 6000 wildlife farms with boundary fencing covering about 10 million hectares in South Africa. According to Muir-Leresche and Nelson (2000), about 5000 hunters spent around $22 million in 1997 and there were still larger numbers of domestic South African hunters who spent an even larger sum in total. In 1997, the wildlife industry yielded a spending of $115 million in total, which generated around 42000 jobs for the South African economy (Child, 1995).

3.2.2 The drivers of private game farming

Grossman (1991) speculates that it is disenchantment with conventional commercial farming, rather than the belief in private game farming as a form of land use, that has and is still encouraging the change in land use currently being observed in South Africa. A number of conventional commercial farmers have compared the flourishing game industry to the ostrich-farming explosion of the late 1890s and many expect that the game farming industry would undergo a similar cycle, i.e. a boom followed by a decline (Grossman, 1991). Consequently, many farmers contend that private game farming practices would in the near future revert to conventional commercial farming (van der Waal & Dekker, 2000).

For the present, private game farming has progressively been recognised as a viable as well as a potentially lucrative land use alternative. In northern KwaZulu-Natal, private game farming is expanding rapidly, as it is regions like these that offer the best habitats for game species diversity. Farmers increasingly perceive private game farming as a viable as well as a more lucrative tourist and animal production enterprise than conventional commercial farming. Some researchers argue that PGRs *"serve as economic engines*" (Langholz & Kerley, 2006, p.15) in localities that are experiencing continuing economic decline. According to Langholz and Kerley (2006), PGRs provide an alternative to agriculture and are economically as well as ecologically attractive. Consequently, PGRs are most likely to increase the land value (Geach, 2000).

South Africa's indigenous game species are also more adapted to the local conditions, diseases and parasites than livestock. Other driving factors that contribute to this change in practice are: fears regarding land ownership after the 1994 democratic elections, farmers wanting to remain on the land that was handed down to them for generations, the monetary returns (e.g. tourism) as well as commitment to the conservation of biodiversity (Wels, 2003). According to Langholz and Kerley (2006), PGRs generally seek to blend their income with ecology and business with biodiversity, providing a land use that reconciles biodiversity with monetary gain.

All indications are that the boom in private game farming is continuing. The impetus behind the growing game industry can be credited to a variety of socio-political, economic and ecological motivations. These motivations were expressed mainly as concerns by landowners or managers. These include:

- ❖ recent modified labour legislation, which requires farm workers' salaries to be increased, making landowners consider private game farming as a suitable replacement to conventional commercial farming as PGRs are less labour intensive than conventional commercial farming,
- ❖ increase in theft of stock, which has left stock farming economically less feasible,

- years of grazing led to the degradation of the land, resulting in a reduction of the production of livestock. By re-introducing indigenous game species, that are better adapted to their natural environment, periodic droughts could be survived both economically and demographically,
- long term belief that PGRs could contribute to the restoration of the landscape rather than landscape degradation and
- large monetary benefit from private game farming (Langholz & Kerley, 2006).

The de-regulation of the agricultural sector by the World Trade Organisation, as well as the agricultural sector's loss of political power in parliament after 1994 (Smith & Wilson, 2002), are two crucial factors that have played a significant role in promoting the switch from conventional commercial farming to private game farming. In addition, the economic incentives have prompted numerous landowners to change from conventional commercial farming to private game farming. The conversion to game by the farm owners may, therefore, be strongly attributed to the high monetary value that has been attached to game and game products over the recent years. According to Smith and Wilson (2002), ecological reasons such as land degradation and soil erosion might have initially caused farmers to consider reducing their stock in favour of game, but it is the economic incentives that have driven them to consider private game farming as a viable alternative land use option.

The tourism industry is a key driver. The presence of big game such as the "Big Five" presents a key draw card to PGRs. In areas where there is the presence of "Big Five" game species, such as in the province of Mpumalanga near Kruger National Park and in the KwaZulu-Natal province, the presence of PGRs permits local farm owners to enjoy substantial monetary returns from their properties (Geach, 2000). For example, instead of selling their land to a stock farmer for R700/ha, landowners can sell their land for more than twice that amount (Geach, 2000). In addition, foreign investors are willing to invest money in the development of private game farms offering ecotourism ventures. Foreign investors as well as local farm owners have amalgamated and expanded their farms, creating extensive, luxury PGRs for ecotourism and hunting. The majority of the PGRs are aimed primarily at the international tourism market, while a few cater for the local tourists.

As the wildlife base within the province of KwaZulu-Natal is expanding, there is also an increase in foreign earnings through international tourists. Northern KwaZulu-Natal PGRs provide an alluring tourist destination and are regarded as a safe haven for tourists. As a result

PGRs are becoming an increasingly popular tourist destination for both wealthy South Africans and international tourists who desire to experience the spectacular game and scenery that the province has to offer.

The development of South Africa's ecotourism sector has drawn much attention over recent years as it is potentially the area of wealth in which environmental sustainability and job creation can be combined most effectively, particularly in less developed regions (Weaver, 1998). This is supported by figures showing that 50% of foreign tourists to South Africa visited game reserve attractions while in the country, whilst according to the 1996 South African Tourism Domestic Survey, only two percent of domestic holidaymakers' main destination has been a game reserve and/or national park (Smith & Wilson, 2002), which amounts to approximately sixty-one thousand domestic game reserve holiday tours per annum.

Besides the benefits that this enterprise brings, several farm owners view private game farming as the most cost-effective approach to utilising the environment and its natural resources whilst at the same time maintaining the sustainability of the environment. Private game farming offers substantial monetary returns as it provides both a consumptive (hunting) and non-consumptive (game viewing) use of wildlife. In addition, the breeding and preservation of endangered and rare indigenous species on PGRs (Bunnage & Church, 1991) provides a positive money-spin off, adding to the positive industry boom within the province.

While the growing interest in game viewing as well as game hunting in South Africa is partly responsible for the expanding industry, it is also the lower number of labourers needed for this industry that is attracting many farm owners to convert to private game farming. On the other hand, private game farming is seen as an enterprise which provides multiple positive spin-offs, as their economic impact is much broader than what is spent at the PGRs. For instance, PGRs support employees' family members who are not employed by the farms (Langholz & Kerley, 2006). Tourists to these PGRs contribute directly to other expenditure in the province. This includes purchasing of artefacts, residing in hotels, hiring of vehicles, flying in planes, buying petrol, purchasing clothes, visiting other tourist attractions and destinations as well as dining in restaurants within the province (Geach, 2000). The presence of PGRs increases the diversity of attractions within the province. It encourages tourists to stay for a longer period of time in the province, thus increasing their impact within the area. In addition (Langholz & Kerley, 2006), PGRs supplement the rural economy.

3.2.3 Problems in private game farming

The drawback to PGRs is that these PGRs face innate risks as farm owners may alter their natural landscape in an endeavour to please their tourists and to capitalise on their economic gains (Kerley *et al.*, 2003 & Radder, 2001). In KwaZulu-Natal, the increase in the number of PGRs over recent years raises key questions with regards to the environment's carrying capacity i.e. the maximum number of PGRs that an area can support, whether the numerous PGRs pose a risk to the environment's ecology as well as its biodiversity, and whether the market competition is a concern for the future (Langholz & Kerley, 2006). In addition, many PGRs diversity their ventures by introducing game-based enterprises in conjunction with stock farming practices.

There are without doubt limitations to the number of tourists as well as the number of PGRs an area can support. There is growing concern that the current rapid growth phase will eventually come to an end (Langholz & Kerley, 2006). Perhaps most importantly, the impacts on the environment are uncertain and largely undocumented. According to Langholz and Kerley (2006), there is anecdotal evidence, which suggests that a number of PGRs are in fact:

- ❖ stocking a very large number of captive species on their reserves in an attempt to please their tourists (e.g. lion and leopard)
- ❖ stocking extra-limital species, which are not indigenous to the region and
- ❖ creating "false" savanna landscapes (i.e. modifying landscape such as a thicket, thereby increasing the visibility of the wildlife) (Langholz & Kerley, 2006).

Such practices could negatively impact the functioning of the environment, thus adversely affecting biodiversity and wildlife. According to Castley *et al.* (2001), the stocking of extra-limital species on PGRs remains a litigious issue in terms of conservation of biodiversity as this could led to negative impacts to the ecosystem and its functioning. National legislation such as NEMA: Biodiversity Act, (2004), requires the removal of extra-limital species from conservation areas and according to Langholz and Kerley (2006), the presence of these species compromise future attempts of PGRs in achieving a legally recognised status as private conservation areas. Furthermore, the presence of extra-limital species excludes PGRs from accessing conservation incentives such as tax rebates, etc that are currently being developed.

Furthermore Langholz and Kerley (2006) state that while government might not have been a significant obstacle in the establishment of PGRs, government could dictate the future of private game farming. Concerns regarding government policy are divided into the following categories:

- compliance with the Black Economic Empowerment (BEE) requirements;
- land taxes
- redistribution of land (including a possible moratorium on foreign ownership of land) and
- policy for wildlife (in particular relating to translocation of non-indigenous species). (Langholz & Kerley, 2006).

Other government-related concerns for PGRs include: political stability/instability, the strengthening of the Rand, lack of support from the municipal and local governments towards PGRs (Langholz & Kerley, 2006). Langholz and Kerley (2006) further add that the strengthening of the Rand makes it complicated for PGRs to remain as a competitive enterprise.

Cousins *et al*. (2010) state that the competitive advantage that PGRs have over their competitors is their locality i.e. Africa has a rich biodiversity, with beautiful scenic views, well-structured infrastructures and is relatively a low risk (in terms of natural disasters, disease and crime) destination for visitors. From an economic perspective, PGRs generate a considerable amount of wealth from travel costs and spending of tourists. Assuming that there is no market-saturation effect, PGRs can therefore offer an economically viable sustainable alternative land use (Kerley *et al*., 1995) to conventional commercial farming.

However, as stated above, there is much debate as to whether the increasing number of PGRs might negatively impact the balance of the ecosystem. Although private game farming has been described as a potential ecological sustainable form of land use (Kerley *et al*., 1995), the introduction of extra-limital species may threaten the equilibrium (Castley, 2002). Farm owners believe that the introduction of extra-limital species is imperative to the PGR industry in certain areas, as the low diversity of indigenous animal species has been inadequate in satisfying foreign tourists, be they ecotourists and/or hunters. However, the stocking of extra-limital species needs to be evaluated in terms of costs and benefits as well as the long-term ecological impacts. Limited guidelines exist for private game farming in conjunction with both indigenous and extra-limital game species, consequently a more detailed analysis of the cost-benefit of practicing private game farming needs to be undertaken.

Landowners also have to keep in mind and take into consideration the genetic preservation of species. Thus, vigorous management of the population's gene pool, particularly on small fenced farms, possesses a growing concern for the managers and landowners. Jooste (2001), in discussing the ecologically sustainable of game practice, warned against the dangers of allowing certain species to hybridise by keeping such species in the same fenced area.

Grossman *et al*. (1999) argue that the difference in management on PGRs as opposed to that on nature reserves is that on PGRs production-related considerations dictate management, whereas in nature conservation, prevailing ecological paradigms such as the maintenance of biotic diversity and natural ecological processes, takes precedence. On the other hand, many PGR owners have started to notice the visible improvement in the landscape condition since their game introductions, and this may serve as a motivation to promote ecological restoration (Grossman *et al*., 1999).

In KwaZulu-Natal the change in land use from conventional commercial farming to private game farming is a reality (Cousins *et al*., 2008). Presently this change in land use practice is market driven. Farmers hope to diversify their choices in order to reside on the land with the result being the exponential growth of PGRs. Current indications are that this practice is expanding spatially exponentially, which has significant ramifications for both the social and economic development within the province of KwaZulu-Natal. Overall this change in practice is a positive trend only if properly managed. PGRs do have the capability to be far more ecologically sustainable than agricultural farming (Grossman, 1991).

Although the game farming industry has continued to expand during the 1990s, it faces several potential limitations on its future growth. Most individual farms are too small to accommodate a full range of wildlife in a natural setting; animals are not free to roam over the long distances that characterised their historical behavioural patterns (Wels, 2003). On smaller farms visitors may have the perception that they are entering into a game enclosure or a large zoo rather than a true encounter with wild animals. In addition, the costs of building and maintaining internal boundary fences for the farm properties would significantly exceed the costs of one exterior fence for all the farm properties collectively. There are other kinds of economies of scale as well that make the economics of wildlife farming more attractive over a larger area than the typical farm type.

In South Africa, the distribution of land ownership further complicates the practice of private game farming as white farmers own majority of the private land despite the fact that these lands were taken from the native black populations during the apartheid era (Brooks *et al*., 2008). This very same land is today converted to PGRs. This raises crucial questions as to whether PGRs on one hand benefit wealthy white landowners, and/or the international wealthy community who have shown a keen interest in Africa's wildlife conservation. On the other hand private game farming is caught up in the policy debacle relating to South Africa's land redistribution programme (Langholz & Kerley, 2006).

Landowners are interested in private game farming for various reasons, but the most significant reason being the monetary value. Some scholars have recently argued that the lack of accountability and responsibility in dealing with the impacts caused by private game farming, continues to threaten the sustainability of this industry and the integrity of South Africa's wildlife (Cousins *et al*., 2010).

The lack of information is evident in northern KwaZulu-Natal. The contribution that PGRs make to the social upliftment in KwaZulu-Natal is unknown, the biodiversity it conserves and in what proportions has not been established. As a result, the implications of this change in trend for management of biodiversity and conservation as well as the impacts on the global biogeochemical cycles are unknown (Biggs & Scholes, 2002). The question of whether PGRs are in fact financially viable ventures that are beneficial to the environment and to the surrounding communities is a question that still remains to be answered (Langholz & Kerley, 2006). As a result PGRs' managers and owners face a predicament: they could either attain a short-term profit by providing tourists with what they want and need, even if it results in the landscape degradation (Langholz & Kerley, 2006); or alternatively PGRs could present a long-term sustainable ecological as well as economical programme by practicing excellent management practices that maintain the land cover for the foreseeable future, thus justifying their marketing claim *"of being a truly sustainable land use"* (Langholz & Kerley, 2006, p.22) practice.

3.3 CONCLUSION

The change in land use from conventional commercial farming to private game farming within South Africa has been broadly acknowledged (e.g. van Rooyen, 1998; Fourie, 2000; Knott-Craig, 2000 & Potgieter, 2001). In spite of the current growth and expansion of PGRs, scientifically very little is known about the impacts and implications of this new trend. Quantitative data on PGRs and their land use trends are limited. Presently the most significant source of uncertainty with regards to the impact of private game farming on land cover is the lack of knowledge and information about the historical and chronological changes that have taken place over the last few years with this change in land use (Biggs & Scholes, 2002).

The aim of the study is to determine the land cover/land use changes related to private game farming in northern KwaZulu-Natal. In an attempt to understand private game farming and the implications that this activity has on the landscape, the results in this dissertation provide an insight into PGRs in northern KwaZulu-Natal, South Africa.

CHAPTER FOUR
METHODOLOGY

Chapter four begins with a brief introduction into satellite imagery, specifically to Landsat 5 TM imagery, followed by a concise background into image processing techniques as well as an outline of the precise methods used to process the imagery for this particular study. The pre-processing techniques used to prepare the images for the classification of the land cover/land use classes, the field methodology employed to identify the land cover/land use classes, as well as the utilisation of the image processing framework and how it endorsed the land cover/land use changes to be analysed in this study, are discussed. Image processing is a process whereby the user employs clearly defined techniques for the manipulation and interpretation of the images, inclusive of the procedures applied throughout the research (Sokolic, 2006). The usage and relevance of climatic data, ancillary and secondary data sets are examined and a change detection analysis for the image processing is discussed. Concluding this chapter is a summary of the methods used to assess the accuracy of the final classified images.

4.1 DATA ACQUISITION

The aim of this study is to determine the land cover/land use changes related to private game farming using remotely sensed data. Establishing which satellite imagery should be used for the investigation was the first step. Subsequently, determining and collecting ancillary and secondary data sets were essential in understanding the topology of the study area.

4.1.1 Satellite Imagery Acquisition

For this study, the decisive imagery needed to be suitable in terms of availability and cost. Another factor that was taken into consideration was the length of availability of the historical record of the imagery: a lengthy data record allowed the researcher to examine land cover/land use changes that have taken place over time. The ability to map land cover/land use changes related to private game farming at a resolution detailed enough for the changes to be noted was another key consideration, hence the spatial, spectral and temporal resolution of the data were also taken into account.

Bearing in mind the above factors, an examination of all the current earth observation platforms in operation revealed that Landsat 5 TM and Spot were the only two suitable imageries that existed (Sokolic, 2006). Landsat 5 TM was selected as SAC provided the imagery at no cost. Even though Landsat 5 TM has a slightly poorer spatial resolution than Spot (Landsat - 30 meters vs. Spot - 20 meters), this imagery was deemed the most suitable to achieve the aim of the study. Landsat 5 TM has been in orbit for twenty-six years, from 1984 to the present day, thus the continuous record of data as well as the seven reflectance bands permitted for a better scope for this study. Having selected Landsat 5 TM as the designated imagery for the study, the next step was to conduct a survey of the availability of data and to select a set of cloud-free scenes covering the study area.

4.1.2 Satellite Scenes and Reference Data

Two cloud free Landsat 5 TM scenes covering KwaZulu-Natal were employed for this study, i.e. a 1990 winter scene and 2007 autumn scene. The characteristics of the imagery are illustrated in Appendix 1. Ancillary data, which included black and white aerial photos at a nominal scale of 1:50,000 as well as topographical maps were used as reference data in the study. During the visual interpretation stage, a combination of both satellite data and ancillary data sets were used to identify the location of the study area and to distinguish between the different land cover/land use classes.

4.1.3 Climatic Data

Climatic data for the period 1994-2007 was taken into consideration to eliminate climatic change as a variable that could be contributing to the changes within the land cover of the study area. Climatic variables such as temperature, humidity and precipitation were taken into account for this study and the results are discussed in Chapter Five.

4.2 OVERVIEW OF IMAGE PROCESSING TECHNIQUES

Image processing can be defined as the manipulation, processing and interpretation of remotely sensed data with the assistance of a computer. Several steps are involved in image processing, many of which are obligatory while others are optional. According to Eastman (2001), the processing of digital imagery can be broken down into four broad yet simple categories, namely:

- image restoration
- image enhancement
- image classification (including imagery accuracy assessment) and

- image transformation.

However Song *et al*. (2001) states that the sequence for processing remotely sensed data is as follows:

- image acquisition
- image pre-processing
- image processing (classification/change detection and accuracy assessment) and
- production of maps.

Most often than not satellite imagery is not ready for immediate use, hence requiring a series of processing steps to be undertaken. For instance to attain an authentic representation of the surface of the earth, remotely sensed data needs to be corrected and calibrated. Eastman (2001) defines this process of correction and calibration as image restoration. However Song *et al*. (2001) assert that the very first step for processing digital imagery is image pre-processing which entails atmospheric, radiometric and geometric correction. Both Eastman (2001) and Song *et al*. (2001), view image pre-processing, also known as image restoration, as the first step in processing remotely sensed data. Eastman (2001) further adds that if one wishes to optimise the visual appearance of the satellite data, one would have to modify the data and this process of modification is known as image enhancement.

Eastman (2001) and Song *et al*. (2001) agree that for the completion of digital image processing the sequence of image classification, change detection analysis as well as accuracy assessment must be followed. In addition to this sequence of completion for image processing, Eastman (2001) further adds that the very last step that one may perform is image transformation, whereby new images are derived as a result of a mathematical transformation of the raw image bands.

The complexity of processing satellite imagery is somewhat concealed in Eastman (2001) and Song *et al*. (2001). Yang and Lo (2002), categorise digital image processing as:

- geometric rectification
- radiometric normalisation
- design of classification scheme
- image classification

- spatial reclassification
- accuracy assessment and
- change detection.

Unlike Eastman (2001) and Song *et al*. (2001), who regard accuracy assessment to be a part of the process of image classification, Yang and Lo (2002), as well as several other authors (such as McCauley & Goetz, 2004 & Sader *et al*., 1995) see this has a separate step. Sokolic (2006) stated that the rationality behind the combination of these two steps is that image classification and accuracy assessment ought to be seen as an interactive process whereby numerous iterations are performed until the optimum level of accuracy is attained.

For change detection studies, the processing of multitemporal images varies to some extent from satellite images that are classified from a single date. For instance Lunetta (1999) recognised six stages for processing multitemporal images for use in change detection studies:

- acquisition of data and pre-processing
- geometric and radiometric correction
- normalisation of data
- change detection analysis
- accuracy assessment and
- generate final product.

Whilst the above steps are applicable to most change detection studies, the steps selected for a specific investigation depend on one's study aim, objectives, goals as well as deliverables of the study. For example Mas (1998) stated that change detection procedures could be grouped into three broad categories:

- enhancement of imagery
- multi-date data classification and
- comparison of two independent land cover classifications.

As a result the researcher must draw out steps applicable to the overall goal of the study. Despite differing to some extent in detail the four methodologies charted above all contain the same broad structure of:

- image preparation
- image classification
- accuracy assessment and
- generate output image.

4.3 IMAGERY ANALYSIS

In this study, several techniques were used to prepare and analyse the remotely sensed data. For image preparation, Genericraster, Thermal Function, Stacking of Layers, Atmospheric and Geometric Correction were utilised. ERDAS Sub-set Function was used to sub-set the imagery to the area of interest. A change detection analysis was performed using ERDAS Delta Cue Model. ERDAS Delta Cue Model was employed to classify the data. Accuracy assessment was used in order to verify the accuracy of the methods used for the classification of the imagery.

4.4 PRE-PROCESSING OF IMAGERY

Idrisi, (Andes Kilimanjaro 15) and ERDAS 9.3 were used to pre-process the imagery. The scenes received from SAC were received on a DVD-ROM. Each spectral band was imported separately into Idrisi using Genericraster. Table 4.1 and 4.2 below illustrates Genericraster, which was used to convert raw data into raster bands.

Each raster band was stored as a separate layer resulting in seven layers respectively for the 1990 scene and seven layers for the 2007 image, totalling a total of fourteen layers. Pre-processing of the imagery was essential as it provided the data with a geographical co-ordinate system. Band six was converted to temperature (degrees Celsius) in Idrisi using the Thermal Function. Each spectral band was exported from Idrisi into ERDAS 9.3. Using the extension tool, Stacking of Layers all seven individual bands were stacked forming a single image.

Table 4.1: Step 1: Genericraster

Output image	band1. RST
File format type	BSQ
File header info	No header
Data size	8-bit unsigned integer (byte)

Table 4.2: Step 2: Output reference parameters entered into Genericraster

No. of columns (lines per image)	6908
No. of rows (pixels per line)	7352
Min. X. co-ordinate	313508.7913
Max. X. co-ordinate	313342.2671
Min. Y. co-ordinate	-262923.7657
Max. Y. co-ordinate	-282136.1944
Reference system	utm 36s
Reference units	meters
Unit distance	1

4.4.1 Atmospheric Correction

The model ATMOSC was used to atmospherically correct each band i.e. radiometric errors due to atmospheric influences such as haze and/or any other interference were removed. Each band was atmospherically corrected using Idrisi's Dark Object Subtraction (DOS) model and Chavez's Cos (t) model. Both models were selected to determine if there was a difference in the resultant image output. Each raster band with a set of atmospheric and viewing condition parameters was used as the input image. Both the Cos (t) and DOS models required a number of input parameters most of which were provided by SAC.

The lowest haze value (which is a digital number) for each band was selected by clicking onto a clear deep-water body. The digital numbers for each raster band was converted to radiances values. It was significant to calibrate all bands to reflectance values as it allowed the images to be compared across different dates. The sensor offset and gain, satellite-viewing angle, sun elevation values and all additional parameters, which were provided by SAC, were used to calibrate the bands. The thermal band (i.e. band 6) was left uncorrected, as it was converted to temperature and was not used in the concluding stages of image classification. Each atmospherically corrected band was exported from Idrisi to ERDAS.

4.4.2 Stacking of Layers

Using the programme ERDAS, tool Stacking of Layers, all layers were stacked forming the 1990 and 2007 scenes. Scenes atmospherically corrected by the DOS model were visually clearer than scenes corrected by the Cos (t) model; hence scenes corrected by the DOS model were used for the remainder of the analysis.

4.4.3 Geometric Rectification

Geometric rectification is a process whereby the satellite data is assigned a map projection (rectification) as well as map coordinates (georeferenced). This method is critical in producing spatially accurate and correct maps of land cover/land use changes over time. Neither of the Landsat images provided by SAC were georectified. Using a 2007 Landsat 7 Enhanced Thematic Mapper Plus (ETM^+) image that was georeferenced by GeoVar, the 2007 Landsat 5 TM scene was rectified. The Landsat 5 TM scenes were rectified to the Universal Transverse Mercator (UTM) Map Projection, zone 36 south, spheroid Hartebeeshoek '94 and datum WGS 1984.

Twelve widely spaced ground control points (GCPs) were located on the Landsat 7 ETM^+ scene (known as the reference image) as well as on the 2007 Landsat 5 TM scene (the target image). The GCP coordinates were used to construct a set of polynomial equations that were used to rectify the Landsat 5 TM scene. The resultant root mean square error (RMSE) was about 0.5 pixels, indicating an excellent registration (Appendix 1). A third-degree polynomial equation was used for the transformation of the Landsat scenes. The nearest neighbour algorithm was performed to resample the imagery into their initial pixel size of 30 m x 30 m thus avoiding the alteration of the original pixel values. The accuracy of the georeferencing was verified by superimposing the KwaZulu-Natal Rivers obtained from the KwaZulu-Natal Terrestrial Plan onto the Landsat TM imagery, which produced a neat fit. The 2007 Landsat 7 ETM^+ image was subsequently used as the reference scene onto which the 1990 scene was geometrically corrected.

4.4.4 Sub-setting Imagery

Each scene was sub-set to the area of interest using ERDAS Subset Function.

4.5 FIELD METHODOLOGY AND VERIFICATION OF LAND COVER/LAND USE CLASSES

Boundary maps for each of the PGRs and the Mkhuze Game Reserve were obtained whereby the boundary lines for each of the PGRs as well as the state reserve were digitised using ArcMap 9.2. A total of five shapefiles, four shapefiles representing the four PGRs and one shapefile representing the Mkhuze Game Reserve were created. Hawth's Analysis Tools was selected as the most appropriate tool for the study as it prevented bias when selecting and identifying the GCPs for the PGRs. Twenty-five stratified random points per PGR were generated using Hawth's Analysis Tools.

A total of one hundred (100) stratified random points were generated covering the entire study area. It was decided that 100 points would be sufficient to accurately represent and reliably identify the land cover/land use of the study area. The generated random points together with the shapefiles illustrating the PGRs were superimposed onto the 1:50 000 topographical maps and the Landsat imagery to verify that the points were randomly as well as spatially distributed.

The ground truth data was collected from the random generated points using a Global Positional System (GPS). A total of sixty-five points were collected in the field. It was impossible to identify each random point, as many of the points were inaccessible. Several of the points were very far apart, the vegetation cover was thick and dense and the presence and possibility of encountering "Big Five" game made it impossible to locate and identify every generated point. The time frame it took to locate each point took longer than expected as in addition to the use of a four-wheel drive vehicle, long distances had to be walked to reach a number of the points. For each generated point identified in the field, the co-ordinates were recorded, land cover/land use class identified and a description of the land cover/land use and the area surrounding the point was noted. This is illustrated in Table 4.3.

Table 4.3: Identification of land cover/land use classes in the field

FID	GPS Point	X Co-ordinate	Y Co-ordinate	I.D. Land Cover Class	Description
1	P1	29	-30.25	Water body	River
2	P2	29.65	-30.65	Cane	Sugar cane

Expert advice obtained from ecologists, as well as background knowledge of the landscape and the information that was obtained from a preliminary visit to the study area, were used to identify the land cover/land use classes. Using both the South African Classification System (Thompson, 1996) and the Council for Scientific and Industrial Research (CSIR) National Land Cover Classification (NLC), (2001) (Appendix 2), the land cover/land use classes were classified. The South African Classification System, which was defined by Thompson (1996), is a hierarchical framework that was designed to suit the South African environments and which conforms to the internationally accepted standards and conventions.

In this study, it was deduced that the land cover/land use definitions that were defined by the above land cover/land use classification systems needed to be modified to suit the aim and objectives of this dissertation. The identified land cover/land use classes are illustrated in Table 4.4.

Table 4.4: Identified land cover/land use classes

Level I land cover/land use classes	**Level II land cover/land use classes**	**A brief description of land cover/cover classes**
Water bodies and riverine vegetation	Rivers, streams, dams, pans and wetlands	Areas in and around water bodies. The CSIR defines wetlands as areas where water is either at or close to the surface. Cover usually woody or herbaceous. Examples being papyrus type vegetation (CSIR, 2001).
Sand forest, forest and rock faces	Forests	Tree canopy cover greater than 70%.
	Sand forest	Dense, almost impenetrable vegetation, up to a height of 25 m/or 25 m tall.
	Rock faces	Natural areas or man induced areas of exposed sand, soil or rock with no or very little vegetation cover.
Woodlands	Woodland	Tree canopy cover between 40 - 70%.
	Valley Thicket/Bushland	Multi-layered community with interlocking communities found in riversides or dense natural vegetation, consisting of shrubbery and natural forest communities.
Old fields and disturbed areas	Old fields	Used for cattle, agricultural grazing, pineapple and cotton plantations/conventional commercial farming.
	Disturbed areas	Areas were vegetation were removed and alien invasive plant species established themselves. Also including the old fields.
Grasslands	Non - woody grasslands	By combining the CSIR's definitions, a broad definition of grassland was created. Defined as an area with less than 10% tree or shrub cover, containing grass as the dominant species, this included planted grass types
	Wooded grasslands	Tree canopy cover between 10 - 40%

Table 4.4 was utilised in the field for the identification and classification of each land cover/land use class, which was identified by a GPS. Several of the generated points were inaccessible in the field owing to their locality, therefore the point closest to the generated point was recorded, the land cover/land use identified and description noted. A few of the generated points were left out of the analysis, as these points were too remote.

4.6 PROCESSING OF IMAGERY

Processing of imagery is achieved through image classification. Image classification is a technique that classifies all pixels automatically i.e. land cover/land use classes or patterns are classified with the assistance of a computer. This technique is based on the theory that each surface feature type is expected to have a distinctive pattern. This distinctive pattern, also known as the reflectance pattern, is characterised by a distinctive set of radiance measurements (Sokolic, 2006). Within multispectral remotely sensed data, each band has a distinctive set of radiance measurements. Image classification techniques endeavour to identify these patterns of radiance.

Using ERDAS software, a tool known as DeltaCue was used to perform a change detection analysis. A change detection analysis identified the changes between the temporally spaced remotely sensed data of the same area (ERDAS, 2009). Sixty-four classes were identified in the classification process. Using the knowledge gained through the literature as well as the field data and ancillary data sets, these sixty-four classes were reclassified, resulting in five classified classes. Private Game Reserves were masked out using the ArcMap's Mask Tool.

4.7 CONTROL EXPERIMENT

Mkhuze Game Reserve was utilised as the control for this study to illustrate whether the land cover/land use changes within the area of interest had in fact most likely resulted as a result of the change in farming techniques within the area, i.e. from conventional commercial farming to private game farming. Seeing as each land cover/land use class displays a unique spectral signature, the land cover/land use classes established for the PGRs were applied to the Mkhuze Game Reserve as well as across the entire image. Using van Rooyen and Morgan's (2007) field data (land cover/land use classes of the Mkhuze Game Reserve as well as vegetation transects of the reserve), the land cover/land use classes were verified for the Mkhuze Game Reserve. Using ArcMap's Mask Tool, the Mkhuze Game Reserve was masked out.

4.8 ACCURACY ASSESSMENT

Accuracy assessment of remotely sensed data is a significant step in the processing of satellite imagery. According to Sokolic (2006), by assessing and knowing the classification accuracy, some degree of confidence can be attached to the final product, thereby influencing not only the interpretation but also its subsequent use. In addition, assessing the accuracy of a classification, analysts can iteratively alter their classification technique so that the best level of accuracy can be attained (ERDAS, 2009). Ultimately, an accuracy assessment is generated that permits various classification techniques to be compared as well as allowing the analyst to select the most suitable and accurate method (Congalton & Green, 1999).

Using ERDAS Accuracy Assessment Tool, the accuracy of the classification technique was calculated. Accuracy assessment is a common and easy method utilised to assess the accuracy of a change detection analysis.

4.9 SUMMARY

This chapter discussed the methodology employed to develop and determine the land cover/land use classes for the study area. The overall techniques used in this study are summarised in a flow chart diagram illustrated in Figure 4.1.

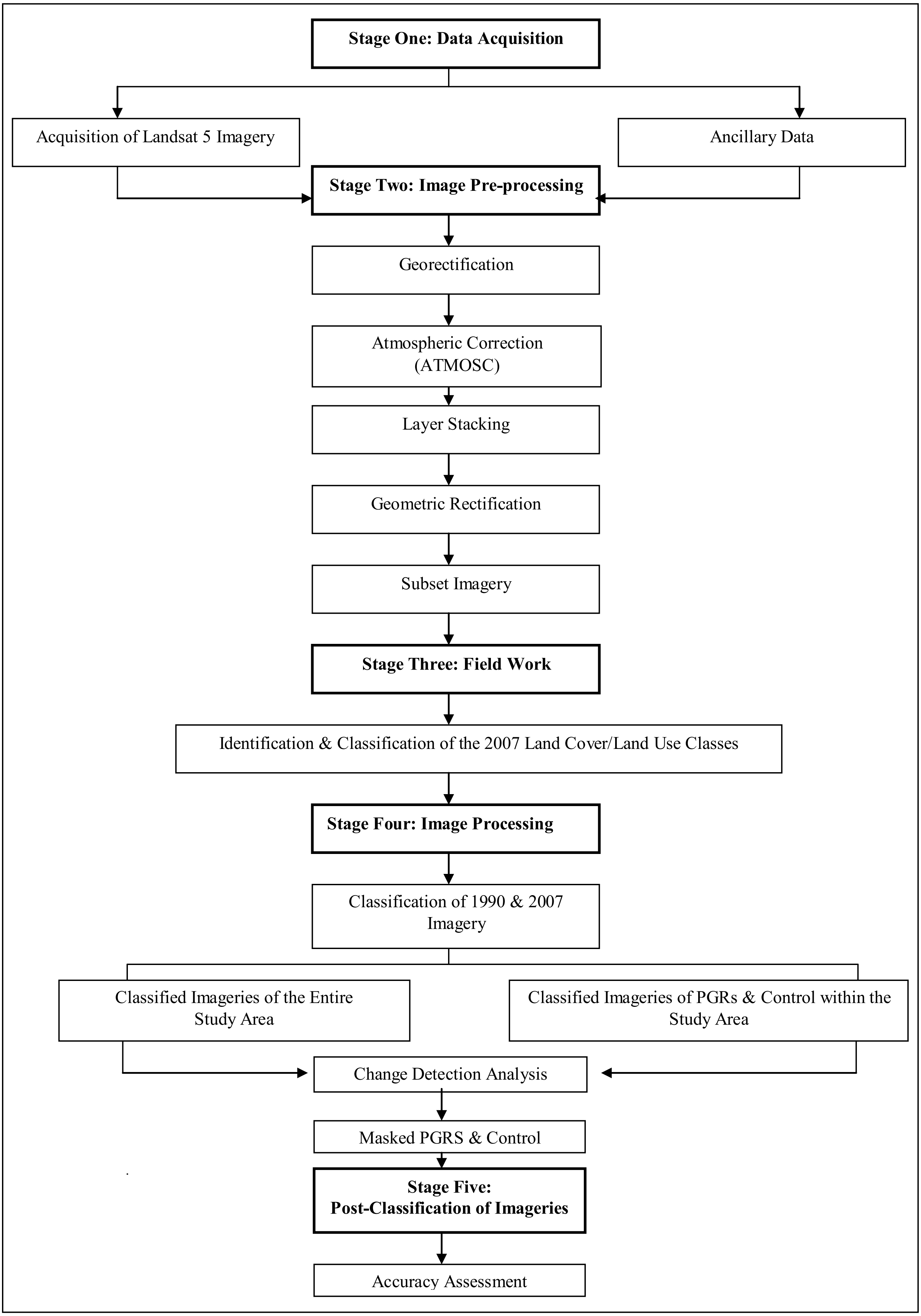

Figure 4.1: Methodology Flow Chart

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 INTRODUCTION

The results of the study are presented in the form of maps illustrating the chronological changes within the study area's land cover. Comparison between the 1990 and 2007 land cover/land use maps allows the identification of changes that have occurred within the PGRs as well as in the control. These changes are illustrated in Figures 5.4 to 5.5 and Table 5.1. Figures 5.6 to 5.13 depict the land cover/land use changes within the individual PGRs and the state game reserve for both periods 1990 and 2007.

Climatic data for this period was also taken into consideration to see whether climate variations had occurred and whether this had impacted the change in land cover/land use of the study area. In addition, Mkhuze Game Reserve, which is owned and managed by the State, was selected as the control for this study, as it has remained relatively undisturbed for a long period of time. A comparison between the PGRs and the state reserve was carried out to compare land cover/land use changes within the study area since the establishment of the PGRs. All produced maps have a uniform scale of 1:50 000.

The study area's land cover/land use classes were identified and classified using a broad scale land cover/land use classification (Level I) system. The interpreted land cover/land use classes, their aerial extents converted as area cover percentage, are illustrated in Appendix 3. Upon examining Table 5.1, Figures 5.1 to 5.13 and Appendix 3, one is able to observe the land cover/land use changes that occurred over time within the area of interest.

The accuracy of the classification was validated using ERDAS Accuracy Assessment Tool. As it was impossible to ground truth each and every pixel within the classified satellite image, a set of reference points was randomly selected and automatically generated using ERDAS Accuracy Assessment Tool. Thus by allowing the reference points to be randomly selected, the possibility of bias was eliminated (Congalton, 1991).

Twenty-five points were generated randomly, generating twenty-five reference classes. The researcher verified the reference classes using the classified classes as well as the ancillary data sets. Using the error matrix, seventy-four percent accuracy was achieved for the 1990 imagery and seventy-six percent accuracy was achieved for the 2007 imagery. Appendix 4 illustrates the results of the accuracy assessment.

In Chapter Four it was established that five classes were used for the land cover/land use classification of the study area. The classes were:

(1) water bodies and riverine vegetation,
(2) sand forest, forest and rock faces,
(3) woodlands,
(4) old fields and disturbed areas, and
(5) grasslands.

Significant land cover/land use changes were observed over the entire study area (Figures 5.4 & 5.5), within each PGR as well as within the control. These include varying changes within the land cover/land use classes as a result of the different land management methods practiced within the area of interest. The results presented in detail below, illustrate how private game farming has changed the land cover of the area of interest. A precise account of the land cover/land use changes is given followed by a discussion of the trends observed.

5.2 INFLUENCE OF CLIMATIC DATA ON THE STUDY AREA

Climatic changes, such as changes in humidity, precipitation, temperature and wind can influence the land cover/land use of an area. It is therefore imperative that when determining land cover/land use changes of an area, one must firstly establish the climatic trends of the area of interest, thus either including or eliminating climatic change as a variable that might be influencing the land cover/land use of the study area.

During the period 1990 to 2007, it was established that the average maximum and minimum yearly temperatures for the study area remained fairly constant. The average maximum and minimum temperatures for the study area are illustrated in Figure 5.1. Figure 5.1 depicts that the average maximum temperatures ranges between 25°C - 27°C whilst the minimum temperatures ranges between 17°C - 18°C.

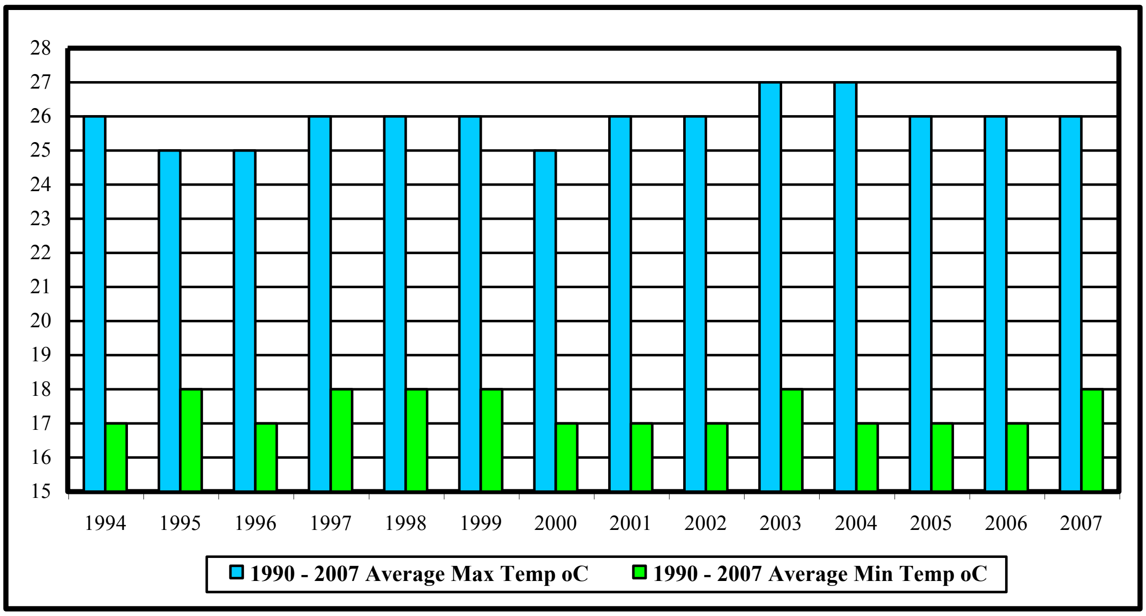

Figure 5.1: Temperature Charters Creek (data provided by the South African Weather Services, 2010)

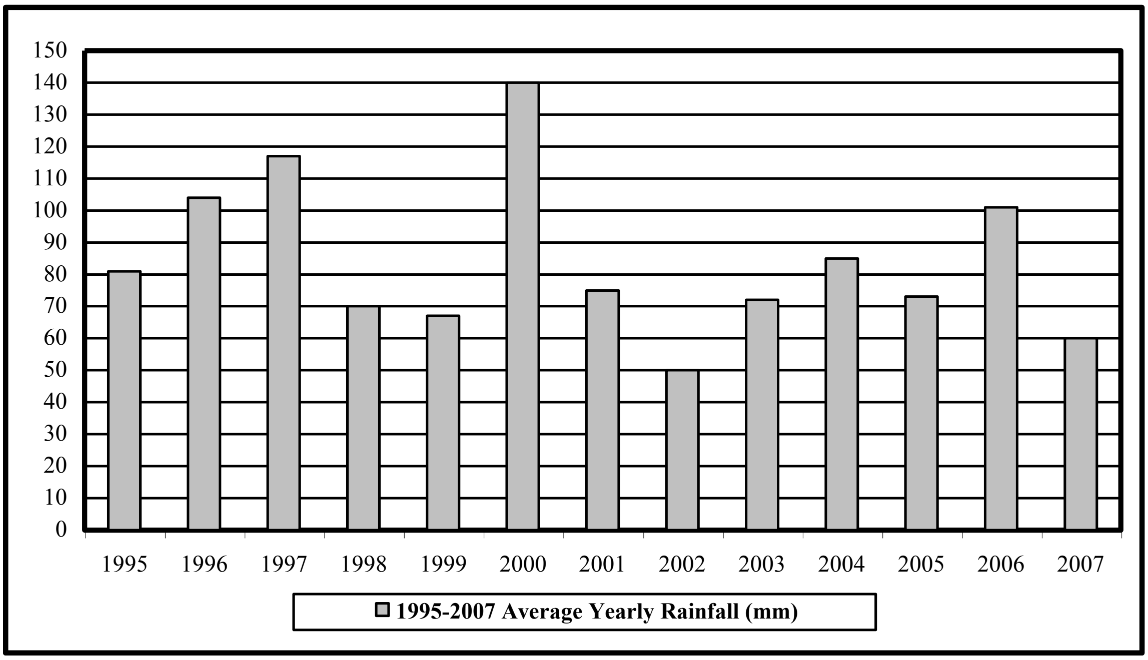

Figure 5.2: Rainfall (mm) Charters Creek (data provided by the South African Weather Services, 2010)

Figure 5.2 illustrates the average yearly precipitation (mm) recorded for the study area during the period 1995-2007. During this period (1995-2007), the area experienced a drought between the years 2001-2006. This is clearly depicted in Figure 5.2, where it is seen that during the drought years the area received its lowest rainfall (see the yearly precipitation averages are below 100 mm for this period) as compared to the yearly precipitation averages experienced during the periods 1995-2000 and 1995-2007. During the period 1995-2007 the study area's total average yearly precipitation was 84 mm. The study area experienced an average yearly rainfall of 97 mm during the 1995-2000 period whilst during the drought years of 2001-2006; the average yearly precipitation was 76 mm. Thus with the exception of the drought experienced in the area, it is most likely that the changes in the area are the result of the change to private game farming.

As seen in Figure 5.3 the average yearly air humidity is relatively high through out the period 1990 to 2007. High humidity, coupled with scorching temperatures received during the summer months, creates a high discomfort index for the region.

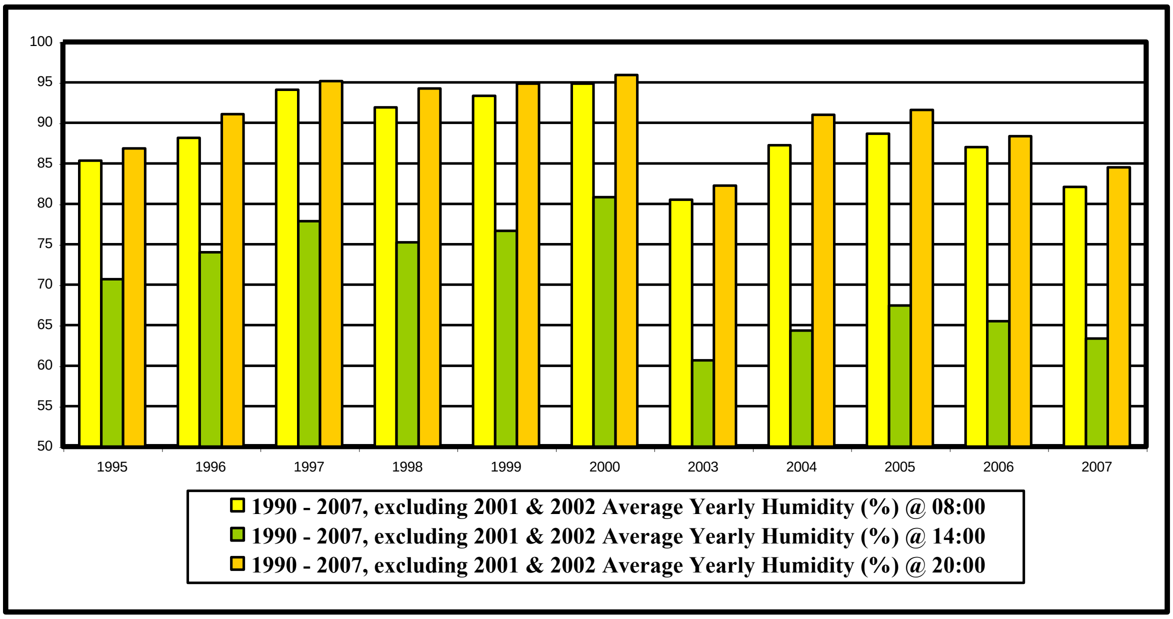

Figure 5.3: Humidity at Charters Creek (data provided by the South African Weather Services, 2010)

Although there have been no major changes in the minimum and maximum temperatures of the study area, the drop in precipitation due to the drought experienced in the area between 2001 to 2006 as well as the high humidity may have assisted and/or contributed to the changes in the land cover/land use classes within the study area. For example the drought may have contributed to the increase in the old fields and disturbed areas as well as to bush encroachment in the area, if not managed appropriately.

5.3 LAND COVER/LAND USE CHANGES OVER THE ENTIRE STUDY AREA

Over the time period 1990 to 2007, the study area's land cover changed significantly. This is clearly depicted in Figures 5.4 to 5.5 and Table 5.1. Table 5.1 shows the overall land cover/land use changes, illustrating a decrease in the water bodies and riverine vegetation (6 percent to 3 percent); sand forest, forest and rock faces (19 percent to 16 percent); woodlands (26 percent to 25 percent); and old fields and disturbed areas (26 percent to 25 percent); whilst revealing an increase in the grasslands (23 percent to 31 percent) land cover.

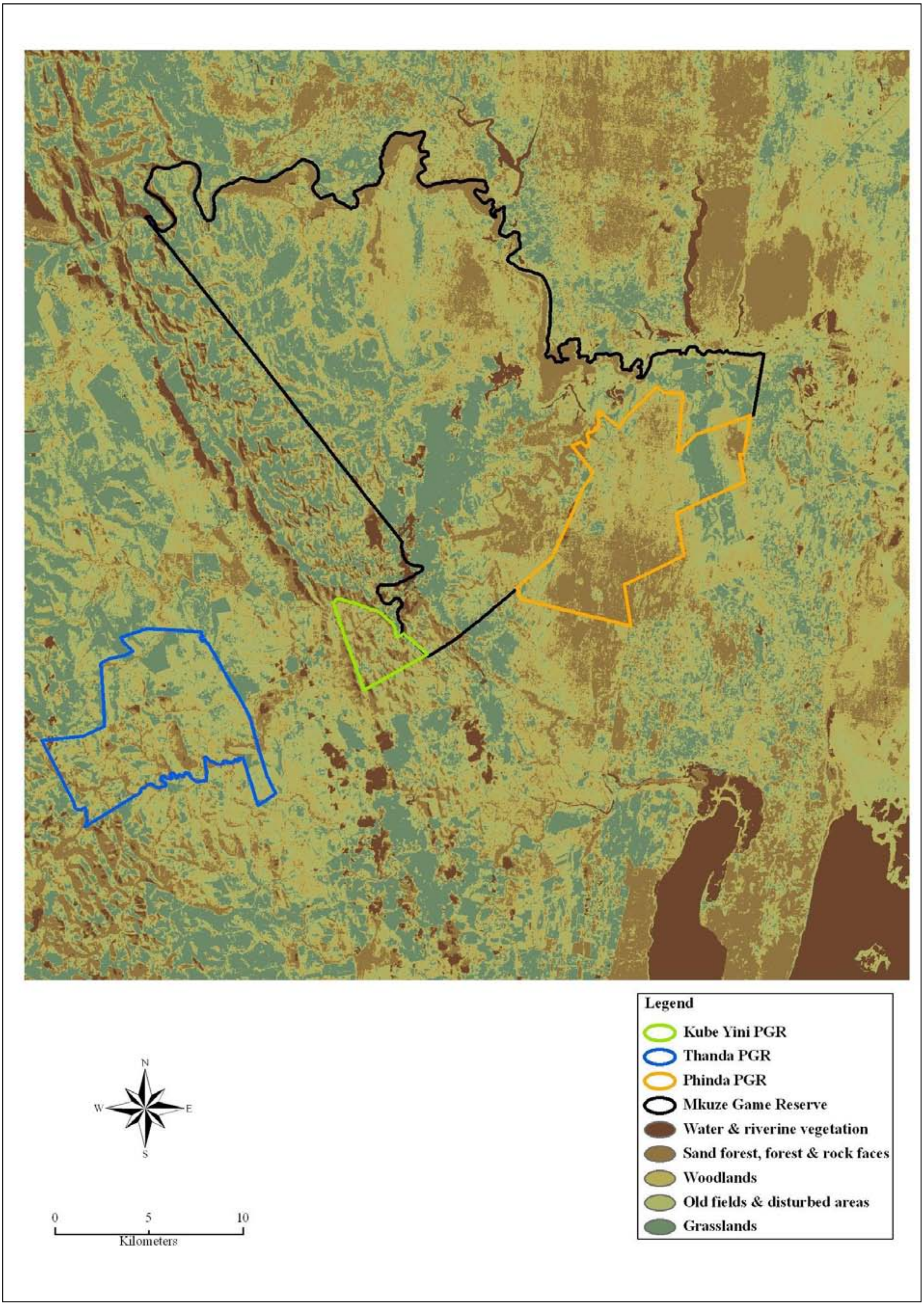

Figure 5.4: 1990 Classified image of the entire study area

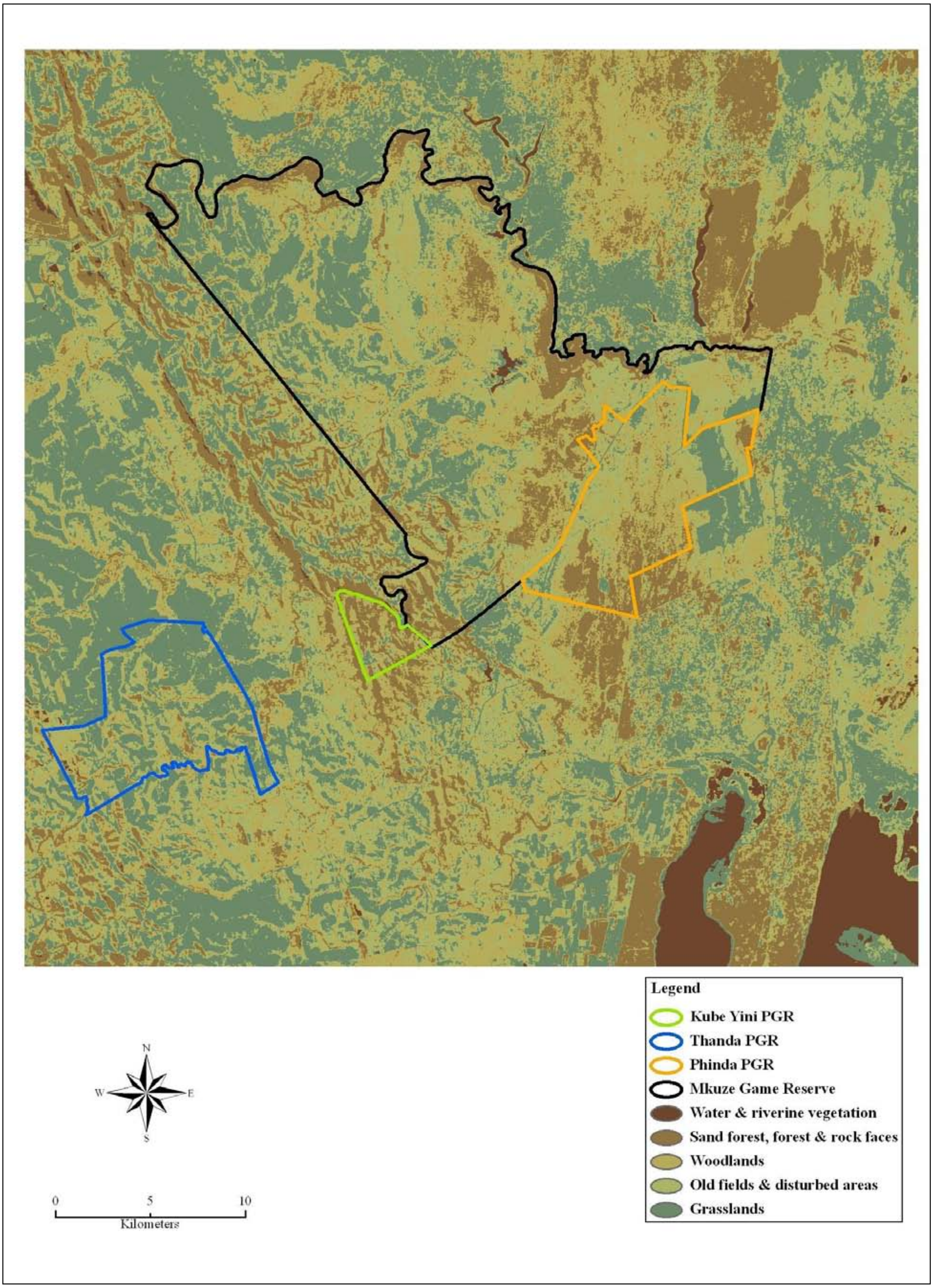

Figure 5.1: 2007 Classified image of the entire study area

In 1990 the water bodies and riverine vegetation covered approximately 14315 ha (6 percent) of the study area. By 2007 this had decreased dramatically to 7523 ha (3 percent). Water bodies included all rivers, streams, dams, pans and wetlands. Water quantity and quality has always been a problem for the area of interest as it lies in a semi-arid region. A drought experienced by the study area during the period 2001-2006, resulted in a decrease in several of the water bodies' levels along with a number of water bodies drying up (Brousse-James & Associates, 2008). The harsh conditions during this period also contributed to the loss of much of the riverine vegetation.

Table 5.1: Changes in land cover/land use over the entire study area (1990 & 2007)

Level I Land cover/land use classes	**1990 Entire study area (%)**	**2007 Entire study area (%)**
Water and riverine vegetation	6	3
Sand forest, forest and rock faces	19	16
Woodlands	26	25
Old fields and disturbed areas	26	25
Grasslands	23	31
Total	100	100

Sand forest, forest and rock faces decreased from 43700 ha (19 percent) aerial coverage to 36402 ha (16 percent). This decrease in land cover/land use was mostly likely due to the different management practices that were practised within the entire area of interest, which resulted in the overall decrease of this land cover. In the PGRs', these management practices are directly related to private game farming. The decreased rock faces could have resulted due to the removal of old infrastructure (such as cattle dips and animal pens), creation of new infrastructure (such as private residences for the farm owners, accommodation for employees and tourists), which resulted in an increase in roads, farm poles and electrical fences, game drives, foot and access paths within the area.

Table 5.1 as well as Appendix 3 (Tables 3.1 & 3.2) illustrate a slight drop in the overall woodlands land cover, from 61888 ha (26 percent) to 57868 ha (25 percent). This was taken up by an increase in the grasslands cover. The woodlands cover remained more or less the same over the period, as the growth of woodlands is suited to the climatic conditions of the area, i.e. woodlands survive the semi-arid conditions very well as they are robust plant species (Low & Rebelo, 1996).

A reduction in the old fields and disturbed areas from 61082ha (26 percent) to 59290 ha (25 percent) as well as a substantial increase in the grasslands land cover from 53348 ha (23 percent) to 73391ha (31 percent) was clearly evident within the study area. This was due to the different techniques that were currently being practiced by the game farm managers such as thinning of vegetation, fire burning and clearing of vegetation in order to modify the landscape. In addition several of the farm owners embarked on clearing regimes, i.e. clearing of old fields and disturbed areas and invasive plant species.

Old fields and disturbed areas have changed to a savanna landscape, as farm owners wish to offer tourists a more open landscape (Brooks *et al.*, 2008), so they can view the game species wandering around freely. A number of farm owners practice bush clearing, a practice whereby owners thin their bush making it easier and more visible for tourists to view the wildlife or hunt the game (N Hawkey and others, pers. comm.[10]) Overall the thinning of the bush and burning of vegetation resulted in a change in the land cover, i.e. land cover was converted to grassland.

Within each individual PGR as illustrated in Figures 5.6 to 5.13, different yet important land cover/land use changes most likely related to private game farming are evident and these findings are discussed below. In all cases, an attempt is made to explain the land cover changes evident in the findings through information obtained locally and through logical deduction processes.

5.4 LAND COVER/LAND USE CHANGES WITHIN PGRS

Due to the dissimilar private game farming management practices practised, each PGR displayed unique changes within its land cover. The results below reveal the ecological footprint of private game farming on the land cover of the study area.

5.4.1 Kube Yini Private Game Reserve

Over the period in question, Kube Yini Private Game Reserve, which was converted to game farming in the year 1991, experienced a decrease in the water bodies and riverine vegetation (4 percent to 1 percent); old fields and disturbed areas (23 percent to 11 percent); and grasslands (6 percent to 5 percent); with an increase in the sand forest, forest and rock faces (31 percent to 47

[10] Interviews with Neville Hawkey, Russell Lloyd, Craig Lloyd and Simon Naylor, PGRs, 16-22 October 2008.

percent). It can be observed that woodlands remained the same (i.e. 36 percent). This is clearly illustrated in Figures 5.6 and 5.7 as well as Appendix 3 (Tables 3.3 & 3.4). During Kube Yini's earlier years, cattle ranching and crop farming, including cotton and maize farming, were practiced (P Binney, 2008, pers. comm.[11]). Unlike a reserve with a commercial lodge operation, Kube Yini was developed into a share block with fifty privately owned sites for its shareholders (P Binney, 2008, pers. comm.[12]). This change in land use must be taken into account in assessing the current land cover within the area.

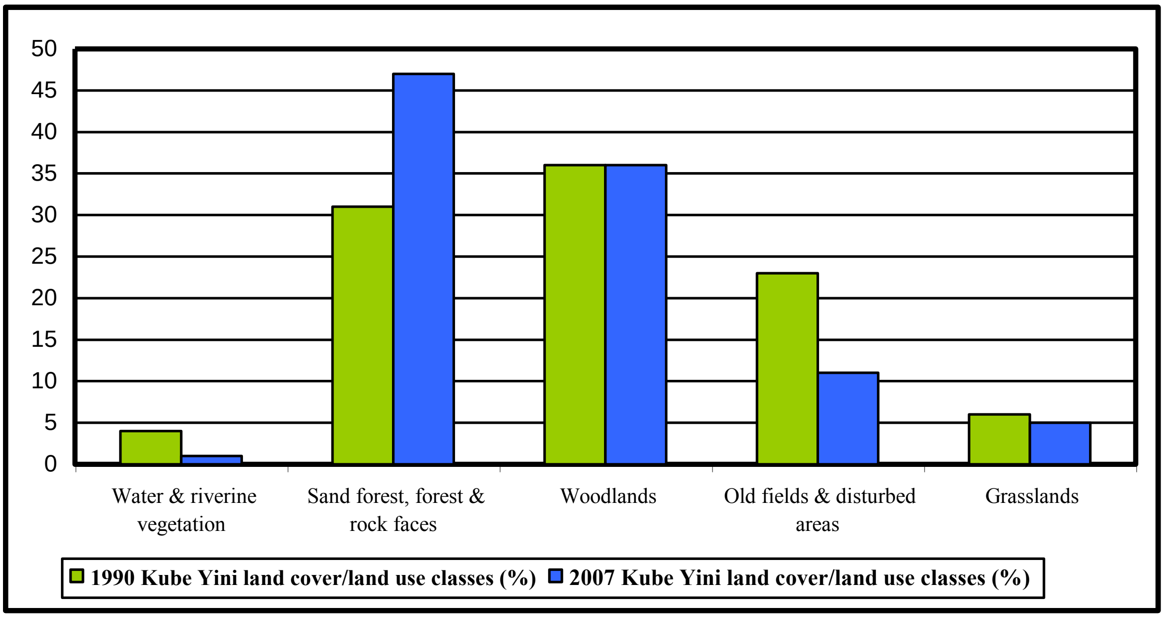

Figure 5.2: Land cover/land use changes within Kube Yini Private Game Reserve (1990-2007)

As illustrated in Figure 5.6 a decrease in the water bodies and riverine vegetation was experienced within the reserve. A decrease from 45 ha (4 percent) to 17 ha (1 percent) within the reserve is partly explained by the reserve's location in a scarce water region (Brousse-James & Associates, 2008). According to the reserve's manager, also contributing to the decreased water bodies and riverine vegetation was the presence of invasive species, of which there were many when Kube Yini was first established as a PGR (N Hawkey, 2008, pers. comm.[13]). The presence of "thirsty" invasive vegetation would have created an increased pressure on the water

[11]Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[12]Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[13] Interview with Neville Hawkey, Kube Yini PGR, 20 October 2008.

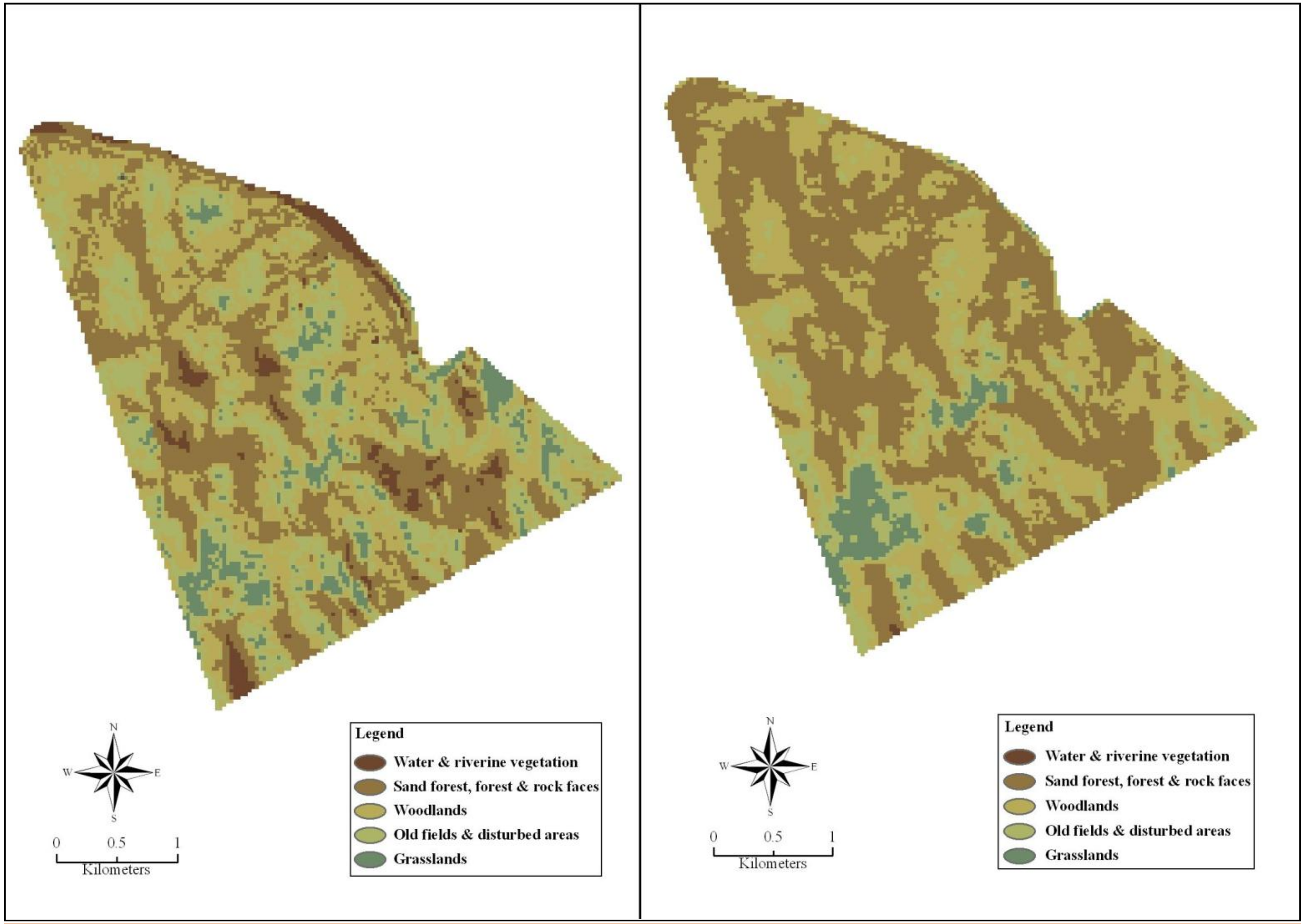

Figure 5.3: Land cover/land use classes within Kube Yini Private Game Reserve (1990 & 2007)

supply, resulting in a further decrease in water and riverine vegetation within the reserve. The increase in wildlife species and the utilisation of more water for the maintenance, removal of infrastructure and the development of the share block properties also impacted the situation.

As seen in Figure 5.7, the land cover sand forest, forest and rock faces increased from 366 ha (31 percent) to 564 ha (47 percent), whilst the old fields and disturbed areas decreased from 272 ha (23 percent) to 128 ha (11 percent). This was likely the result of the conversion from conventional commercial farming to private game farming, since a sand forest, forest and rock faces landscape aided the clear viewing of the wildlife for the reserve's shareholders. This increase in land cover might have resulted due to the decrease in the old fields and disturbed areas (23 percent to 11 percent). Accordingly old fields and disturbed areas were cleared to accommodate a savanna landscape (seen in Plate 1) i.e. open space, clear viewing for the game species. In addition the old fields and disturbed areas were cleared to make way for the fifty new private ownership residence properties.

Plate 1: Land cover of Kube Yini PGR (2007 Field work)

An increase in the rock faces is a result of the location of the reserve: it is located in hilly terrain with steep slopes, with the Ubombo and Lebombo mountains contributing to the rock faces, seen in Plate 1. Furthermore the removal of past infrastructure, construction of private properties, fences, roads and access paths led to the increased erosion of soil, which would have resulted in increased rock faces within the reserve.

As already noted, due to the historical mismanagement of Kube Yini, alien invasive species (non-indigenous plants) invaded the reserve, which resulted in the increase in the old fields and disturbed areas observable in 1990 (P Binney, 2008, pers. comm.[14]). In 1990 the old fields and disturbed areas occupied 272 ha (23 percent) of the reserve, whilst in 2007 this land cover had been reduced significantly due to management interventions, occupying only 128 ha (11 percent) of the reserve, which is clearly depicted in Figure 5.6. Alien plants, in particular Triffid weed, posed a significant problem for Kube Yini in its earlier years as it occupied old fields and disturbed areas as well as encroaching into the other land covers (N Hawkey, 2008, pers. comm.[15]).

Kube Yini's management has made use of the Invasive Alien Species (IAS) clearing programme, used to help eradicate the alien species and to clear the old fields and disturbed areas (N Hawkey, 2008, pers. comm.[16]). The employees of this programme were local women who cut and burned the invasive plants and vegetation occupying the old fields and disturbed areas. Women were selected to work as the men chose not to work (C Lloyd, 2008, pers. comm.[17]). This initiative led to the drastic decrease in the land cover category "old fields and disturbed area" which dropped from 272 ha (23 percent) to 128 ha (11 percent). The removal of invasive species has been seen as a priority for Kube Yini over the years and continues today (P Binney, 2008, pers. comm.[18]). The effects of the alien eradication programme are reflected in the decrease in the old fields and disturbed areas, leading to an increased sand forest, forest and rock faces; and grasslands land cover. (Also contributing to the decrease of this land cover is the fact that in a number of areas within the reserve the land cover was replaced with residential homes for the shareholders).

[14] Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

[15] Interview with Neville Hawkey, Kube Yini PGR, 20 October 2008.

[16] Interview with Neville Hawkey, Kube Yini PGR, 20 October 2008.

[17] Interview with Craig Lloyd, Thanda PGR, 20 October 2008.

[18] Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

Kube Yini experienced a slight decrease within the grassland land cover, from 76 ha (6 percent) to 55 ha (5 percent) as seen in Figures 5.6 and 5.7. It is likely that, since Kube Yini is a residential home for shareholders who prefer an open space grassland landscape to view the wildlife, enjoy their game drives and walks using the access paths. Grasslands have therefore been carefully maintained.

5.4.2 Thanda Private Game Reserve

Historically the area known as Thanda Private Game Reserve today, as well as its surrounding area, would have been dominated by open woody grassland and riverine vegetation and bush along the drainage lines of the area (Brousse-James & Associates, 2008). According to Brousse-James and Associates (2008), grassland dominated the area as a result of the low herbivore numbers, which produced a low grazing pressure on the area as browsers play a crucial role in the domination of grassland cover (Brousse-James & Associates, 2008). Also assisting the domination of the grassland cover was the high frequency fires. In northern KwaZulu-Natal, fire seldom occurred as a result of lightning strikes (Brousse-James & Associates, 2008), thus it has been speculated that the historical fire regime within the area was to a large degree man induced. The correct management of fire is crucial for the maintenance of biodiversity at both the local and regional levels, as well as for the enhancement of ecosystem productivity.

In the 1940s, tsetse fly eradication programmes denuded the area of much of its wildlife. In addition, artificial watering points were introduced in the late 1940s, when the region experienced a huge influx of cattle (after the eradication of tsetse fly, cattle farming became viable in the region). These factors resulted in the extension of the non-woody grassland (Brousse-James & Associates, 2008). Due to the vegetation changing from woody grassland to non-woody grassland, a doubling of CO^2 in the atmosphere resulted, which favoured the re-growth of woody vegetation (Brousse-James & Associates, 2008).

When Thanda became a PGR, a woody grassland cover dominated the landscape as a result of the relatively high grazing pressure (due to the large number of cattle and restricted use of wildlife) and low fire frequency (R Lloyd, 2008 pers. comm.[19]). Since the inception of Thanda, the livestock changed from cattle to more wildlife (inclusive of the "Big Five" and extra-limital species) (Brousse-James & Associates, 2008).

[19] Interview with Russell Lloyd, Thanda PGR, 18 October 2008.

During the period 1990 to 2007 as illustrated in Figures 5.8 and 5.9, it is most likely that the following land cover/land use changes related to private game farming (i.e. from a cattle farm with limited wildlife use to a PGR) occurred. Thanda PGR experienced a decrease in the sand forest, forest and rock faces (13 percent to 4 percent); woodlands (29 percent to 18 percent); and old fields and disturbed areas (38 percent to 28 percent) (see Plate 2). There was as well an increase in the grasslands land cover from 19 percent to 49 percent during this period. Water bodies and riverine vegetation remained overall the same during this period i.e. 1 percent though the hectare coverage decreased from 46 ha to 39 ha. The decrease in the water bodies and riverine vegetation from 46 ha (1 percent) to 39 ha (1 percent) can be attributed to the change in the land use practice within the area, i.e. a cattle farm converted to a PGR as well as to the semi-arid conditions and drought that was experienced in the area during the 2001-2006. In addition several artificial water pans, seen in Plate 2, were created in the area ensuring that during the dry, winter months the wildlife survived (R Lloyd, 2007, per. comm.).

Plate 2: Artificial water pans, old fields and disturbed areas and savanna landscape of Thanda PGR (2007 Field work)

Figures 5.8 and 5.9) illustrate a drastic drop in the following land covers: sand forest, forest and rock faces from 859 ha (13 percent) to 270 ha (4 percent); old fields and disturbed areas from 2588 ha (38 percent) to 1857 ha (28 percent); and woodlands from 1922 ha (29 percent) to 1249 ha (18 percent). This has been accompanied by a striking increase in the grassland cover from 1310 ha (19 percent) to 3337 ha (49 percent).

The clearing away of the sand forest, forest and rock faces; woodlands; and old fields and disturbed areas was done by management to accommodate the increased game species, providing more space for the "Big Five" and extra-limital species, as well as creating space for new infrastructure, such as tourist accommodation and villas, game viewing as well as creating access, foot paths and game drives for the tourists. Thanda caters for the rich, affluent people who seek quiet time away from their busy urban life (Brooks *et al.,* 2008). As a result the reserve created open space for tourists to relax and enjoy the wildlife. The open spaces have resulted from the clearing away of sand forest, forest and rock faces; woodlands; and old fields and disturbed areas.

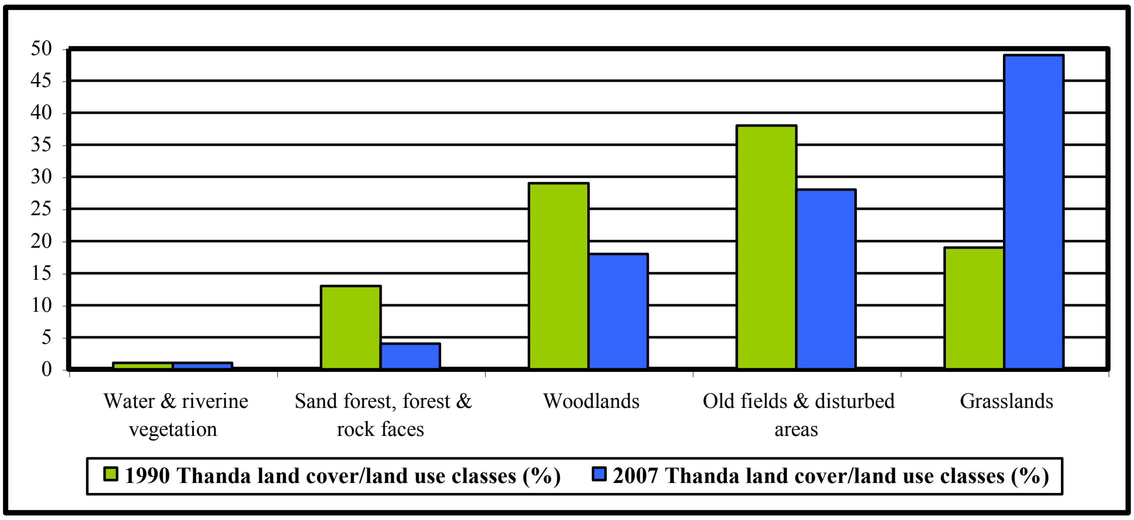

Figure 5.4: Land cover/land use changes within Thanda Private Game Reserve (1990-2007)

During the period 1990 to 2007 grasslands more than doubled i.e. from 19 percent to 49 percent within the reserve as depicted in Figure 5.8. Thanda's management used a process known as "self-thinning", which was carried out in the hope of changing the landscape back to an open grassland land cover (Brousse-James & Associates, 2008). As a result the sand forest, forests and rock faces; woodlands; and old fields and disturbed areas were thinned and cleared out, encouraging the growth of grassland and visibility of the game species.

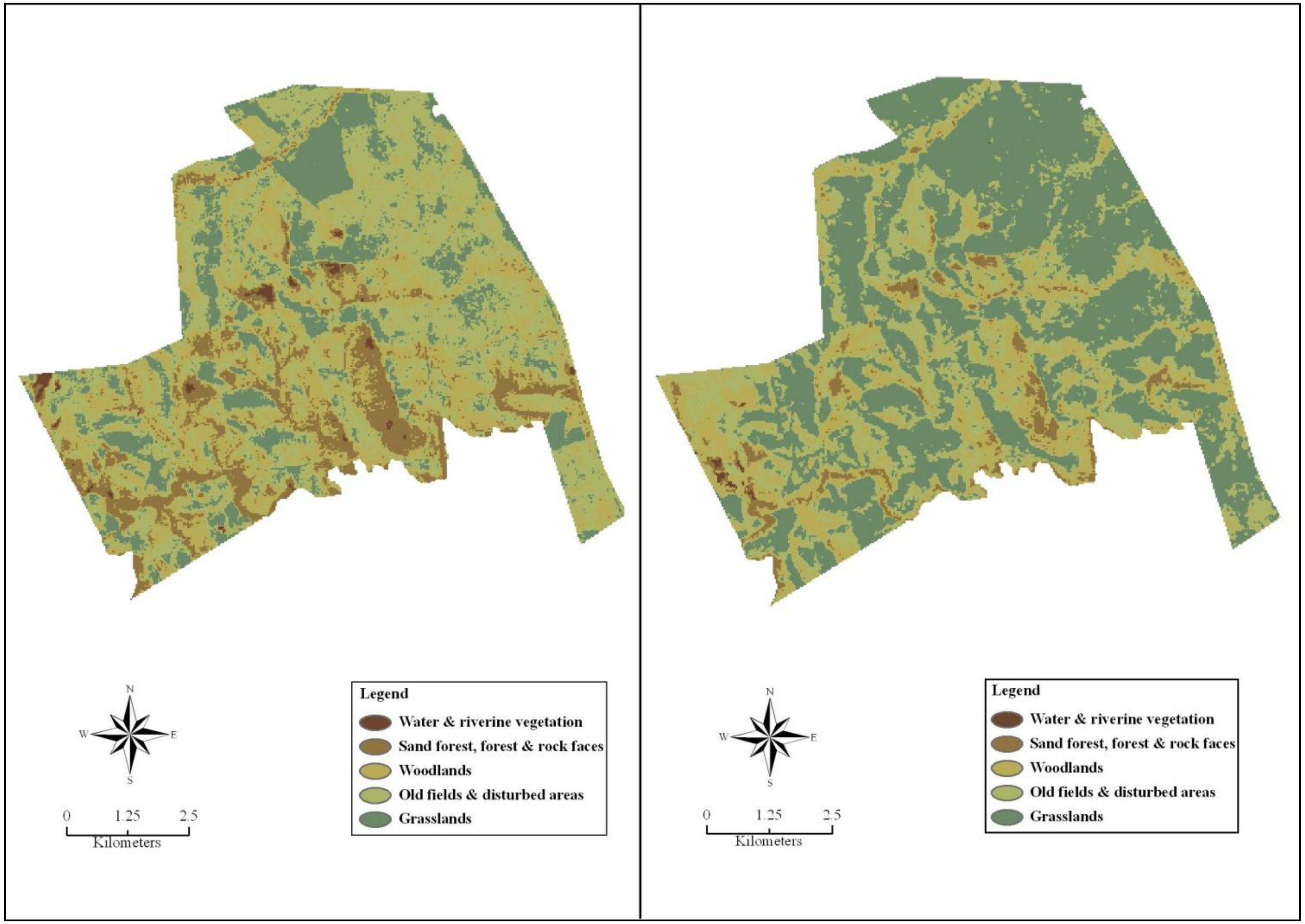

Figure 5.9: Land cover/land use changes within Thanda Private Game Reserve (1990 & 2007)

In addition, the utilisation and damage caused by the game species - in particular the presence of "Big Five" species - resulted in the decreased sand forest, forest and rocks; and woodlands land covers and increased grasslands cover. There is also now a regular burning regime. Each area was burnt once every two years, aiding the grassland cover (R Lloyd, 2008, pers. comm.[20]).

5.4.3 Phinda Private Game Reserve

Like the other two PGRs, conventional farming was attempted at Phinda. Cattle as well as maize, tobacco, cotton and pineapple were farmed (Varty & Buchanan, 1999). According to Varty and Buchanan (1999), the harsh semi-arid conditions, i.e. high temperatures and infrequent but heavy hailstorms contributed to the idea of Phinda becoming a private wildlife-based venture. With the new reserve came a change in the farming practice, which resulted in a change in land cover. These changes are discussed below.

The results (Figures 5.10 & 5.11) reveals that within Phinda the water bodies and riverine vegetation remained the same (i.e. 1 percent); sand forest, forest and rock faces (32 percent to 19 percent); woodlands (43 percent to 41 percent) decreased whilst an increase in the old fields and disturbed areas (15 percent to 26 percent); and grasslands (9 percent to 13 percent) was evident. Figure 5.10 clearly shows the changes in the land cover/land use related to private game farming within Phinda.

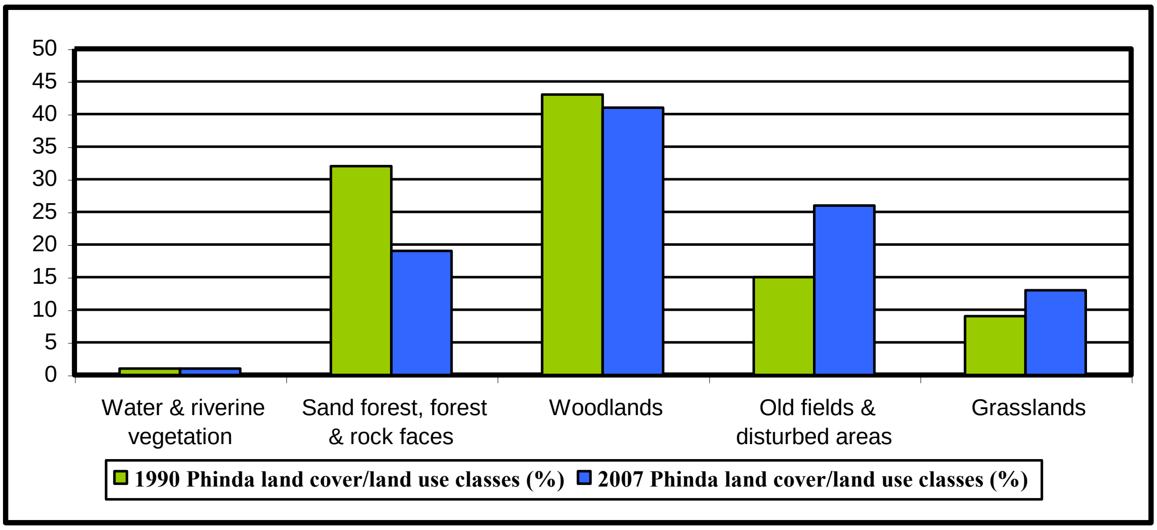

Figure 5.10: Land cover/land use changes within Phinda Private Game Reserve (1990-2007)

[20] Interview with Russell Lloyd, Thanda PGR, 18 October 2008.

Between 1990 and 2007, water bodies and riverine vegetation remained overall the same, i.e. 1 percent, though the hectare coverage of this land cover decreased from 40 ha to 37 ha (Appendix 3: Table 3.7 & 3.8) as a result of the drought experienced in the area during the period 2001-2006. The land cover sand forest, forest and rock faces dropped drastically from 2325 ha (32 percent) to 1422 ha (19 percent), illustrating a difference of 13% over the years. Plate 3 illustrates the sand forest land cover. Sand forest is a sensitive land cover (Low & Rebelo, 1996) that has decreased due to the disturbance caused by the removal and construction of infrastructure as well as an increased wildlife using the landscape. Also during the period 1990 to 2003, Phinda experienced an exponential increase in its elephant population, which increased from 58 to 110 elephants. This helps explain the decrease in the sand forest due to the activity of elephants destroying trees and vegetation crossing their path (Slotow *et al.*, 2004). Elephants enjoy tossing trees as part of their playtime and this contributes significantly to the decrease in the sand forest, forest and rock faces (as seen in Plate 3).

Plate 3: Sand forest and fencing out of elephants at Phinda PGR (2007 Field work)

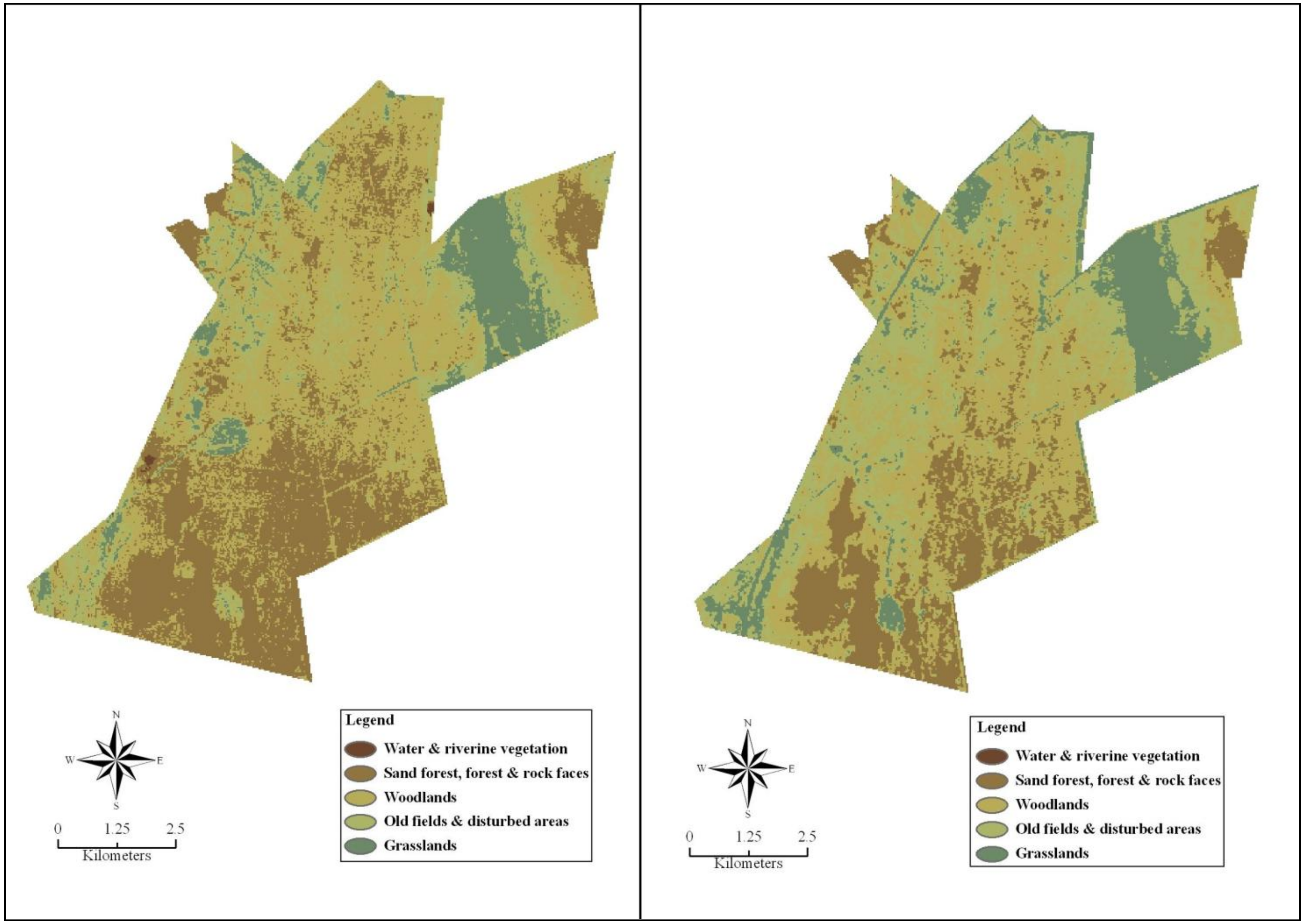

Figure 5.5: Land cover/land use changes within Phinda Private Game Reserve (1990 & 2007)

Thereafter, in consideration of Phinda's sensitive habitat i.e. sand forest, management decided to remove about one-third of the elephants on the reserve. In 2003, a total of 37 elephants were moved from the reserve, leaving a total of 73 elephants (Slotow *et al*., 2004). In addition, Phinda fenced off a proportion of the sand forest area so as to keep the elephants out thereby allowing the sand forest to expand naturally. This is seen in Plate 3. During the 2008 fieldwork the number of elephants on the reserve was not established, so it is not known whether the elephants had increased or decreased in population size.

Over the period 1990 to 2007 as illustrated in Figure 5.10, woodlands decreased from 3177 ha (43 percent) to 2987 ha (41 percent) and this was mostly likely due to the tourism infrastructure (tourist and employees accommodation, etc) that had been constructed. Also a decrease in the woodlands; and sand forest, forest and rock faces might have resulted in the increased grasslands; and old fields and disturbed areas land covers (seen in Plate 4). In addition, Phinda created a woodlands land cover as a result of the addition of the "Big Five" game. Some "Big Five" predators prefer a woodland cover as a woodlands habitat makes it easier for leopards and lions to catch their prey (Balme *et al*., 2006).

Plate 4: Old fields and disturbed areas of Phinda PGR (2007 Field work)

Figure 5.11 depicts that the old fields and disturbed areas increased from 1104 ha (15 percent) to 1942 ha (26 percent) and this was due to the disturbance caused to the sand forest, i.e. decreased sand forest, forest and rock faces; and woodlands land covers were matched by an increase in the old fields and disturbed areas. The increased game species on the reserve could have also contributed to more disturbed areas. It was clearly seen that the grasslands cover has increased considerably over the years, i.e. from 675 ha (9 percent) to 941 ha (13 percent). Browsers such as nyala and impala prefer grasslands to the dense habitats such as woodlands; as a result the management of Phinda created more grassland cover to accommodate the increased wildlife. Through a combination of seasonal burning as well increased browsers, Phinda has managed to increase its grassland land cover.

5.5 COMPARATIVE ANALYSIS OF THE PGRS

A comparative analysis was undertaken to determine the overall impact that private game farming has had on the land cover of the study area, as well as the differences between the PGRs. Table 5.2 and Table 5.3 (including Appendix 3) summarise the land cover/land use changes within each PGR. It is clearly evident that during this period, the water and river vegetation decreased from 14315 ha (6 percent) to 7523 ha (3 percent) across the entire study area. This can be attributed to the drought that was experienced in the area during the 2001-2006 period.

Table 5.2: 1990 Land cover/land use changes within each PGR and total area of PGRs land cover

Level I Land cover/land use classes	1990 Kube Yini land cover (%)	1990 Thanda land cover (%)	1990 Phinda land cover (%)	1990 Total area (%) of PGRs land cover
Water and river vegetation	4	1	1	6
Sand forest, forest and rock faces	31	13	32	76
Woodlands	36	29	43	108
Old fields and disturbed areas	23	38	15	76
Grasslands	6	19	9	34
Total	100	100	100	300

Table 5.3: 2007 Land cover/land use changes within each PGR and total area of PGRs land cover

Level I Land cover/land use classes	2007 Kube Yini land cover (%)	2007 Thanda land cover (%)	2007 Phinda land cover (%)	2007 Total area (%) of PGRs land cover
Water and river vegetation	1	1	1	3
Sand forest, forest and rock faces	47	4	19	70
Woodlands	36	18	41	95
Old fields and disturbed areas	11	28	26	65
Grasslands	5	49	13	67
Total	100	100	100	300

Overall, the land cover: sand forest, forest and rock faces decreased in the PGRs during this period, from 43700 ha (19 percent) to 36402 ha (16 percent) (refer to Table 5.1). Within each individual PGR, individual changes within this land cover occurred. While at Kube Yini there was an increase from 366 ha to (31 percent) to 564 ha (47 percent) the sand forest, forest and rock faces land cover decreased at both Thanda (859 ha to 270 ha) and Phinda (2325 ha to 1422 ha) (refer to Appendix 3) PGRs. A decrease in this land cover resulted due to the infrastructure construction for tourism purposes. Also at Thanda, the sand forest, forest and rock faces decreased due to the change to a grassland land cover, i.e. Thanda's management practices most likely altered the landscape to grassland. At Phinda, decreased sand forest, forest and rock faces cover may have occurred due to the increased number of game species (in particular elephants) that lived on the reserve during the period.

Table 5.2 and 5.3 illustrates that woodlands as a land cover decreased from 5522 ha (108 percent) to 4670 ha (95 percent) across all the PGRs taken together during this period. In Kube Yini the woodlands land cover remained the same, i.e. 36 percent, though the hectare coverage increased slightly from 423 ha to 434 ha (refer to Appendix 3, Tables 3.3 & 3.4). Thanda experienced a decreased woodlands land cover from 1922 ha to 1249 ha (29 percent to 18 percent) as management made a concerted effort to "thin" the woodlands and encourage grassland. At Phinda, the woodlands land cover decreased slightly from 3177 ha (43 percent) to 2987 ha (41 percentage). This could be due to the interventionist management policy adopted there.

A decrease in the old fields and disturbed area category from 3964 ha (76 percent) to 3927 ha (65 percent) was evident across the three PGRs if viewed as a whole (see Tables 5.2 & 5.3). A drop in this land cover class was due to all PGRs encouraging and enforcing the removal of invasive plant species as well as practising bush clearing practices. In all PGRs a concerted effort was made to ensure that the old fields and disturbed areas were cleared so that the natural vegetation and in some cases grassland cover could grow. Kube Yini and Thanda displayed a clear decrease in the old fields and disturbed areas land cover. This was not the case at Phinda, where the increased old fields and disturbed areas could have resulted due to the decreased sand forest, forest and rock faces: as the sand forest, forest and rock faces land cover was removed, disturbed open areas could have resulted as the increased game and elephant species would not have allowed the vegetation to grow back easily (refer to Table 5.2 & 5.3).

Overall, grasslands increased from 2061 ha (34 percent) to 4333 ha (67 percent) across all PGRs, as all PGRs preferred the grassland land cover for game viewing. Kube Yini is the exception: here the grassland land cover increased by 1 percent (see Figure 5.7), as residents were pleased with the open forest landscape. Thanda experienced a marked increase in its grassland land cover from 1310 ha to 3337 ha (19 percent to 49 percent), as its management aim was to convert the reserve back to a grassland landscape. Phinda's grassland cover also increased from 675 ha (9 percent) to 941 ha (13 percent) (see Table 5.2 & 5.3).

5.6 LAND COVER/LAND USE CHANGES WITHIN MKHUZE GAME STATE RESERVE (CONTROL)

In this study, Mkhuze Game Reserve, which is owned by the State, was used as a control to establish whether private game farming is altering the landscape of the Mkhuze area in northern KwaZulu-Natal. Mkhuze Game Reserve is a state reserve that is managed differently from PGRs within the area of interest. Unlike PGRs, whose main aim is to maximise profit from wildlife utilisation, state reserves prioritise conservation of wildlife (animal and plant) species and their habitats currently and in the future. In addition state reserves like Mkhuze endeavour to keep its landscape in its pristine form, i.e. as far as possible unaltered by human influences. The reserve has been in existence since 1912 and no commercial farming has taken place there.

The results illustrated in Figures 5.12 and 5.13 depict that during the period 1990 to 2007 there have been slight changes within Mkhuze's land cover. The land cover classes: water and riverine vegetation (2 percent to 1 percent); sand forest, forest and rock faces (16 percent to 15 percent); and grasslands (29 percent to 26 percent) decreased. The woodlands (27 percent to 30 percent); and old fields and disturbed areas (26 percent to 28 percent) land cover classes increased during this period.

Within the Mkhuze Game Reserve, water and riverine vegetation decreased from 735 ha (2 percent) to 182 ha (1 percent). This decrease in land cover is most likely due to the semi-arid locality where the reserve is situated as well as the drought that was experienced in the area during the period 2001 to 2006.

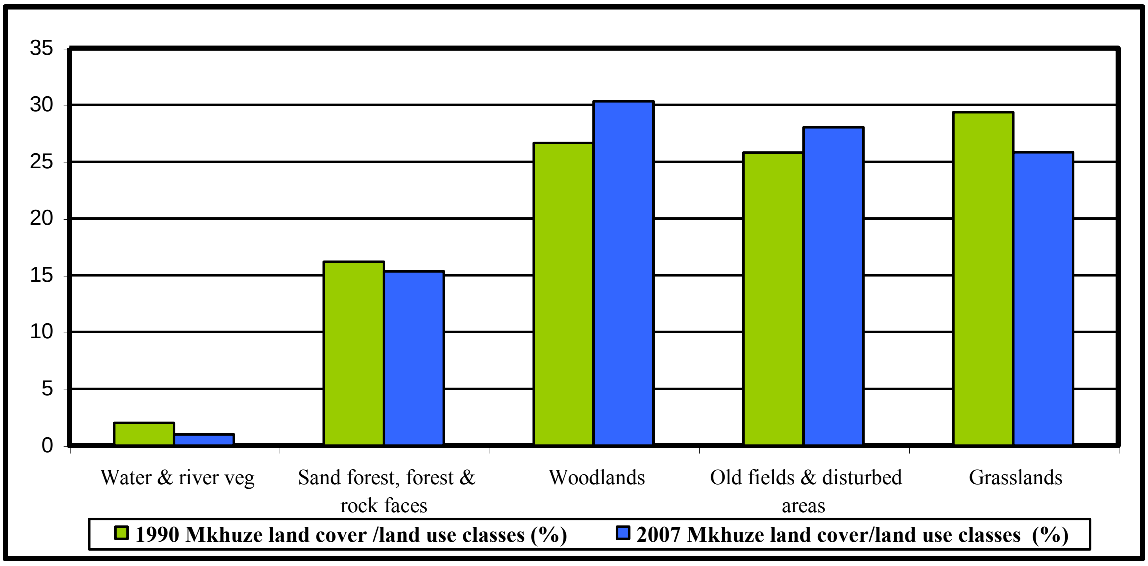

Figure 5.12: Land cover/land use changes within Mkhuze Game Reserve (1990-2007)

During this period, as evident in Figures 5.12 and 5.13, the land cover sand forest, forest and rock faces decreased marginally from 5897 ha (16 percent) to 5589 ha (15 percent). It is likely that the sand forest, forest and rock faces land cover may have been carefully maintained and this may be due to management understanding the sensitive nature and importance of this land cover.

Woodlands increased from 9710 ha (27 percent) to 11051 ha (30 percent) whilst the grasslands decreased from 10696 ha (29 percent) to 9418 ha (26 percent). This increase in land cover mostly likely resulted due to the decrease in the grasslands land cover (29 percent to 26 percent) (see Appendix 3: Tables 3.9 & 3.10). Woodlands are robust plant species that can survive the harsh conditions within the area. Seeing as the study area experienced a drought during the years 2001-2006, it is most likely that the woodlands land cover fared better during this period than the grasslands land cover, hence increasing its coverage of the area. Since Mkhuze's priority is conservation, it is likely that Mkhuze's management allowed natural competition and selection to occur between the land covers. Also since there is the presence of "Big Five" species, it is most likely that management decided to increase the woodlands cover to accommodate the increased wildlife and game species.

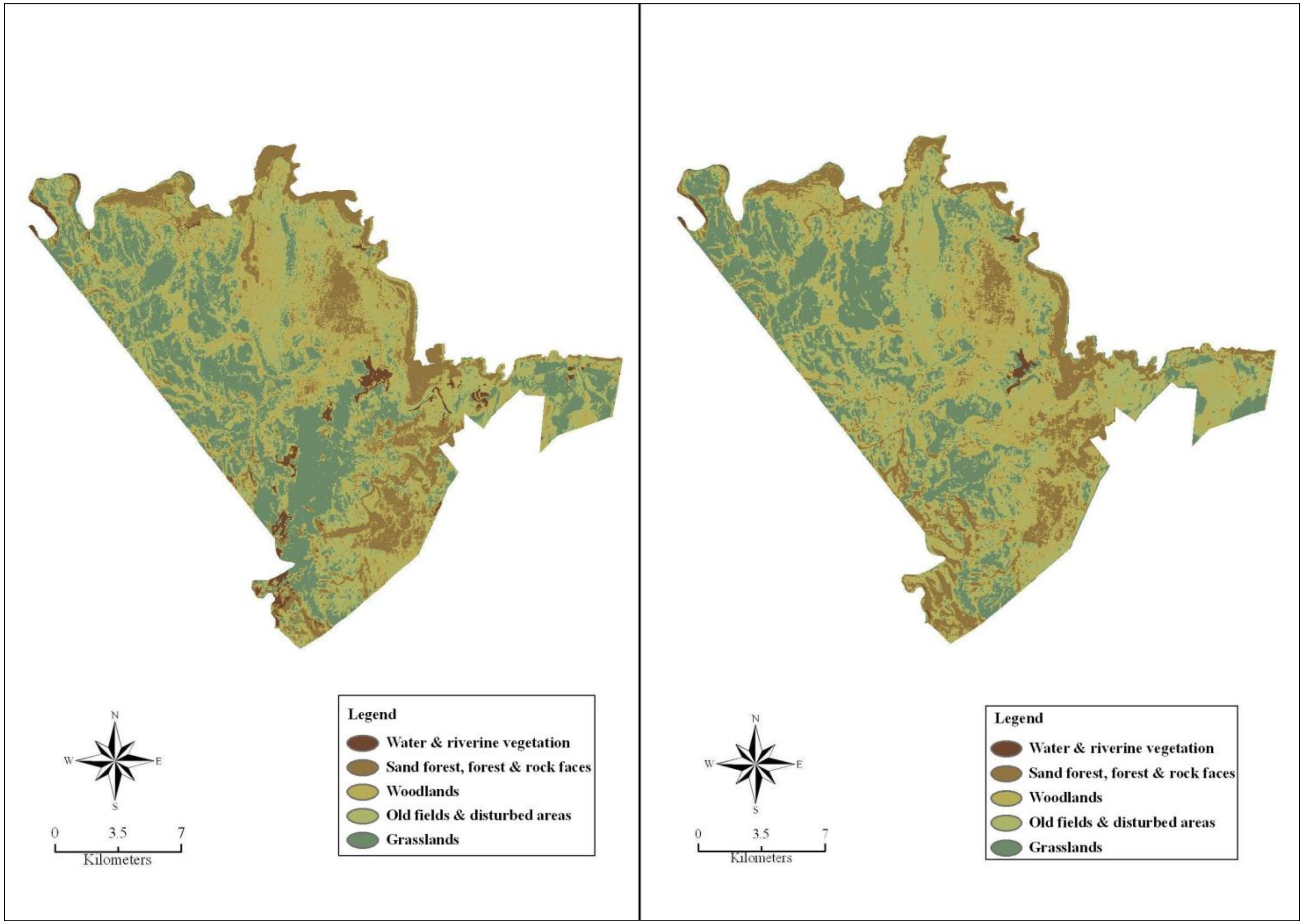

Figure 5.13: Land cover/land use changes within Mkhuze Game Reserve (1990 &2007)

Figures 5.12 and 5.13 depict that the old fields and disturbed areas increased from 9407 ha (26 percent) to 10223 ha (28 percent). This is most likely due to the decrease in the grasslands cover from 10696 ha (29 percent) to 9418 ha (26 percent). It is possible that the grasslands land cover was reduced due to the drought experienced in the area. In addition the construction and expansion of infrastructure within the reserve could have resulted in the increased old fields and disturbed areas land covers. Grasslands may have also decreased in quality (vegetation index of the grassland cover) to "degraded grasslands," which may have also contributed to the increase in the old fields and disturbed areas. Competition between invasive species may have also resulted in the decrease in the grassland cover.

Overall, it is evident that in the control area, the changes in land cover were fairly minimal compared with the major changes that have occurred in the neighbouring Private Game Reserves.

5.7 COMPARATIVE ANALYSIS OF THE PGRS AGAINST THE CONTROL

A comparative analysis of PGRs against the control was carried out to determine the overall changes that private game farming has had on the study area's land cover, inclusive of the changes within the PGRs versus the state reserve, which in this study was used as the control. Figures 5.6 to 5.13 depict the land cover/land use changes within the PGRs and the Mkhuze Game Reserve, allowing the comparison to be made.

In general (see Figures 5.6 to 5.13) all PGRs as well as the state reserve experienced a decrease in the water and riverine vegetation. This was due to the drought experienced in the area during the period 2001 to 2006 as well as the harsh, semi-arid conditions experienced in this region. Although Mkhuze Game Reserve experienced a slight decrease in its sand forest, forest and rock faces land cover from 5897 ha (16 percent) to 5589 ha (15 percent), the PGRs on the other hand experienced significant changes within this cover. The slight decrease in Mkhuze's sand forest, forest and rock faces cover (illustrated in Appendix 3: Tables 3.9 & 3.10), had mostly likely occurred due to Mkhuze's management practices, which aim primarily to conserve and maintain this land cover currently and in the future. Mkhuze's management plan endeavours to nurture biodiversity naturally without human influence. Thus the variation between PGRs and Mkhuze's sand forest, forest and rock faces class was most likely a result of the different management practices practised within each reserve that resulted in changes within this land cover.

For instance Kube Yini's sand forest, forest and rock faces increased from 366 ha (31 percent) to 564 ha (47 percent). This may have resulted due to Kube Yini's management altering this cover, creating an open savanna landscape to view the wildlife. The decrease in this land cover at Thanda PGR was most likely due to Thanda's management modifying its landscape to a grassland type as well as the construction of infrastructure for tourism purposes, which could have resulted in the decreased cover. In addition, it was most likely that Phinda PGR also experienced a decrease in the sand forest, forest and rock faces land cover as a result of the increased wildlife as well as the increased elephant population size experienced during this period.

Within Mkhuze Game Reserve (refer to Figures 5.12 & 5.13), woodlands increased from 9710 ha (27 percent) to 11051 ha (30 percent). Compared to Thanda and Phinda PGRs, which experienced a decrease in this land cover as a result of management intervention, Mkhuze's woodlands land cover increased due to management allowing natural selection and competition of plant and animal species to occur. Woodlands are known to be highly resistant vegetation that can withstand the harsh environmental conditions thus it is mostly likely that the woodlands naturally survived the drought conditions better than the other land cover/land use classes. Woodlands remained more and less the same at Kube Yini i.e. 36 percent, though the hectare coverage increased slightly from 423 ha to 434 ha and this was mostly likely due to Kube Yini's management practices (see Appendix 3: Tables 3.3 & 3.4).

During the period 1990 to 2007, old fields and disturbed areas increased from 9407 ha (26 percent) to 10223 ha (28 percent) within Mkhuze reserve. In all likelihood, this increase in land cover resulted due to natural competition within the reserve's land cover classes as well as the grassland cover decreasing from 10696 ha (29 percent) to 9418 ha (26 percent). The 2001 to 2006 drought experienced in the area may have also led to the decrease of Mkhuze's grassland cover, resulting in an increase in the old fields and disturbed areas. In addition, the presence of wildlife at Mkhuze Game Reserve may have resulted in the increased disturbance within the reserve, which could have resulted in an increase in the old fields and disturbed areas land cover.

Thanda, Kube Yini and Phinda PGRs have implemented successful management plans to reduce the old fields and disturbed areas land cover within their reserves, left over from the commercial farming era. This is clearly evident in Figures 5.6 to 5.11. However, it can be seen that within Phinda PGR, the old fields and disturbed areas land cover have increased from 1104 ha (15 percent) to 1942 ha (26 percent): this could be due to the increased wildlife this reserve supports, which has possibly led to the increase in the old fields and disturbed areas.

Overall, Mkhuze's grasslands land cover decreased from 10696 ha (29 percent) to 9418 ha (26 percent) whilst the PGRs experienced varying changes within this land cover. Kube Yini experienced a slight decrease in the grasslands land cover from 76 ha (6 percent) to 55 ha (5 percent), Thanda experienced an exponential increase in its grasslands land cover from 1310 ha (19 percent) to 3337 ha (49 percent) and Phinda experienced a decrease in this cover from 675 ha (9 percent) to 941 ha (13 percent).

5.8 DISCUSSION

With the establishment of each PGR, came a number of changes. These include: the erection of fencing for the game species; the removal of existing as well as internal infrastructure (e.g. cattle fencing, cattle dipping); the development of new infrastructure (roads, water supply, owners' private properties/villas, lodges for tourists as well as employees, roads for game drives, foot and other access paths); the introduction of certain game species such as "Big Five" and extra-limital species; alien eradication programmes; seasonal burns; and the thinning and clearing of vegetation to achieve the savanna land cover that tourists desire.

The unanswered question that remains is whether private game farming has benefited the landscape ecologically. Had the land cover/land use not changed, i.e. from conventional commercial farming to PGRs, would the area have been further invaded by alien plant species and bush encroachment, for example? What is known is the effects of these changes on the land cover are impacting the ecological, biological as well as physical landscape of the area of interest. The increased number of game species, the presence of "Big Five" and extra-limital species may pose a threat to the ecological carrying capacity of the environment. The area of interest has never been stocked with so many diverse game species as seen today. The results of overstocking numerous game species can be seen at Phinda PGR whereby the increased carrying capacity has decreased the sensitive sand forest, forest and rock faces significantly within the area. This was recognised by Phinda's management, who in 2003 decided to reduce the number of elephants in the reserve (Slotow *et al.*, 2004).

The introduction of extra-limital species and other wildlife species may also have resulted in a loss of several indigenous species. Private Game Reserves stock extra-limital species because tourists demand to see these species, and in some cases PGR managers tend to modify their landscape to suit the visibility of these extra-limital species. This appears to support the conclusion that economic incentives, rather than ecological integrity, are the primary motivation of PGR management (Smith & Wilson, 2002).

Indigenous species in the area play a crucial role in maintaining the balance of the ecosystem. For example, indigenous plant species trap and anchor important nutrients that are essential for the functioning and sustainability of the ecosystem whilst indigenous animals contribute to the equilibrium and balance of the system. Extra-limital species on the other hand may require a different land cover than the indigenous species of an environment. As a result of the altered land cover in some of the PGRs, several indigenous species were removed, lost or migrated to other habitats that are more suitable for their co-existence (Pasquini, 2007). With the introduction of numerous game species, competition for space, food and water results. Consequently, the stronger species occupy areas closest to the water, making it more difficult for the remainder species to access the water points, resulting in several species moving to newer areas (Balme *et al.*, 2006).

It is possible that the continuous change in land cover could result in habitat fragmentation, which may cause radical changes in the habitat resulting in losses of populations of plant and animal species (Anon, 1994; Bennet, 1999). One of the ways of reducing the impact of habitat fragmentation is the creation of corridors or linkages between various PGRs. This would alleviate pressure on the environment as game species would be able to roam more freely with the increased space and the number of fences in the area could be reduced. This is a subject under discussion among the PGR managers, but to date it has not been implemented (N Hawkey, 2008, pers. comm.[21]). It is only Thanda PGR that has, of the year 2009, dropped its internal fences within its reserve (R Lloyd, 2009, per. comm.[22]).

[21] Interview with Neville Hawkey, Kube Yini PGR, 20 October 2008.

[22] Telephonic interview with Russell Lloyd, 18 June 2010.

Finally, the increased infrastructure within the study area and especially the PGRs poses a threat to the area of interest. Today the area supports more infrastructure than ever before. With this increased infrastructure came the removal of vegetation cover. Loss of vegetation impacts the functioning of the ecosystem. It is unknown at this stage whether the continued increase in infrastructure can be continually sustained by the ecosystem, as the increased demands placed by the infrastructure on the system were not investigated. Together with the continued increase in infrastructure, increased game species (including the presence of "Big Five" and extra-limital species) as well as change in land cover/land use could result in the ultimate degradation of the ecosystem functions.

5.9 PREDICTION OF POSSIBLE FUTURE LAND COVER/LAND USE CHANGES WITHIN PGRS

In predicting the land cover/land use changes related to private game farming within northern KwaZulu-Natal in the near future, it would be useful to adopt a conceptual model which could combine both biophysical as well as socio-economic data. This study did not take into account in a systematic way the biophysical and socio-economic information, thus this section provides only a tentative forecast of future trends of the land cover/land use changes related to private farming.

One future scenario is that if PGRs continue with their current farming practices such as increased stocking of wildlife species, the building of more infrastructure to accommodate tourists as well as the continued changes in land cover to satisfy tourists' desires, a degradation and eventual collapse of the ecosystem could result due to the increased pressure placed on the system. Another problem is the diversity of management practices on different PGRs and the lack of consensus as to best practice. If PGRs continue their current farming trend of a non-uniform farming practice, whereby PGRs continue to manage their individual PGR differently in keeping to their tourist demands, this could result in PGRs reaching their peak and then declining. The ecosystem would not be able to sustain its functionality, as changes in land cover/land use would impact its carrying capacity hence the system functionality would degrade and eventually collapse. In addition due to the increased game species, "Big Five" and wildlife, competition for food, space and water would occur and survival of the fittest species would emerge, resulting in a loss of species, especially rare and unique species indigenous to the province of KwaZulu-Natal.

Furthermore since the area of interest is located in a semi-arid region, the increased volumes of game stocked would result in a continued decrease in water, as more water would be needed for the livelihood of the game species. Moreover the change in land cover/land use accompanied with either higher temperatures and less precipitation would result in further decrease in the water supply. Water might then have to be pumped from neighbouring reserves to sustain the survival of the PGRs.

With a continual increase in the movement of people, tourist accommodation, lodges, game drives, foot and access paths would result in loss of vegetation cover, an increase in rock faces and soil erosion. A loss of vegetation would result in soil disturbance, resulting in the nutrient-rich topsoil being lost, which is essential for the anchorage of plant species and sustains smaller animal life. An increase in rock faces and soil erosion would result in the loss of many plant and animal species.

It could also be postulated that in the years to come, government laws and legislation with regards to private game farming would be firmly established and more clearly defined. This would create a greater awareness by game farmers regarding conservation of natural resources, which would aid the increase of indigenous vegetation and species within the area of interest.

5.10 SUMMARY

In recent years numerous Private Game Reserves have been converted from conventional commercial farming to private game farming in northern KwaZulu-Natal. For this study three such PGRs as well as a control (i.e. Mkhuze Game Reserve) were selected. The land cover changes between 1990 and 2007 were identified through the application of GIS and Remote Sensing techniques and a series of maps and graphs (see Figures 5.6 to 5.13) were generated. In this chapter, an attempt was made to understand the relationship between the change of land use (i.e. from conventional commercial farming to private game farming) and associated changes in the land covers. This was assisted by discussions conducted with the managers of the three PGRs so that a better understanding of the management practices adopted at each reserve could be gained. By close study of the Remote Sensing results, conclusions were arrived at regarding the impact of the different game farming management practices on the land cover changes in the reserves.

Maps and graphs (Figures 5.6 & 5.13) generated through GIS and Remote Sensing techniques based on the use of Landsat 5 TM, revealed that over the past seventeen years land cover/land use changes related to private game farming have resulted. The methodology employed in this study led to a series of results (see Appendix 3) that allowed the changes in land cover/land use related to private game farming to be mapped. Each methodological step was crucial in obtaining accurate results. A change detection analysis was selected as the best and most accurate technique in determining the general trends with regards to mapping land cover/land use changes related to private game farming. This chapter presented the results and discussed their significance in light of management practices in the PGRs and Mkhuze (state) Game Reserve. The final chapter provides the Conclusion to the study.

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1 GENERAL CONCLUSION

PGRs have been in existence for the last few decades, yet scientific studies into the impacts and implications of this trend are few. Hence this study was undertaken to try to understand the land cover/land use changes related to private game farming. The lack of scientific literature with regards to land cover/land use changes related to private game farming, has been a significant hurdle in understanding this change in land use. This thesis serves as a baseline study, limited to one part of the KwaZulu-Natal province, as an attempt to identify what is happening to the land cover with this change of land use. Further studies must be undertaken to verify and validate the findings as well as to attain a clearer understanding of the impacts and benefits of this change in land use to the landscape.

Water quantity and quality is an ongoing problem in an area such as this part of northern KwaZulu-Natal, which experiences a semi-arid climate. As a result conventional commercial farms in the area are always faced with the dilemma of sustaining a reliable water supply for farming and irrigation. In addition the study area's rough terrain is not suited for conventional commercial farming practices such as the dipping of cattle, counting and gathering of individual herds at various times of the month or year, making this difficult to achieve (P Binney, 2008, pers. comm.[23]). Another factor was uncertainty regarding the future of agriculture in the minds of several farm owners after the first democratic election - several farm owners began converting their conventional commercial farms to private game reserves, as they were afraid of losing their land to the land reclamation process. In addition the boom of the PGR industry both locally and internationally as well as the monetary returns received by the PGRs, appeared as an opportunity for many farm owners within KwaZulu-Natal. These factors fuelled the establishment of PGRs.

During the period 1990 to 2007, it is most likely that the study area's land cover/land use was altered due to the establishment of PGRs. Within the three PGRs studied, significant changes within each land cover/land use class can be seen. Although the biophysical and socio-economic

[23] Interview with Peter Binney, Kube Yini PGR, 7 April 2008.

factors were not examined in detail, the results of this study illustrate the general changes within the land cover/land use patterns in the study area.

The climatic variables such as temperature of the area remained fairly unchanged, i.e. temperature remained fairly constant, with no significant increases or decreases within the temperature variable, humidity remaining fairly high. With the exception of the drought experienced in the area between the period 2001 to 2006, it is most likely that the changes in the area resulted as a result of the change to private game farming. This is borne out by the fact that changes in land cover in the established state game reserve, Mkhuze, were fairly minimal.

The drought experienced in the area between 2001-2006 likely did make a contribution or assist the land cover changes within the study area, i.e. drought probably contributed to the increased old fields and disturbed areas within the Phinda PGR as well as the Mkhuze Game Reserve. In addition the drought may have resulted in the decrease of water and riverine vegetation of the study area.

However visible changes in the land cover/land use that are clearly related to private game farming have occurred (Figures 5.6 to 5.11) over the period 1990 to 2007. These land cover/land use changes have resulted from the changes in the farming techniques practiced within the area, i.e. from conventional commercial farming to private game farming. Private game farming has had a significant impact on the water and riverine vegetation; sand forest, forest and rock faces; woodlands; old fields and disturbed areas; and grasslands land cover classes in the PGRs.

The PGRs saw the removal of old infrastructure and increased new infrastructure such as tourists and employees accommodation, game drives, foot and access paths, increased game species, as well as increased water points for the increased number of game species. To accommodate the new requirements, modifications in land cover had to be made. However, since each PGR employed a different game farming technique, results within the individual reserves were different in terms of its land cover/land use changes.

Since the commencement of private game farming in the region, the land cover has changed considerably. The long-term effects of this change in land cover are uncertain as it is still in its early days, but what is certain is that the changes in the different land cover/land use classes could alter as well as break the links and bonds between the natural habitat by impeding the movement of species between them (Biggs & Scholes, 2002). It is the conclusion of this study that, overall, the impacts of these changes may be detrimental to the ecological functioning of the ecosystem. The increased carrying capacity places a greater pressure on the ecosystem, i.e. increased game species in an area, results in increased competition for food, water and space. In addition, with the introduction of extra-limital species comes the threat to indigenous species. It is also uncertain whether the land cover can continue to support the increased infrastructure as well as increased game species.

This study shows how remotely sensed data can be used to map the land cover/land use changes related to private game farming. Not only has the study shown that remotely sensed data is a cost effective approach to reliably identify and map the land cover/land use changes related to private game farming, but it also makes mapping of large areas at one time feasible. Multispectral imagery such as Landsat 5 TM has proved effective in broadly identifying and accurately mapping land cover/land use changes related to private game farming in the study area.

6.2 FUTURE APPLICATIONS OF THE STUDY

Since no other study has to date been undertaken to determine the land cover/land use changes related to private game farming using remotely sensed data, this investigation provides a baseline study into the land cover/land use changes related to this shift in practice. This study looked broadly at the overall changes in land cover/land use related to private game farming using multispectral data. To investigate detailed land cover/land use changes related to private game farming, at a finer resolution, imagery such as Spot, Ikonos, etc must be utilised.

6.3 RECOMMENDATIONS

The results presented in this study shed some light on the land cover/land use changes related to private game farming in northern KwaZulu-Natal. It illustrates that the establishment and practices of PGRs have brought about land cover/land use changes within the area of interest. The comparison between the PGRs and the control illustrate that the changes within the study area have most likely resulted due to private game farming practices, practised in the area. The research presented in this dissertation was influenced by previous research described in the literature, and has assisted in providing a greater understanding of the land cover/land use changes related to private game farming. At the same time, this research has raised concerns and presented new opportunities for further investigation.

Clearly defined legislation needs to be formulated and implemented by government, ensuring that PGRs practise sustainable land cover/land use practices that do not negatively impact and imbalance the ecosystem of the study area. In the interim, a number of recommendations can be made here for the managers of PGRs.

It is recommended that the land cover/land use distribution maps produced in this study be used by managers to understand the land cover/land use changes related to private game farming within the area of interest. Understanding the complex environmental interactions occurring within the study area is the key to the effective management of the area (Sokolic, 2006).
It is also recommended that the internal fences between the PGRs be dropped and corridors or links between the reserves be established.

Open communication and understanding between PGR owners and government needs to be established, as PGRs cannot function as isolated islands: these islands are not beneficial to a healthy, functional ecosystem.

Furthermore the need for close, continuous and up-to-date monitoring of PGRs and their practices is essential in determining its current as well as future impacts and implications on the environment. Accordingly it is recommended that the use of remote sensed data, which provides an easy and cost effective approach in determining and monitoring land cover/land use changes related to PGRs could be utilised to keep up with the changes.

Lastly it is recommended that an increased awareness of private game farms, their spatial occurrence as well as the benefits of well-conserved PGRs needs to be developed by researchers. This researcher believes that properly managed Private Game Reserves could be a beneficial innovation, not only to the physical health of the environment but also to the South African economy, as PGRs present an unique draw card to both the international as well as local tourists.

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APPENDICES

APPENDIX 1: IMAGERY CHARACTERISTICS

Date	Landsat no	Imagery type	Scene	Spatial res (m)	Sun elevation (^{o})	Sun azimuth (^{o})	Scene location	Rectif. RMSE	Radiometric normalisation
2/6/99	5	TM	6479	30	37.77	40.22	KZN	0.5105	No
30/4/07	5	TM	6938	30	26.74	40.49	KZN	0.5	No

APPENDIX 2: STANDARD SOUTH AFRICAN LAND COVER/LAND USE CLASSIFICATION SYSTEM AND ASSOCIATED DESCRIPTION (SOURCE: CSIR, 2001)

2.1. FOREST AND WOODLAND

All wooded area with greater than 10 percent tree canopy cover, where the canopy is composed of mainly self-supporting, single stemmed woody plants > 5m in height. Essentially indigenous tree species, growing under natural or semi-natural conditions (although it may include some localized areas of self-seeded exotic species). Excludes planted forests (and woodlots). Typically associated with the Forest and Savanna biomes in South Africa.

2.1.1 Forest

Tree canopy cover > 70 percent. A multi-strata community, with interlocking canopies, composed of canopy, sub-canopy, shrub and herb layers.

2.1.2 Woodland

Tree canopy cover between 40-70 percent. A closed to open canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer.

2.1.3 Wooded Grassland

Tree canopy cover between 10-40 percent. An open to sparse canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer.

2.2. THICKET, BUSHLAND, SCRUB FOREST AND HIGH FYNBOS

Communities typically composed of tall, woody, self-supporting, single and/or multi-stemmed plants (branching at or near the ground), with, in most cases no clearly definable structure. Total canopy cover > 10 percent, with canopy height between 2-5m. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some localised areas of self-seeded exotic species, especially along riparian zones). Typically examples are Valley Bushveld, Mopane bush, and tall Fynbos. Dense bush encroachment areas would be included in this category.

2.2.1 Thicket

Areas of densely interlaced trees and shrub species (often forming an impenetrable community). Composed of multi-stemmed plants with no clearly definable structure or layers, with > 70 percent cover. A typical example would be Valley Bushveld.

2.2.2 Scrub Forest

Vegetation intermediate in structure between true forest and thicket. A multi-layered community with interlocking canopies, with > 70 percent canopy.

2.2.3 Bushland

Similar to "thicket," but open in terms of canopy cover levels. Composed of multi-stemmed plants with no definable structure or layers, and with < 70 percent cover.

2.2.4 Bush Clumps

Scattered islands of thicket-like vegetation (i.e. > 70 percent cover) within a matrix of more open bushland or grassland.

2.2.5 High Fynbos (Heathland)

Fynbos communities between 2-5m in height, > 70 percent cover, and composed of multi-stemmed evergreen bushes typically growing on infertile soils. The Proteaceae family dominates.

2.3. SCRUBLAND AND LOW FYNBOS

Communities dominated by low, woody, self-supporting, multi-stemmed plants branching at or near the ground, between 0.2-2m in height. Total tree cover < 1 percent. Low shrublands and heathlands are combined at Level 1 due to similar overall physiognomic structure and (in many cases) appearance on remotely sensed imagery. Examples would include low Fynbos, Karoo and Lesotho (alpine) communities.

2.3.1 Shrubland

Typically broad-leaved or bushes, frequently deciduous. A typical example would be vegetation from the Karoo biomes. Category also includes dwarf succulent shrublands.

2.3.2 Low Fynbos (Heathland)

Typically small-leaved (i.e. nanophyllous), sclerophyllous, evergreen plants growing on infertile soils. Proteacea, Ericaceae and Restionaceae frequently dominate.

2.4. HERBLAND

Communities dominated by low, non-woody, self-supporting, non-grass like plants, between 0.2-2m in height. Total tree cover < 1 percent typical vegetation examples are found in Namaqualand, and „wee' dominated degraded areas.

2.5. GRASSLAND

All areas of grassland with less than 10 percent tree and/or shrub canopy cover, and greater than 0.1 percent total vegetation cover. Dominated by grass-like, non-woody, rooted herbaceous plants. Typical associated with the Grassland Biome.

2.5.1 Unimproved grassland

Essentially indigenous species, growing under natural or semi-natural conditions.

2.5.2 Improved Grassland

Planted grassland, containing either indigenous or exotic species, growing under managed conditions for grazing, hay or turf production, recreation (e.g. golf courses).

2.6. FOREST PLANTATIONS

All areas of systematically planted, man-managed tree resources composed of primarily exotic species (including hybrids). Category includes both young and mature plantations that have been established for commercial timber production, seedling trials, and woodlots/windbreaks of sufficient size to be identified on satellite imagery. Unless otherwise stated, Level 1 and Level 2 include clear-felled stands within plantations. Excludes all non-timber plantations such as tea and sisal, as well as orchards used in the production of citrus or nut crops. Level 1 category will include associated land cover/use's such as roads, fire-breaks and building infrastructure if these are too small to be clearly mapped off the satellite imagery.

2.7. WATER BODIES

Areas of (generally permanent) open water. The category includes natural and man-made water bodies, which are either static or flowing, and fresh, brackish and salt water conditions. This category includes features such as rivers, dams (i.e. reservoirs), permanent pans, lakes, lagoons and coastal waters.

2.8. WETLANDS

Natural or artificial areas where the water level is at (or very near the land surface) on a permanent or temporary basis, typically covered in either herbaceous or woody vegetation cover. The category includes both fresh, brackish and salt water conditions. Examples include salt marsh, pans (with non-permanent water cover), reed-marsh or papyrus-swamp and peat bogs.

2.9. BARREN LANDS

Non-vegetated areas, or areas of very little vegetation cover (excluding agricultural fields with no crop cover, and opencast mines and quarries), where the substrate or soil exposure is clearly apparent.

2.9.1 Bare rock/soil

Natural areas of exposed sand, soil or rock with no or very little vegetation cover during any time of the year, including rocky outcrops, dunes and gravel plains.

2.9.2 Degraded Land

Permanent or seasonal, man-induced areas of very low vegetation cover (i.e. removal of tree, bush and/or herbaceous cover) in comparison to the surrounding natural vegetation cover. Category includes major erosion scars (i.e. sheet and gully erosion). Should be sub-divided by Level I vegetation classes i.e. Degraded-Woodland, and Degraded-Grassland wherever possible to allow reconstruction of full class extent. Typically associated with subsistence level farming and rural population centres, where overgrazing of livestock and/or wood-resource removal has been excessive. Often associated with severe soil erosion.

2.10. CULTIVATED LAND

Areas of land that are ploughed and/or prepared for raising crops (excluding timber production). The category includes areas currently under crop, fallow land), and land being prepared for planting. Unless mapping scales allow otherwise, physical class boundaries are broadly defined to encompass the main areas of agricultural activity, and are not defined on exact field boundaries. As such the class may include small inter-field cover types (i.e. hedges, grass strips, small windbreaks etc), as well as farm infrastructure. Subdivided into:

i. Subsistence/semi-commercial cultivation: Characterised by numerous small field units in close proximity to rural population centres. Typically dryland crops produced for individual or local (i.e. village) markets. Low level of mechanisation.

ii. Commercial cultivation: Characterised by large, uniform, well managed field units, with the aim of supplying both regional, national and export markets. Often highly mechanised.

iii. Irrigated/Non-irrigated: Major irrigation schemes (i.e. areas supplied with water for agricultural purposes by means of pipes, overhead sprinklers, ditches or streams), are characterised by numerous small farm-scale irrigation dams, close proximity to major water sources and/or centre pivot irrigation systems.

2.10.1 Permanent Crops

Lands cultivated with crops that occupy the area for long periods and are not replanted after harvest.

2.10.2 Temporary Crops

Land under temporary crops (i.e. annuals) that are harvested at the completion of the growing season that remains idle until replanted. Examples would be maize, wheat, legumes, potatoes, onions, and Lucerne. Lands cultivated with crops that occupy the area for long periods and are not replanted after harvest. Examples would include tea plantations, vineyards, sugarcane and citrus orchards, hops and nuts.

2.11. URBAN/BUILT-UP LAND

An area where there is a permanent concentration of people, buildings, and other man-made structures and activities, from large village to city scale. Small rural communities are often included within the surrounding land-cover category (i.e. subsistence/semi-commercial agriculture) if mapping scales do not permit identification of such settlements as individual features. Where mapping scales permit, the limits of the urban boundary are delineated to exclude open areas within the built-up region (i.e. vegetated or non-vegetated areas with few or no structures).

2.11.1 Residential Area

Areas in which people reside on a permanent or non-permanent basis. The category includes both formal (i.e. permanent structures) and informal (i.e. no permanent structures) settlement areas, ranging from high to low building densities, (including smallholdings on the urban fringe).

2.11.2 Commercial

Non-residential areas used primarily for the conduct of commerce and other mercantile business, typically located in the central business district (CBD).

2.11.3 Industrial/Transport

Non-residential areas with major industrial (i.e. the manufacture and/or processing of goods or products) or transport related infrastructure. Examples would include power stations, steel mills, dockyards and airports.

2.12. MINES AND QUARRIES

Areas in which mining activity has been done or is being done. Includes both opencast mines and quarries, as well as surface infrastructure, mine dumps etc, associated with underground mining activities.

APPENDIX 3: CALCULATIONS OF THE STUDY AREA`S LAND COVER/LAND USE CLASSES

TABLE 3.1: 1990 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES OVER THE ENTIRE STUDY AREA

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	159058	14315	6
Sand forest, forest and rock faces	485550	43700	19
Woodlands	687647	61888	26
Old fields and disturbed areas	678693	61082	26
Grasslands	592752	53348	23
Total	2603700	234333	100

TABLE 3.2: 2007 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES OVER THE ENTIRE STUDY AREA

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	83587	7523	3
Sand forest, forest and rock faces	404469	36402	16
Woodlands	642981	57868	25
Old fields and disturbed areas	658781	59290	25
Grasslands	815460	73391	31
Total	2605278	234475	100

TABLE 3.3: 1990 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN KUBE YINI PRIVATE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	505	45	4
Sand forest, forest and rock faces	4063	366	31
Woodlands	4699	423	36
Old fields and disturbed areas	3020	272	23
Grasslands	844	76	6
Total	13131	1182	100

TABLE 3.4: 2007 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN KUBE YINI PRIVATE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	185	17	1
Sand forest, forest and rock faces	6265	564	47
Woodlands	4823	434	36
Old fields and disturbed areas	1427	128	11
Grasslands	615	55	5
Total	13315	1198	100

TABLE 3.5: 1990 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN THANDA PRIVATE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	515	46	1
Sand forest, forest and rock faces	9539	859	13
Woodlands	21354	1922	29
Old fields and disturbed areas	28752	2588	38
Grasslands	14553	1310	19
Total	74713	6724	100

TABLE 3.6: 2007 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN THANDA PRIVATE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	429	39	1
Sand forest, forest and rock faces	2995	270	4
Woodlands	13879	1249	18
Old fields and disturbed areas	20637	1857	28
Grasslands	37082	3337	49
Total	75022	6752	100

TABLE 3.7: 1990 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN PHINDA PRIVATE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	440	40	1
Sand forest, forest and rock faces	25828	2325	32
Woodlands	35301	3177	43
Old fields and disturbed areas	12266	1104	15
Grasslands	7495	675	9
Total	81330	7320	100

TABLE 3.8: 2007 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN PHINDA PRIVATE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	419	38	1
Sand forest, forest and rock faces	15795	1422	19
Woodlands	33184	2987	41
Old fields and disturbed areas	21581	1942	26
Grasslands	10459	941	13
Total	81438	7329	100

TABLE 3.9: 1990 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN MKHUZE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	8165	735	2
Sand forest, forest and rock faces	65520	5897	16
Woodlands	107894	9710	27
Old fields and disturbed areas	104519	9407	26
Grasslands	118841	10696	29
Total	404939	36445	100

TABLE 3.10 2007 CLASSIFICATION OF CHANGES IN LAND COVER/LAND USE CLASSES IN MKHUZE GAME RESERVE

Level I Land cover/land use classes	No. of pixels	Land cover (ha)	Land cover (%)
Water and riverine vegetation	2026	182	1
Sand forest, forest and rock faces	62103	5589	15
Woodlands	122786	11051	30
Old fields and disturbed areas	113587	10223	28
Grasslands	104643	9418	26
Total	405145	36463	100

APPENDIX 4: ACCURACY ASSESSMENT

Table 4. 1: 1990 ACCURACY ASSESSMENT

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : 1990 Landsat image
User Name : Student
Date : Wed Sep 08 12:24:56 2010

ERROR MATRIX

Reference Data

Classified Data	Unclassified	Class 1	Class 2	Class 3
Unclassified	0	0	0	0
Class 1	0	2	0	0
Class 2	0	0	6	2
Class 3	0	0	5	11
Class 4	0	0	0	0
Class 5	0	0	0	0
Column Total	0	2	11	13

Reference Data

Classified Data	Class 4	Class 5	Row Total
Unclassified	0	0	0
Class 1	0	0	2
Class 2	0	0	8
Class 3	1	0	17
Class 4	5	1	6
Class 5	0	2	2
Column Total	6	3	35

----- End of Error Matrix -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy

Unclassified	0	0	0	---	---
Class 1	2	2	2	100.00%	100.00%
Class 2	11	8	6	54.55%	75.00%
Class 3	13	17	11	84.62%	64.71%
Class 4	6	6	5	83.33%	83.33%
Class 5	3	2	2	66.67%	100.00%
Totals	35	35	26		

Overall Classification Accuracy = 74.29%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.6379

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
Class 1	1.0000
Class 2	0.6354
Class 3	0.4385
Class 4	0.7989
Class 5	1.0000

----- End of Kappa Statistics -----

TABLE 4.2: 2007 ACCURACY ASSESSMENT

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : 2007 Landsat image
User Name : Student
Date : Wed Sep 08 12:50:54 2010

ERROR MATRIX

Reference Data

Classified Data	Unclassifi	Class 1	Class 2	Class 3
Unclassified	0	0	0	0
Class 1	0	4	0	0
Class 2	0	0	5	1
Class 3	0	0	2	5
Class 4	0	0	1	1
Class 5	0	0	0	0
Column Total	0	4	8	7

Reference Data

Classified Data	Class 4	Class 5	Row Total
Unclassified	0	0	0
Class 1	0	0	4
Class 2	0	0	6
Class 3	0	0	7
Class 4	3	0	5
Class 5	1	2	3
Column Total	4	2	25

----- End of Error Matrix -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Class 1	4	4	4	100.00%	100.00%
Class 2	8	6	5	62.50%	83.33%

Class 3	7	7	5	71.43%	71.43%
Class 4	4	5	3	75.00%	60.00%
Class 5	2	3	2	100.00%	66.67%
Totals	25	25	19		

Overall Classification Accuracy = 76.00%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.6914

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
Class 1	1.0000
Class 2	0.7549
Class 3	0.6032
Class 4	0.5238
Class 5	0.6377

----- End of Kappa Statistics -----

APPENDIX 5: KUBE YINI QUESTIONNARIE

Kube Yini Survey

UNIVERSITY OF
KWAZULU-NATAL

This survey forms part of the research for an MSocSci in Geography and Environmental Management within the School of Life and Environmental Sciences at the University of KwaZulu-Natal. This research is in collaboration with the South African Netherlands Programme for Alternatives in Development (SANPAD), looking at the current context to agrarian change and the development of wildlife based forms of land use in Kwazulu-Natal. The following Private Game Reserves (PGR's) have been selected to participate in the survey.

Private Game Reserves (PGR's)
Mun-Ya-Wana (Phinda, Mziki, Zuka)
Thanda and Intibane
Mkuze
Kube-Yini
Sungulwanae

The aim of this particular survey is to:

- Establish the driving forces behind the growing trend to convert traditional agricultural farms to wildlife-based forms of land-use across the Zululand region.
- Investigate the establishment of the PGR's, their current tourism activities, socio-economic trends within the industry and environmental/ conservation issues that have been encountered.
- Assist in the mapping and remote sensing analysis of the vegetation change that has occurred across the selected region.

Your Involvement in this Research

Your anonymity and confidentiality will be ensured at all times. Your personal details are not required for this study and under no circumstances will they be disclosed. Your participation is voluntary and you may withdraw your permission to participate at any stage without any negative consequences. A copy of the completed thesis may be obtained by you or your organisation on request. This information may assist your organisation to establish trends, improve operations and lead to possible solutions to many social and environmental problems that may occur in the establishment and operation of your game reserve. It is requested that one give as full information as possible as to ensure a comprehensive and accurate data set. Your participation in this survey will be greatly valued and will also provide your organisation with a wealth of knowledge on the conservation and tourism sector in your region.

Contract between Researcher and Respondent/ PGR

Student Name: *Andrew Hickman*

Student Number: *202523867*

Contact Details: 082 883 5513
andrew.hickman@erm.com

If you or your organisation has any queries or concerns with any aspect of this work, you may also contact the dissertation supervisor whose details are provided below:

Supervisor: Dr Shirley Brooks

Contact Details: (031) 260 2416
brookss2@ukzn.ac.za

I, Andrew Hickman , expressly undertake to keep and hold secret and confidential all information, however obtained, regarding the activities of any of the PGR's involved in this study, and all matters associated therewith, and shall not use any information obtained for any other reason than set out above. I will not disclose or discuss the same with any other party without the express prior consent of the PGR's. All information presented in the final dissertation shall not be with specific reference to any particular PGR's.

This Undertaking shall be valid and effective for a period of 10 years.

Thus done and signed at, UKZN on this 7th day of April 2008

WITNESSES:

1. ....

2. ....

....
Andrew Hickman

1 ***ESTABLISHMENT OF THE GAME RESERVE***

Please complete the follow:

1.2 **RESERVE DETAILS**

Name of respondent: Peter Binney	(Reserve Manager)
Contact details of respondent:	035-5620495 082-2932537
Name of Game Reserve (Trading Name):	Kube Yini Shareblock
Name of land owner/s or organisation that owns the reserve:	± 100 shareholders comprise the Shareblock
Physical address:	Bayala, between Hluhluwe and Mkuzi
Postal address:	P.O. Box 1 Bayala 3966
Email address:	kubeyini@telkomsa.net
Website address:	—

Date of establishment: Purchased 1989 – First phase developed in 1991.

Previous land use/s: Cattle ranching, cropland including cotton and maize.

Name of previous owner/s: Dr. Prigge / Andrew Montgomery.

Telephone number of previous owner/s: —
Andrew Montgomery – Original Developer of Kube Yini 00/618 9293 4398
00 61 417 921 673

Current total area (ha) of the reserve: 1214 ha

1.3 **CONVERSION TO A GAME RESERVE**

What are the reasons for the conversion from traditional agriculture to a Game Reserve? Typically the Terrain of K-Y. is not suitable for crop growing. In some of the flat areas, bush was removed as well as rocks etc, and lands were established. A reliable water supply for irrigation was also a problem. In terms of cattle the rough terrain would have made dipping, counting and gathering of individual herds at various times of the year, or month, difficult. An opportunity for ecotourism was realized. Unlike a reserve with a commercial lodge operation, K-Y. was developed into a shareblock with 50 privately owned sites.

What have been some of the biggest constraints in establishing a game reserve with regards to:

a) **Financial constraints** e.g. Cost of land, costs of converting land from agriculture to game, value of the rand etc? The original developer, Andrew Montgomery, purchased in the late 80s when the Rand was strong. Erection of game fencing, removal of internal infrastructure (eg. cattle fencing), development of new infrastructure (Roads, H_2O supply etc), EIA's, introduction of certain game species, alien eradication programme all required substantial financial investment.

b) **Human resource constraints** e.g. Finding skilled builders to build high quality accommodation, services, skill labour, reliable labour etc? K.Y. has used local skilled and unskilled labour over the years. External contractors have come in and also utilized local skills. There are definitely reliable and skilled individuals from the local communities available.

c) Government constraints e.g. Environmental Impact Assessments (EIA's) and approvals, translocation policies, BEE policies, land taxes, land redistribution etc?

The original development would have met all the various requirements. Any additions, eg. Vodacom Tower (in process) will meet all requirements.

d) Environmental constraints e.g. Lack of quality and quantity of water, vegetation change (alien vegetation), animals dying from diseases etc?

Water quantity and quality is a problem for most Reserves and Farms in the area. K.Y. was fortunate to make it through the drought (2001 → 2006). Aliens (particularly Triffid weed) has been a priority over the years and today K.Y. is a "Flagship" in terms of alien eradication. Bushencroachment is also an issue (result of historical mismanagement).

General Constraints/ Added Detail:

What are some of the reserves plans for the next 5 years?

K.Y. is in the process of updating the Reserve Management plan.
Of the 50 sites available, 46 are developed, and ongoing upgrades continue.
Ecologically speaking, emphasis will remain on managing and improving the quality and diversity of the various ecosystems. Work on alien vegetation controll will forever be a priority, management of bush encroachment to improve grazing potential, the sustainable utilization of Natural, Renewable Resources (cropping and stocking, Firewood etc) and the movement toward environmentally friendly practices, eg. replacing thatch with harvey tile for H_2O harvesting, use of Solar and Wind power and recycling.

2 ***TOURISM RELATED ACTIVITIES***

Does your reserve allow hunting? No, not presently. Shareholder majority vote against stands.

How long has the tourism aspect of this reserve been operational?
Since January 1991.

What are the reserves three biggest attractions?
1) Situation and location – on the Ubombo mountain range with breathtaking views and landscapes
2) Prime vegetation with outstanding birding opportunities – over 300 species. Shareholders able to walk unguided.
3) A history of excellent, professional management providing a product of excellent quality.

Who is the target market for your reserve?
The majority of our shareholders are South African. Successful businessmen etc. utilize K-Y. as a bush retreat.

How is the reserve marketed (e.g. Internet, tour companies, brochures, outfitters etc)?
This is not a commercial operation in terms of tourist groups etc. There is no rental to the public. If sites or houses are for sale the individual owners market as they please.

Who is your dominant cliental/tourist origin (e.g. British, German, South Africa etc)?
Mainly South African – All K-Y. shareholders ~~own~~ (± 100 as some sites have syndicated) are owners. Every site (50 in total) own a 50th of everything on the reserve (Shareblock)

Do you facilitate day visitors? No.

What activities does your reserve offer (e.g. conference centre, wellness centre, game drives/walks, fishing trips, hunting etc)?
Shareholders drive, walk or cycle on the reserve.

What are your projected tourist numbers for the coming year?

Accommodation Details

Accommodation Type (Luxury lodge, rustic cabins, private holiday homes etc – please specify):	**Date of Establishment of Accommodation Type**	**Tourist Capacity** (Please specify bed numbers for each accommodation type):	**Tourist Price Range** (Please specify for each accommodation type):	**Average Duration of Stay** (Please specify the average time guests book into a particular accommodation type):	**Additional Information:**
Private holiday and Residential homes	From 1991 onwards	50 sites with maximum 8 beds = 400 beds	Purchase price + Monthly Levy		

Accommodation Type (Luxury lodge, rustic cabins, private holiday homes etc – please specify):	**Date of Establishment of Accommodation Type**	**Tourist Capacity** (Please specify bed numbers for each accommodation type):	**Tourist Price Range** (Please specify for each accommodation type):	**Average Duration of Stay** (Please specify the average time guests book into a particular accommodation type):

3 LOCAL COMMUNITIES AND EMPLOYMENT

3.1 PREVIOUS LABOUR AND LAND TENANTS

Numbers of staff employed under previous land use (If unsure, please state so and give an estimated figure)?

Unsure

How many of those workers still work or live on the reserve (Please specify)?

If there are still workers from the previous land use, what jobs do they currently hold (Please specify)?

Have there been any issues related to tenants or farm workers with the conversion from agriculture to game reserve (Please specify)?

3.2 *CURRENT LABOUR*

Number of labourers/staff both permanent, temporary/contractors that work for the reserve? (Please provide available staff lists)

Permanent: 16.

Temporary/ Contractors (Please specify work conducted):

Armed Patrol Unit (outsourced) – 2
Alien teams – 10
Other tempory – 3

What sort of work is outsourced? (e.g. alien plant control, game fencing etc)

APU.
Part of Alien controll programme.
Maintenance of units.

What is the reason for outsourcing work at the reserve?

APU – for legal reasons.
Aliens – create local jobs.
Maintenance of units – create local jobs.

Do staff receive any benefits? (e.g. Food, accommodation, medical aid, dependant's benefits, staff training etc – Please specify all benefits)?

Yes – Food (Vegetables and occasional meat)
– Accomodation
– UIF
– Provident Fund
– Funeral Policy
– HIV programmes – vitamins.
– high protein porridge.
– vegetables.
– Uniforms + Protective clothing.

Has your reserve sent any staff on training (Please specify)?

Drivers licences.
Basic maintenance and building.

What is the closest community to your reserve?

Ngwenya Tribal Authority.

Do you know the name of the Nduna of this community?
Nduna Mtshali

Do you have any problems with local communities (Please specify)?

Theft and poaching. Some locals have been caught and sentenced. Some outsiders could also be responsable.

Does your reserve have a community liaison? Yes.

Additional Detail/Comments

4 ENVIRONMENTAL AND CONSERVATION ISSUES

What are some of the game species that you have introduced into the reserve? Big five? (Please provide lists if possible)
White Rhino.
Giraffe
Blue Wildebeest
Zebra
Impala

What vegetation types occur on the farm (e.g. grassland, thicket, savanna, forest etc)? Mixed bushveld, Riverine, open mixed grassland.

How has vegetation changed since the land use change? Some of the present open mixed grasslands were historically croplands (cotton and mielies). Bush encroachment from past overgrazing, alien veg eradication and good fire management to improve graze quality.

Is poaching a problem? Not massive – 50 snares in 16 months
Does your farm have an anti poaching unit?
Yes.

If there is poaching, is the poaching from local communities or organised syndicates? Some have been local, but there are outsider syndicates.

What is being poached? Impala, Nyala, Red/Grey Duiker and 1x Hyaena.

What do you feel is the greatest problem to conservation in the area?

Land claims and Alien Vegetation.

Does your reserve have formal management plans? (Please provide a copy if possible) In process of upgrading.

Additional Detail/Comments

5 ECONOMICS

5.1 COST AND REVENUE PROFILES

What are the reserves operational costs (e.g. maintenance, staff, stock, anti poaching costs etc – Please specify a monthly figure and if possible the total cost since the reserves inception)?

Monthly: ± R80000-00.

What supplements your game reserve's operational costs?

Each site pays a monthly Levy.
Game Capture and Sales.

What has been the total cost of establishing this reserve with regard to:
Primary expenditures: (e.g. land purchase, construction and renovation of buildings, interior décor, game purchase, infrastructure, roads, waterholes, fencing, equipment, vehicles, rehabilitation of land etc)?

Andrew Montgomery may be able to answer some of these questions.

What has been the greatest cost in establishing the reserve?

What do you feel is the carrying capacity, according to the market, for PGR's in the area?

The more the better, but resulting in "island" conservation unless fences are dropped.

Do you feel there are too many PGR's in KZN and in particular Northern Zululand?

No.

What is you reserves contribution to Black Economic Empowerment (BEE) and social development in this area?

Job creation and donations.

Please specify initiatives, past projects that your reserve has undertaken to assist local communities?

- Water Supply
- Donations - schools, clinics etc.
- Job creation.
- Skills development.

What projects do you feel would be the most worthwhile in the future (for either conservation and/or local communities)? ____________________

6 *GENERAL COMMENT*