An Assessment of Changes in Land Use/Cover Patterns in the Albert Falls Area, KwaZulu-Natal, South Africa.

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Abstract

The Albert Falls Area had witnessed severe competition over land use between agriculture, recreation, conservation and other land uses. The area also has been the scene for inefficient land management that led to degradation of land resources. For proper land use planning and environmental management, information on land use/cover change is vital. This study has developed a spatial and descriptive historical land use/cover databases for the years 1944, 1967, 1989, and 2000 to provide an understanding of land use/cover patterns in Albert Falls Area. The databases were created by interpreting historical aerial photographs and using Geographic Information Systems. The data was subsequently analyzed to detect relevant trends in land use/cover patterns in the study area.

Generally land use/cover pattern of Albert Falls Area during the period 1944 to 2000 may be described as being mainly agricultural. The results showed a marginal increase of indigenous forests attributed to the continuous efforts by different governmental departments and policies that focused on the protection of the remaining patches of indigenous forests. Grassland not only decreased by more than half but it also deteriorated in quality during 1944 to 2000. Commercial Forestry predominates the study area and showed an increasing trend from 1944 to 1967. Cultivated Land was observed to decrease at the expense of Commercial Forestry plantations and Waterbodies. Although sugarcane plantations increased after 1967, total Cultivated Land showed a decreasing trend. The construction of Albert Falls Dam and other small Farm Ponds within the agricultural farms increased the land areas covered by Waterbodies. Residential Area coverage generally decreased irrespective of the encroachment of informal settlements, while that outside Non-Residential Area and Transportation Routes generally increased with the development of commercial agriculture in the area. Barren Land decreased continuously due to higher land demand in the study area.

The study showed that land use/cover changes in Albert Falls Area have resulted in habitat fragmentation, development of monoculture land use, flourishing of Farm Ponds

in agricultural farms, and expansion of agricultural activities on marginal lands. Creation of corridors/linkages between the fragmented forest patches; commencement and implementation of the already well drafted land and land resource policies and regulations; commencement of the holistic management plans in the area were recommended for a sustainable land use.

Declaration

The work described in this dissertation was carried out in the Discipline of Geography, School of Applied Environmental Sciences, University of Natal, Pietermaritzburg, from October 2001 to February 2003. This work was undertaken under the supervision of Dr. F. Ahmed (School of Applied Environmental Sciences).

This study represents the original work of the author and has not otherwise been submitted in any form, in part or in whole, for any degree or diploma to any other university. Where use has been made of work by others, this has been duly acknowledged in the text.

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Acknowledgements

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Chapter One: Introduction

1.1 Introduction

It is generally accepted that land is the basic natural resource. Land is used to meet a multiplicity and variety of human needs and to serve numerous purposes (Lounsbury *et al.*, 1981). Land is a fundamental factor of production, and through much of the course of human history it has been tightly coupled to economic growth (Clawson and Stewart, 1965). Land is a key and finite resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchments and storage (USGS, 2001).

The ability of the world's natural resources to provide the needs of its growing population is a fundamental issue for the international community (Turner and Meyer, 1994). Human population growth is placing ever-increasing pressure on the land resources with the expanding requirements and economic activities (Qi, 2000). Land resources are declining both in quantity and quality due to such factors as competition with different land use demands, degradation and pollution (Marcus *et al.*, 1996). To provide for the well-being of existing and future generations a sustainable land management is needed. Land use/cover change assessment can have a great role in any sustainable land use planning.

1.2. Land Use/Cover Change

There is no standard, universally accepted set of categories for classifying land by either use or cover, and the most commonly used classification are hybrids of land cover and land use (Anderson *et al.*, 1976; Meyer, 1995). Land cover describes the physical state of the land surface, its vegetation (natural or planted) or man-made structures (e.g. buildings) which occur on the earth's surface (Turner and Meyer, 1994; Meyer, 1995; Meerkerk, 1997). The term land use implies use by humans: and the purposes for which humans formerly, presently, or may in the future change the landscape for the purpose of resource extraction and processing, housing, and transportation (Turner and Meyer, 1994; Meyer, 1995; LUCC, 2000). Land use is based on activities chosen and carried out by

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humans. The activities are usually directly related to land, make use of the land resources or have an impact upon it. The purposes for which lands are being used commonly have associated types of cover, whether they are for forest, agricultural, residential, or industrial uses (Anderson *et al.*, 1976). As such the link between land cover and land use focuses on the human interventions on the land.

There is nothing inherently stable about land use/cover pattern in an area. When the users of land decide to employ its resources, towards different purposes, land use/cover change occurs. Land cover change by definition is the alteration of the physical or biotic nature of a site, for example, the transformation of forest to grassland (Turner and Meyer, 1994; LUCC, 2000). Land cover change takes two forms: conversions from one land cover class to another and modifications within one class (Meyer, 1995; USGS, 2001). Land cover change describes differences in the area occupied by cover types through time. Both losses and gains are included. In addition to tracking the amount of cover types, land cover change also describes shifts in the spacing of cover types across the landscape over time.

Land use change involves alterations in the human management of land, including settlement, cultivation, pasture, rangeland and recreation (Turner and Meyer, 1994; LUCC, 2000). It encompasses all those ways in which human uses of the land have varied through time. Because contemporary land cover is changed mostly by human use, an understanding of land use change is essential to understanding land-cover change (Bibby and Shepherd, 1999). This shows there is interdependence between classifying land either by use or cover. For this reason the hybrid of both words use/cover will be used in this thesis.

1.3 The Significance of the study

Land use/cover change produces both desirable and undesirable impacts. Some of the undesirable effects of land use/cover change include biodiversity loss, soil erosion and degradation, albedo alteration and microclimate change, and water flow and water quality

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change (USGS, 2001). However, as any changes made by users are meant for improvements and desirable effects on their living, economy and resources, not all land use/cover changes result in land degradation (Turner and Meyer, 1994).

In South Africa there is a competition over land use between agriculture, recreation, conservation and other land uses (Rivers-Moore, 1997). The 1996 White Paper on sustainable forestry development in South Africa has reported that there have been inefficiencies, inequities, and environmental degradation of land resources due to improper land use planning. This resulted in land dispute conflicts, conflicts about water resources, loss of potential lands to non-agricultural purposes, and loss of habitats for native species which led to the loss of biodiversity (Marcus et al., 1996).

Albert Falls Area, in the midlands of KwaZulu-Natal, has been subjected to major land use/cover changes during 1944 to 2000. The maintenance of an adequate quantity of land with the required qualities to support a wide range of social, ecological, and aesthetic values of the area is needed in order to use the existing land sustainably. Land resources can potentially be used in a sustainable way if appropriate land management practices, regional planning and the policy complement one another in a purposeful way (Hurni, 1998).

One of the prime prerequisites for better use of land is information on land use/cover patterns as well as their changing proportions through time (Anderson et al., 1976; Pontius et al., 2001). Such information is needed by scientists and policy makers to understand, anticipate and possibly prevent the adverse effects of land use/cover change (Pontius et al., 2001).

Without a clear land use planning system, development can proceed both unattractively and unsustainably. A better understanding of land use/cover change can assist in making sound land and land resource policies; developing more appropriate land use systems to sustain growing populations, help improve degraded lands and alleviate deforestation

(Pontius *et al.*, 2001; LUCC, 1999). Moreover, land use/cover change information can contribute to knowledge of trends, and can permit the prevention of potential problems before they develop beyond the reach of local solutions.

1.4 The Importance of Albert Falls Area

In South Africa there is a competition over land use between different land uses (Marcus *et al.*, 1996). Careful planning is needed to preserve the restricted high agricultural land from being lost to non-agricultural land uses. Furthermore, as the country's population grows, it becomes even more important to work the land in a way that is ecologically responsible, cost effective, and ensures food security (Department of Land Affairs, 1997a). Careful planning helps achieve wise uses of the limited space available to meet the often-conflicting demands of different land uses.

Water is a scarce and unevenly distributed national resource in South Africa. Increasing water demands, reduction in water yields and deteriorating water quality are amongst the most pressing environmental issues facing the people of South Africa (DWAF, 1999). The Albert Falls catchment a sub-catchment of the Mgeni catchment is part of Albert Falls Area. Mgeni catchment supports the water needs of more than three million people and supplies water to industry and agriculture producing 20% of South Africa's Gross National Product (Natal Town and Regional Planning Commission, 1973; Tarboton, and Schulze, 1990). The Midmar and Albert Falls catchments contribute 50% of the mean annual runoff of the entire Mgeni catchment and provide water of good quality due to relatively little industrial development within these areas (Tarboton, and Schulze, 1990). Agricultural developments in the form of land cover changes and the construction of numerous small farm dams has been a continuous land use activity (Tarboton, and Schulze, 1990). In order for water quality to be maintained, developments in Albert Falls Area need to be controlled. Land use/cover change information can help improve catchment management planning.

Albert Falls Area lies in an area of high potential soils suitable for agriculture and afforestation. Albert Falls Area is an important farming area of KwaZulu-Natal. The farming types of the study area are comprised of four major activities including sugarcane, commercial forestry, dairying and chicken farming which may be found singly or in combination in the various parts of Albert Falls Area.

Generally information regarding the characteristics and spatial distribution of land use/cover in Albert Falls Area over the recent and distant pasts may assist in developing more appropriate land use systems to sustain growing populations, help improve degraded lands, and overcome the problems of haphazard and uncontrolled development.

1.5 Aim and Objectives

The aim of this study was to create a series of historical land use/cover databases of the important Albert Falls Area for the years 1944, 1967, 1989 and 2000 in order to assess the land use/cover change patterns which had occurred pre- and post the construction of Albert Falls Dam. The following are the specific objectives of the study:

a- Develop historical land use/cover databases of Albert Falls Area from aerial photographs

b- Quantify the rate and amount of land use/cover changes that took place in the study area between 1944 and 2000.

c- Determine the mechanisms responsible for land use/cover change in the region.

d- Assess the impacts of the existing land use/cover changes in the study area.

e- Recommend management strategies of the existing land use/cover patterns for sustainable use of the available land resources.

Although land use/cover change occurred prior to 1944, this study focused after this year, as this is the earliest year where aerial photographs of the entire area were flown.

1.6 Structure of the Thesis

An introduction to the significance of land, land use/cover change problems, the importance of assessing land use/cover change, and the aim and objectives of the study were provided in chapter one. Chapter two discusses the literature part including the land use/cover change driving forces, change impacts, and significance of assessing land use/cover changes. In addition, the common methods of assessing land use/cover change are also discussed briefly in chapter two. Chapter three describes the study area in detail. Materials and methods adopted in this study are described in chapter four. Chapter five describes the results and provides discussions thereof. Chapter six concludes the study and provides relevant recommendations.

Chapter Two: Literature Review

2.1 Introduction

When the users of land decide to employ its resources towards different purposes, land use/cover change occurs. Land use/cover modification and conversion are driven by the interactions in space and time between different biophysical and socio-economic factors. Climate, geology, soil characteristics, topography, and vegetation are the main physical characteristics that are responsible for land use/cover changes (Turner and Meyer, 1994).

The possible socio-economic forces driving land/cover changes include: population density, level of affluence, technology, political structure, economic factors such as systems of exchange or ownership; and attitudes and values (Turner et al., 1993). The element of time is also important in understanding land use/land cover change as past land use practices have an influence on the present land use/cover patterns of an area and the way in which current land uses may be constrained (Langran, 1993; Heathcote, 1998). The same will clearly hold true for the influence of current land use on future development.

An analysis of these factors provides basic information for developing scenarios of future land use for a particular region (Verburg et al., 1999). However, the importance of a given driving force varies depending on the study region (Verburg et al., 1999; Stephen and Lambin, 2001). Among the possible land use/cover driving forces that are especially important in Albert Falls Area are agriculture, market developments, environmental conditions, social context (including the history of the area), and policies relating to land use planning.

In this chapter the possible causes and impacts of land use/cover changes will be discussed briefly. In addition, the significance of assessing land use/cover changes and the methods employed for land use/cover change assessment will be discussed.

2.2 Major Determinants of Land Use/Cover Change

Different biophysical and socio-economic factors and the interactions among them in space and time drive land use/cover changes (Chen *et al.*, 2001). Varied human driving forces mediated by the socio-economic setting (e.g., market economy) and influenced by the existing environmental conditions, lead to an intended land use of an existing land cover through the manipulation of the biophysical conditions of the land (LUCC, 2000). Even in a smaller scale, minor changes in one system (for instance, climate) can have important implications for the structure and function of other systems (e.g., soils, hydrologic processes, plant communities), (Jakubuskas and Legates, 1999).

Land use/cover changes can also be driven by external or off-site drivers, which do not experience close feedback with local environmental mismanagement. These external drivers include processes such as industrialization, urbanization, transport infrastructure development, population growth and migration and the globalization of markets and economies (LUCC, 1999). For instance, changing consumption patterns in urban centers may be particularly important in expanding the overall ecological footprint of cities on the rural hinterland and creating demand for new agricultural products and faster rates of extraction of natural resources.

In addition to the biophysical factors which set limits to resource use, there are many other social and economic variables, related to both the past use patterns and to new needs and desires of users, which are important determinants of land use both current and future (Manning, 1991). The biophysical variables and the socio-economic variables link to provide opportunities and/or constraints affecting the need, or ability to respond in the face of changing circumstances (Manning, 1991; Verheye, 1991). From a practical perspective these variables must be identified to help assess and understand land use/cover changes (LUCC, 2000).

The possible land use/cover change driving factors in the study area can be grouped into biophysical or environmental conditions (related to climate, vegetation, topography, and

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soils); socio-economic and political factors related to socio-economic conditions of farmers and consumers, population density, technological achievements and progress, and land and natural resource policies and regulations including land tenure and South African land and land resource related policies. These factors will be discussed briefly below.

2.2.1 Biophysical Factors

Land use is obviously constrained by environmental factors such as soil characteristics, climate, topography, and vegetation (Stolobovoi, 1997). These biophysical factors determine to a considerable degree, the form that human's economic activities may take, particularly those activities which are closely tied to natural endowments (Natal Town and Regional Planning, 1973; Horwood, 1967).

2.2.1.1 Climate

Climate is an important criterion when assessing the potential of land for development, be it agricultural, industrial or urban (Smith and Camp, 2002). In an agricultural context, climate has a significant effect on crop selection, the nature of management system, and the type of farming to be applied (Verheye, 1991; Camp, 1999).

Climatic change has profound effects on all types of land. Cultivated lands and forests are vulnerable to a change in climate. Temperature and precipitation are important factors determining natural as well as managed vegetation. Water availability is a major factor for crop growth and forest production. Seasonal variations of temperature and precipitation are important for determining land suitability for agriculture and other purposes, since they affect water availability for agricultural crops or forest and the length of the growing season (Schulze, 1997).

It is generally accepted that climate is a major influencing element in man's utilization of the land (Horwood, 1967). Adaptation to recent and expected climate variation may influence land use decisions although this often will be compounded by other external

economic and social factors (Parry, 1990; Verheye, 1991). With climate change two broad types of adjustments may be anticipated: changes in land use and changes in management (Parry, 1990). For instance, as a result of climate change land users can change the size of farmed areas, crop type and location. Similarly, a large number of changes in management can be adapted overtime as the effects of climate changes are perceived. The most important changes would probably occur in the use of irrigation and fertilisers, in the control of pests and diseases, in soil drainage, in farm infrastructure, and in the forms of crop and livestock husbandry.

2.2.1.2 Vegetation

Forest ecosystems have important functions from an ecological perspective and provide services that are essential to maintain the life-support system on a local and global scale. Green house gas regulation, water supplies and regulation, nutrient cycling, genetic and species diversity as well as recreation are only some examples of the services that forest ecosystems provide (Goudie, 2000; Rao and Pant, 2001).

Forest removal has a range of consequences. Some of the most important of these changes are changes in runoff and sediment yields, which determine the quantity and the quality of water, and the speed with which it reaches stream channels. It also influences the amount of erosion that may occur on slopes and the sediment yields of the catchments (Cumming, 1993). This in turn constrains the land use type to be adopted and influences the management strategies for the area of interest. Therefore, depending on the priorities of users, environmental and socio-economic settings, vegetation type of an area can determine the land use type to adopt.

2.2.1.3 Topography

Topography is an important determinant of land utilization patterns. It plays an important role in the movements and settlements of people and their dynamic adaptation to the environment. As topography is an important aspect of the background to people and their

interactions within their surroundings, it can determine the type of land use/cover types of an area (Archer *et al.*, 1995).

2.2.1.4 Soil

Most of the time soil is assumed to be relatively stable and is not considered in the analysis of land use/cover changes. However, past studies by Bastian and Rooder (1996) in Western Lusatia (Saxony) show that soil erosion could be responsible for land use/cover changes (Rooder and Syrbe, 2000).

2.2.2 Socio-economic and Political Factors

2.2.2.1 Socio-economic Factors

Socio-economic factors are important to societies' ability to adjust to land allocation and management, given new goals or opportunities or changed biophysical bases. The situation with respect to the socio-economic factors that influence societal response to future biophysical or political scenarios is complex (Manning, 1991). The possible socio-economic forces driving land/cover changes can be grouped into six categories: population density, level of affluence, technology, political economy, political structure, and attitudes and values (Turner and Meyer, 1994; Turner *et al.*, 1993). Political economy, political structure, and attitudes and values do not yet encompass clearly defined variables and causal relationships, but comprise similar explanations of relationships of societal and environmental change.

Political structures such as property rights and the structures of power from the local to the international level, influence access to or control over land resources. Others, such as population density and the level of economic and social development, affect the demands that will be placed on the land, while technology influences the intensity of exploitation that is possible (Turner and Meyer, 1994). Still others, such as agricultural pricing policies shape land use decisions by creating the incentives that motivate individual decision-makers (Brouer *et al.*, 1991; Manning, 1991).

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The socio-economic factors are at least as complex as the biophysical factors and are diverse (USGS, 2001). To get an understanding of the role of socio-economic factors in driving land use/cover change population density, technology and land and land resource related policies will be discussed briefly in the following sub-sections.

2.2.2.1.1. Human Causes of Land Use/Cover change

Worldwide land use/cover changes of the present and the recent past are the result of human activities largely aimed at modifying or converting land covers for the fulfillment of basic needs and wants (Ford, 2000). Consequently, a large percentage of the earth's surface has been changed, and the pace of change is accelerating. These changes are particularly related to increases of the human population (Turner *et al.*, 1993).

Population growth is positively correlated with the expansion of agricultural land, and deforestation (Qi, 2000). Such actions arise as a consequence of a very wide range of social objectives, including the need for food, fiber, living space, and recreation (Qi, 2000). However, high population does not necessarily imply acute pressure on available resources (Marcus *et al.*, 1996), if land is properly planned and administered and servicing is adequate. But without good management strategies, long-term environmental degradation is inevitable (Marcus *et al.*, 1996).

2.2.2.1.2. New Technologies and Changing Land Use/Cover Patterns

It is not only environmental changes but also changes in technological development that result in the transformation of land use patterns (Verheye, 1991). Technological development alters the usefulness and demand for different natural resources. The extension of basic transport infrastructure such as roads, railways, and airports, can open up previously inaccessible resources and lead to their exploitation and degradation (Meyer, 1995). Therefore, the progress made in science and technology has facilitated the exploitation and utilization of natural resources.

Rapid advances in new technology notably biotechnologies and information technologies may particularly lead to further unexpected transformations (Brouer *et al.*, 1991). A wide application of available information technology at the farm level may improve the management of the land. The application of information technology may decentralize production and also conserve energy and material through an improvement in the efficiency of using agricultural inputs (Brouer *et al.*, 1991). However, the role of technology as a potential cause of past and prospective changes in land use/cover requires further study (Ford, 2000).

2.2.2.2 Land and Natural Resource Policies and Regulations
2.2.2.2.1. Land Tenure in KwaZulu-Natal

A land tenure system may encompass freehold ownership, public (state) ownership or it may comprise multiple parcels with a diverse range of owners including private individuals, companies, government agencies or authorities, and community or conservation groups (Montgomery, 2000; Bennet, 1999).

Tenure is a constraint or facilitating mechanism for land use activities. Changes in land tenure have direct impacts on land use. For instance, short-term leasing arrangements are not conducive to long-term investment in sustainable soil management or in products whose value will not be realized for decades (Manning, 1991).

Tenure rights and tenure forms across the country are differentiated according to race patterns of land ownership and a variety of available tenure differs from province to province (Marcus *et al.*, 1996). In the former Natal areas, freehold, leasehold and other forms of co-ownership exist, while formerly 'black' areas feature a variety of tenure systems including communal tenure, trust tenure, quitrent, and freehold (Montgomery, 2000). By far the greater proportion of the farms in the Albert Falls Area is owner-occupied. Leasing is not common. There are quite a large number of farms, embracing substantial areas of land, which are owned by companies.

Currently in South Africa policy in respect to tenure reform is under process. Land tenure reform is the most complex area of reform (Mini, 2000). The White Paper points out that land reform in South Africa aims to bring all people occupying land under a unitary, legally validated system of landholding. It devises secure forms of land tenure; helps resolve tenure disputes and provides alternatives for people who are displaced in the process (Department of Land Affairs, 1997a).

The Land Reform study committee (Anon, 1995) believed that freehold tenure promotes a land market and individual wealth. It also promotes landlessness and servitude. Although the committee did not advocate for free hold tenure abolition in the legal system, it stands firmly not to deny all people rights of access to land to satisfy their basic needs and to have reasonable access to natural resources (Marcus *et al.*, 1996; Anon, 1995). Therefore, land tenure reform may affect the land use in Albert Falls Area in the future.

2.2.2.2.2. South African Land and Land Resource Related Policies

Land use may also be important in determining the applicable legislation, oversight agency, and interested nongovernmental organizations (Brondizio, 2001; Heathcote, 1998). Agricultural activities, for instance, are subject to a different legislation than are manufacturing facilities, have available different loan and grant opportunities, are overseen by government agencies with an interest in protecting and promoting agriculture and its products, and have well-developed farmer and conservation outreach networks. However, appearance may be a minor concern in some communities or landscapes; it can also be an important contributor to community economics, for example, through tourism and recreational opportunities available, or unavailable, in the area (Bauman, 1969; Heathcote, 1998). Thus, as land use is important in determining legislations and policies, legislations and policies related to land resources could also play greater roles in driving land use/cover change. In this sub-section South Africa's policies that can drive land use/cover changes will be briefly discussed.

2.2.2.2.2.1 *White Paper on South African Land Policy*

Current land ownership and land development patterns strongly reflect the political and economic conditions of the Apartheid era (Anon, 1995; Marcus *et al.*, 1996). Racially based land policies were a cause of insecurity, landlessness and poverty amongst the black people, and a cause of inefficient land administration and land use (Mini, 2000; Marcus *et al.*, 1996). The current government's land policy is based on land restitution, redistribution and land tenure reform to reduce poverty, diversify sources of income and allow people more control over their lives and their environments (Department of Land Affairs, 1997a).

Land restitution involves returning of land lost since 19 June 1913 because of racially discriminating laws. Land redistribution makes it possible for poor and disadvantaged people to buy land with the help of settlement/land acquisition grants on a willing-seller willing-buyer basis (Department of Land Affairs, 1997a; Marcus *et al.*, 1996).

The government is aware of the environmental risks associated with Land Reform program (Mini, 2000). To reduce the environmental risk a proper planning of projects and involvement of the land users is needed to govern the zoning, planning and ultimate use of land and water resources (Department of Land Affairs, 1997a; Marcus *et al.*, 1996). For this reason the white paper emphasizes the need for the new owners to participate in the planning process.

The prime purpose of government's land development policy is to establish procedures to facilitate the release of appropriate public land for affordable housing, public services and productive as well as recreational purposes (Marcus *et al.*, 1996). In settlements, which have been established in remote locations without formal planning, land development involves upgrading services and infrastructure in situ.

Land use and development in the Natal Midlands area of KwaZulu-Natal Province are controlled by the Town Planning and Development Act 1999 (Montgomery, 2000). In urban areas land use and activities that impact on the natural resource base are subject to the provisions and regulations of a Town Planning scheme. Uses are generally permitted, conditionally permitted or prohibited within an urban area zone, as the case may be found (Montgomery, 2000).

2.2.2.2.2.2 *South African Environmental Policy*

South Africa has drafted a new policy on environmental management to ensure South African peoples survival and an improved quality of life by protecting the environment (Government Gazette, 1997, 1998). Section 24 of the bill of rights of South Africa's constitution provides that every one has the right to an environment that is not harmful to their health or well-being; and to have the environment protected, for the benefit of present and future generations (Government Gazette, 1998; Marcus *et al.*, 1996).

The environmental policy was formulated to secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development (Government Gazette, 1998). Integration of environmental impact management with all economic and development activities is needed to achieve sustainable development (Government Gazette, 1998; Fuggle and Rabbie, 1992).

2.2.2.2.2.3 *White Paper on Conservation and Sustainable Use of South Africa's Biological Diversity*

Like in other parts of the world South Africa's biodiversity have been changing for thousands of years, but the pace and extent of change increased rapidly with the recent agricultural and industrial development (Government Gazette, 1997). Consequently, substantial proportions of natural habitats have been transformed largely by agriculture, urban developments, afforestation, mining, and dams (Huntley *et al.*, 1989). In addition to habitat loss and land degradation, the overexploitation of certain species, the introduction of exotic species, and the pollution or toxification of the soil, water and

atmosphere had major effects on South Africa's biodiversity (Government Gazette, 1997).

South Africa is globally renowned for its nature conservation practices, gained primarily through the well-developed system of protected areas in the country, and its efforts towards conserving threatened species (Government Gazette, 1997). In this regard past government policies have been extremely supportive of biodiversity conservation and developing the scientific capacity to manage biological resources (Government Gazette, 1997). Of particular importance have been the extensive efforts to expand nature conservation functions to private and communal lands, through conservancies, natural heritage sites, and community conservation areas (Government Gazette, 1997). Albert Fall Nature Reserve is an example of such reserves designed to conserve biodiversity wealth of South Africa. Consequently, the policy on conservation and sustainable use of South Africa's biodiversity has been formulated to protect the available biodiversity of the country.

2.2.2.2.2.4 *Water Resources Legislations*
There are several reasons for water scarcity in South Africa, ranging from climatic conditions to patterns of allocation and distribution fostered by policies that favored agriculture, industry, and domestic use (Marcus *et al.*, 1996; Government Gazette, 1998). Thus, legislations related to water provision have been influencing the availability of water in South Africa.

According to the Water Act No. 8 of 1912 the use of water from a public stream was primarily for agriculture with the right of farmers along the rivers protected (Horwood, 1967). However, with increasing demands from the industrial sector, and the growth of towns, the 1956 Water Act was passed to ensure equitable distribution of water between competing users (Marcus *et al.*, 1996). This act proclaims water control areas whereby the rights to the use of water from a stream are virtually taken by the government. Moreover, it enforces the purification of water which has become polluted by industrial

use, before it is returned to a public stream (Horwood, 1967). Still divergent interests of water use remain, with competition increasing and relating both to water resource allocation and the development of water supplies (CSIR, 2000). There is also a conflict between the use of scarce water for rural domestic purposes and for irrigation schemes. The government believes the existing allocations and practices, such as the construction of private dams and uncontrolled use of private water, reflect neither the availability of water nor the ecosystem needs of the rivers (Anon, 1998; Marcus *et al.*, 1996).

The National Water Act has replaced the old Water Act (Act 54 of 1956) (Anon, 1998). This Act is based on the principles of sustainability of use and equity of distribution of water resources (Anon, 1998). Now the Department of Water Affairs and forestry is responsible for the control and licensing of water abstractions from all significant water bodies within the country (Anon, 1998). Part of the legislation, refers to the need to ensure that the requirements for both basic human needs and the environment are met before potential users can be licensed to abstract water.

2.3 Impacts of Land Use/Cover Change

Land use/cover change has occurred at all times in all parts of the world (Ford, 2000). These changes have affected both the quality of environmental resources, such as soils and water, and the sustainability of food production that are closely linked to biophysical factors (LUCC, 2000; Manning, 1991). Land/cover changes, besides affecting the current and future supply of land resources, are important sources of many other forms of environmental change (Meyer, 1995; Turner and Meyer, 1994). A thorough understanding of the possible effects of past, present-day and future land use changes is not only scientifically important it is also a prerequisite for the development of a sustainable land use policy (Verheye, 1991). A review of these impacts is provided in the following sub-sections.

2.3.1 Land Degradation

Applying various land use systems and changing them in a historical perspective has actively shaped the environment (Bibby and Shepherd, 1999). These changes are driven by a combination of physiographic peculiarities of the territory and a variety of land uses occurring in the area. These interrelated elements affect the environment, and changes in one area may have positive or negative impacts in others (Stolobovoi, 1997).

Land degradation can broadly be defined as the impoverishment of the land by human activities and by natural causes (Stockings and Murnagham, 2000). Land is considered "degraded" when its productivity is diminished. Land degradation affects land quality and/or functioning, often indicating a negative reaction of land on inappropriate human activity (Conacher and Maria, 1998; Forbes, 2002). Land degradation develops severely where current land use does not fit environmental conditions (Conacher and Maria 1998).

Most land use/cover changes are motivated by the desire to improve the land for human use or pleasure (Turner and Meyer, 1994). Degradation may occur nevertheless. It may be unintentional and unperceived; it may result from carelessness or from unavoidable necessity if it occurs in the course of working for personal survival (Ford, 2000). However, not all changes in land cover by land use imply a degradation of the land. Indeed, it might be presumed that any change produced by human use is an improvement, until demonstrated otherwise (Turner and Meyer, 1994).

Land degradation is a central challenge to sustainable development (Hurni, 1998). At global level key problems threatening natural resources and the sustainability of life support systems are soil degradation, the availability of water and the loss of biodiversity (Hurni, 1998).

Land degradation caused by agriculture takes many forms and has many causes. Some of the most important types of land degradation include degradation related to soil erosion;

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here related to inappropriate cultivation practices; degradation attributable to water pollution; natural resource depletion and degradation related to overgrazing by livestock.

2.3.1.1 Soil Erosion

Soil erosion can result from cultivating land that is inappropriate for cultivation (e.g. steep slopes and thin soils) or using inappropriate techniques of planting row crops and lack of contouring on sloping land (Conacher and Maria, 1998). Either can result in excessive erosion above the rate of soil formation although the rate and severity of soil erosion depends on the type of soil of the area in part (Stolobovoi, 1997; Stockings and Murnagham, 2000).

Soil erosion degrades topsoil and with the topsoil goes most of the organic matter and nutrients. It degrades the soil's structure, diminishes its water holding capacity, and increases its tendency to become compacted in part through loss of organic matter with the topsoil (Shrestha, and Zink, 1999; Stockings and Murnagham, 2000). This results in crops having less moisture available to them, and hence aggravates drought stress. Thus, soil erosion has immediate impacts on land productivity, vegetation changes, mid-term impacts on landscape fragmentation and land productivity, and possible long-term impacts on climate change (Stolobovoi, 1997).

Soil erosion has a secondary effect on water bodies and downstream farming areas. Much of the eroded sand and soil ends up in rivers and finally in the seas. Sediment loads in rivers can make it difficult for certain fauna to live in rivers, degrade water quality for humans, and cause silting of productive estuaries and reservoirs. Sediment loads can also cause problems for settlements in lowlands, which can be damaged by flooding or siltation (Heathcote, 1998).

Rooder and Syrbe (2000) emphasized that it is helpful, but insufficient, to only analyze the changes of land use and landscape elements at several times considering the soil as

relatively stable. The authors substantiated this idea by studies undertaken in Western Lusatia (Saxony) by Bastian and Rooder (1996 and 1998) and Rooder (1998).

KwaZulu-Natal has the second highest provincial soil degradation index in South Africa (National Botanical Institute South Africa, 2000). It has been reported that rates of soil degradation in grazing lands and communal areas are significantly higher than commercial farming areas, particularly in the steeply sloping parts along the eastern escarpment (Montgomery, 2000). The lower land degradation rate in some commercial croplands of KwaZulu-Natal is attributed to good agricultural extension services, farmer study groups, minimum tillage, government-subsided soil conservation works and strict application of agricultural legislation (National Botanical Institute South Africa, 2000; Montgomery, 2000).

2.3.1.2 Water Resources Degradation

Water availability is heavily dependent on climate, water use and management, and land use practices (Tarboton and Schulze, 1990). The quality and quantity as well as the spatial and temporal interdependency of water within a catchment or an area are determined by the land use/cover types of the area (Heathcote, 1998). Land use/cover often changes the permeability of the soil, thus affecting surface drainage systems and natural hydrology (Heathcote, 1998; Bauman, 1969). Land use also affects pollutant yields, both in terms of the total mass and type of pollutants released (Heathcote, 1998).

An assessment of land use/cover change provides insights into many facets of a catchment including altered drainage regimes, pollutant sources, valued natural and built features and, indirectly, regional economic forces and community priorities (Heathcote, 1998). These in turn become important in anticipating the impact of possible management actions within the catchment.

The Umgeni River is the dominant physical feature in the study area. It influences the surrounding land use and has a considerable effect on water resources, whether from soil

erosion in the source areas, or the siltation and pollution of the major dams or lakes (Tarboton and Schulze, 1990) in the study area. A land use/cover change study might help in protecting or zoning land use categories with allowable uses and possible management action within the Albert Falls Catchment.

2.3.1.3 Biodiversity Loss

Biodiversity is the abundance, variety, and genetic constitution of native animals and plants (Government Gazette, 1997, 1998). Biodiversity refers to the life-support systems and natural resources upon which human beings depend. There is worldwide concern over human activities such as pollution, habitat destruction, over exploitation and foreign plant and animal introductions that result in the ever-increasing loss of the earth's biological wealth (Turner and Meyer, 1994; Government Gazette, 1997; USGS, 2001). Further impacts of these activities are seen in the loss of crucial life-support systems through the loss of important habitats; degradation of the natural resource base on which people depend; and diminishing economic opportunities, as options for developing medicines and foods are reduced and the natural resource for tourism is damaged (Government Gazette, 1997; USGS, 2001).

Land use/cover change has an important influence in the richness of biodiversity for a number of reasons (Meyer, 1995; Turner *et al.*, 1993). Land use/cover changes reduce biodiversity abundance by reducing or changing the natural habitats. Land use/cover change induces habitat fragmentation which results in loss of plant and animal species (Bennet, 1999). Land use activities may change the natural patterns of environmental variations by causing changes in natural disturbance patterns and thus creating unfavorable conditions for plants and animals (Anon, 1994; USGS, 2001). In general, land use/cover change may affect biodiversity by disrupting ecological functions; creating problems for protected area and wild life corridors; or improve the biodiversity of an area if nature reserves and corridors are maintained (Anon; 1994; Bennet, 1999).

2.4 The Significance of Land Use/ Cover Changes

There are very few of the world's major environmental issues and very few types of global and regional environmental change in which land use/cover changes are not implicated (Chen *et al.*, 2001; LUCC, 2000). Changes in land use and land cover have important consequences for natural resources through their impacts on soil and water quality and the operation of the hydrological cycles, biodiversity loss resulting from habitat removal and fragmentation, and global climatic systems (Chen *et al.*, 2001; Turner *et al.*, 1994). In terms of areal extent land use/cover changes are of great importance. The rate at which land cover change is taking place is also dramatic. This leads to the discussion of how to use the limited space available to meet the often-conflicting demands of different land uses (Goudie, 2000).

Accurate, up-to-date information on land cover and land use is essential for strategic planning, sustainable resource management, and environmental research (Fairbanks and Thompson, 1996). Improved knowledge of the present distribution and areal extent of land use/cover units in an area as well as information on their changing proportions, is needed by different decision-makers and scientists to project transportation and utility demand, to identify future development pressure points and areas, and to implement effective plans for regional development (Anderson *et al.*, 1976; Pontius *et al.*, 2001). This helps to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of biodiversity (LUCC, 1999; Anderson *et al.*, 1976). Capabilities to record and map land use/cover conditions and to monitor change are required for among others in environmental research, establishing rates of land transformation, and habitat destruction for biodiversity conservation planning (Pontius *et al.*, 2001; Fairbanks *et al.*, 2000)

Thus, assessment of land use/cover change in Albert Falls Area can provide valuable base line information and an insight into the historical land use/cover patterns of the area. This information can be used for environmental studies to be done at the local and provincial

level and could assist in improved management and formulation of future land use plans for the study area.

2.5 Analysis of Land Use/Cover Changes in Support of Sustainable Development

The World Commission on Environment and Development defined sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their needs", (Government Gazette, 1998). The widely accepted concept of sustainable development is that it encompasses three key elements: the economic, social and environmental (Manning, 1991; Montgomery, 2000).

The environmental view of sustainable development focuses on the stability of biological and physical systems. The emphasis is on preserving the resilience and dynamic ability of such systems to adapt to change, rather than conservation of some ideal static state (Fuggle and Rabbie, 1992; Government Gazette, 1998). In this regard natural resource degradation, pollution, and loss of biodiversity all contribute to the reduction of system's resilience (Stockings and Murnagham, 2000).

In terms of land, sustainability can be defined as the maintenance of an adequate quantity of land with the required qualities to support indefinitely the full range of societal demands upon it (Manning, 1991). These demands include not only the productive functions of the land but also the support of a wide range of social, ecological, and aesthetic values (Montgomery, 2000; Manning, 1991).

Natural resources can potentially be used in a sustainable way if appropriate land management technology, regional planning and the policy complement one another in a purposeful way (Hurni, 1998). Thus, sustainable land management combines technologies, policies, and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously maintain or enhance production, reduce

the levels of production risk, and enhance soil capacity, protect the potential of natural resources, and prevent degradation of soil and water quality (Marcus *et al.*, 1996).

The issue of sustainable land use is recognized in the province of KwaZulu-Natal and the mission of the Department of Agriculture is " to foster an improvement in the quality of life and promote the development of a progressive and prosperous agricultural community by promoting the implementation of appropriate, economically viable and environmentally responsible production systems" (Land Care South Africa, 2001).

The Land Reform Program is expected to reduce the risk of land degradation (Mini, 2000). Nonetheless, the land redistribution program is not without environmental risks. One of the challenges of land reform is to relieve land pressure without environmental degradation over a wider area. So the government has a plan for any land development project to be properly planned and the necessary measures are being taken to govern the zoning, planning and ultimate use of land and water resources for sustainable use of the land (Marcus *et al.*, 1996; Department of Land Affairs 1997a)

2.6 Assessment of Land Use/Cover Changes

2.6.1 Land Use/Cover Scenario Analysis

Conceptually, the basic objective of any land use/cover change assessment is to record or portray change over time. Change implies not only difference in land surface between two dates, but also that the difference is uncharacteristic of the normal variation that might be found from one time period to the next (Langran, 1993). For the purpose of land use/cover assessment change can be defined as "a change in state of one or more locations, entities, or both", (Peuquet, 1999). Expansions of agricultural land or changes in the type of farming are some examples of land use/cover change.

Land use/cover change occurs at different rates for various entities and locations (Peuquet, 1999). Land use/cover change is not a simple phenomenon to detect. While differences from one time to another are readily measured, the more substantial issue is

that of isolating true change from normal environmental variability and artefacts of the measurement process (Eastman *et al.*, 1995). Additionally, the effective and efficient measurement of trends or significant departures from typical profiles in the time series datasets can provide a considerable challenge (Eastman *et al.*, 1995).

Time series analysis concerns the examination of change over a sequence of images or maps representing land use/cover. This refers not only to the perception of trends in change but also to the description of characteristic values and the abstraction of anomalies (Eastman *et al.*, 1995).

There are no standard techniques that are always appropriate for change and time series analysis (Peuquet, 1999; Veldkamp and Lambin, 2001). While some are focused on assessing the rates (or quantities) of change, others put more emphasis on spatial patterns (Peuquet, 1999; Veldkamp and Lambin, 2001). Therefore, it is important to develop a suite of techniques that can be used to assess land use/cover changes in a study area relevant to the application of the results.

2.6.2 The Role of Geographic Information Systems in Land Use/Cover Change Analysis

Assessment of land use/cover change involves improved remotely sensed data quality and other ancillary data to derive the needed land use/cover information. The data collected through remote sensing have no notion of purpose by themselves since it is not usually probable to identify land use/cover type correctly; and it is not always the case that inference about land use/cover type can be made from the physical structure only (Bibby and Shepherd, 1999; LUCC 1999). Therefore, it is necessary to complement remote sensing data with a range of other data and to enhance them by the application of technologies such as GIS in land use/cover change studies.

GIS technology makes it possible to compile, retrieve, analyze, and display vast quantities of spatial data interalia of the different factors involved in land use/cover

changes (Anderson and Starr, 1984; Clarke, 1988). GIS also provides facilities for the presentation of results in both graphic and tabular forms from geographically referenced data (Clarke *et al.*, 1988; Kleynhans *et al.*, 1999). GIS is a useful decision support tool in land management and have been used before to map land use patterns (Rivers-Moore, 1997). Moreover, GIS enables many different role players to make better-informed decisions on the utilization of geographic resources (Andersen and Starr, 1984; Kleynhans *et al.*, 1999).

The capability of GIS to integrate data from different field observations and remote sensing offers the potential for rapid, cost-effective surveying and assessment of land use/cover change patterns (Larsen, 1999; de By, 2001). Moreover, when the land use/cover data has been collected and stored in well-organized databases, GIS provides an opportunity to update the land use/cover databases in subsequent land use/cover or other studies (Ahmed, Pers.comm. 2001).

Currently almost all land use/cover change studies employ GIS as a tool for mapping and manipulating land use/cover databases. The scale-free registration procedures and broad analytical techniques of GIS offer a range of approaches, and may be used for example, to analyze the projected effects of current trends at some later date (Eastman *et al.*, 1995). Rivers-Moore (1997) and Weyer (2000) have used GIS in their land use/cover change studies in the Natal Midlands of KwaZulu-Natal near Albert Falls Area.

Rivers-Moore (1997) produced land use/cover maps of the Midmar catchment for the years 1944 and 1996 using aerial photography and GIS to examine changes in land use patterns during the 42 years. Rivers-Moore (1997) quantified the areal coverages of different land use types to assess the land use change between these years.

Similarly Weyer (2000) produced land use/cover maps and associated databases for the period 1944 and 1996 by interpreting aerial photography and using GIS to assess land transformations in the Karkloof catchment. Based on these maps and some ancillary data

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obtained from government departments, personal interviews and field visits, and 1944 and 1998 cadastral GIS databases Weyer (2000) provided baseline information useful for land management plan of the Karkloof catchment.

2.6.3 Projecting Future Land Use/Cover Changes

Land use/cover changes result from a complex set of interactions (Turner and Meyer, 1994). The most likely determinants of land use/cover change are: demographic factors such as population size or density, technology, level of affluence, political structures, economic factors such as systems of exchange or ownership, and attitudes and values (Turner and Meyer, 1994). The ability to forecast land use/cover changes and, to predict the consequences of change, depends on the ability to document and understand these drivers of changes (Veldkamp and Lambin, 2001; Stephen and Lambin, 2001). However, the related importance of a given driving force varies depending on the study region.

Since land use/cover change dynamics can have biophysical, social, economic or ecological drivers, an interdisciplinary approach is needed to develop projections of future land use and management decisions (Veldkamp and Lambin, 2001; Verburg et al., 1999). Consequently, projecting land use/cover change requires an integration of socio-economic data, which are usually compiled in statistical areal units, and biophysical data, which are often compiled in grids or polygons independent of statistical areal units, and the subsequent analysis of such data (Verburg et al., 1999; Himyama, 2001).

Some land use/cover change analysts use models to project future rates and patterns of land use/cover change. Models can take diverse forms, and there can be various types of model that are potentially useful for the study of land use/cover changes (Verburg et al., 1999; Veldkamp and Lambin, 2001; Pontius et al., 2001). Typical forms of output of models for land use/cover change include schematic representation of the mechanisms of the changes, spatial databases to show the past, present and future land use/cover patterns, and future scenario maps of the changes, and policy recommendations (Himyama, 2001; Pontius et al., 2001).

Land use/cover change modeling is an important technique for the projection of alternate pathways into the future, for conducting experiments to test the stability of linked social and ecological systems, through scenario building (Verburg *et al.*, 1999). While, by definition, any model falls short of incorporating all aspects of reality, a model may provide valuable information on the system's behavior under a range of conditions.

Modeling land use/cover change requires the understanding and datasets related to land use/cover change driving factors and approaches capable of handling, in a spatially explicit way, drivers that operate at different scales (LUCC, 1999; Veldkamp and Lambin, 2001; Pontius *et al.*, 2001). Modeling land use/cover change is complicated by the fact that many of the most important future influences are unpredictable (Brouer *et al.*, 1991). Most of the available land use/ cover change models are developed for specific purposes and locations (Veldkamp and Lambin, 2001).

2.7 Summary

In this chapter the possible causes and impacts of land use/cover changes have been briefly discussed. Among the diverse land use/cover change drivers some biophysical factors including climate and vegetation, and socio-economic factors including human factor, technological developments, land tenure, land use policies and legislations were briefly discussed to give a background information to understand land use/cover change drivers.

Although land use/cover changes can have social and environmental impacts this chapter highlighted only the impacts of land use/cover change on land and land resource degradation. In order to show the significance of the assessment of changes in land use/cover change patterns the general usage and applications of such information were highlighted in this chapter. Moreover, the relevance of land use/cover change assessment to sustainable development was briefly discussed. Finally, the chapter concluded by a brief review of the methods of land use/cover change analysis, the role of GIS in land

use/cover change analysis and an overview of modeling land use/cover change. The study area will be described in the following chapter.

Chapter Three: Study Area

3.1 Introduction

Albert Falls Area is located about 15 km north west of Pietermaritzburg in the midlands of KwaZulu Natal, South Africa (Figure 3.1). It covers the area between 29°21′ and 29°30′ South, and 30°18′ and 30°27′ East, and falls in the Indlovu Magisterial District. The study area covers 24670 ha. It extends from north west of Pietermaritzburg to north of Jepsons Vley; and from Brodershoek, Do Jong Ranch, Fountaindale, Inkiwane, and hawkstone in the west to Ranchester Grange, Umgeni Park, part of Broughton, Cramond Satellite Dam and Comins in the east (Figure 3.2).

Albert Falls Area has a wide range of ecological conditions as it includes four Bioresource groups of KwaZulu-Natal (Camp, 1999). The Moist Coast hinterland Ngongoni Veld dominates the north and northeast of the study area (Figure3.3). The Moist Midlands Mistbelt mostly covers the northwest and a small portion of the southwest of the study area. The Dry Coast hinterland Ngongoni Veld runs across the middle part of the study area in a narrow east-west strip. The Coastal Hinterland Thornveld covers most of the southern third part of the study area.

3.2 The Biophysical Environments

The biophysical environment determines to a considerable degree, the form which human's economic activities may take, particularly those activities which are closely tied to natural endowments (Horwood, 1967; Verheye, 1991). A vast array of biophysical characteristics (viz. climate, water resources, soil, vegetation) and a variety of past and present human activities combine to make every parcel of land on Albert Falls Area unique in the cover it possesses and the opportunities for use that it offers.

Legend

⋀ National Roads

⋀ Main Roads

⋀ Railways

● Cities

▮ Study area

KwaZulu-Natal

Greytown

Albert Falls Area

Pietermaritzburg

Durban

Eastern Cape

30 0 30 60 Kilometers

N

ZIMBABWE

BOTSWANA

Northern Province

Mpumalanga

Gauteng

SWAZILAND

North West

NAMIBIA

Free State

KwaZulu-Natal

Lesotho

ATLANTIC OCEAN

Northern Cape

Eastern Cape

INDIAN OCEAN

Western Cape

20 0 20 40 Kilometers

Fig 3.1 Location Map of Albert Falls Area

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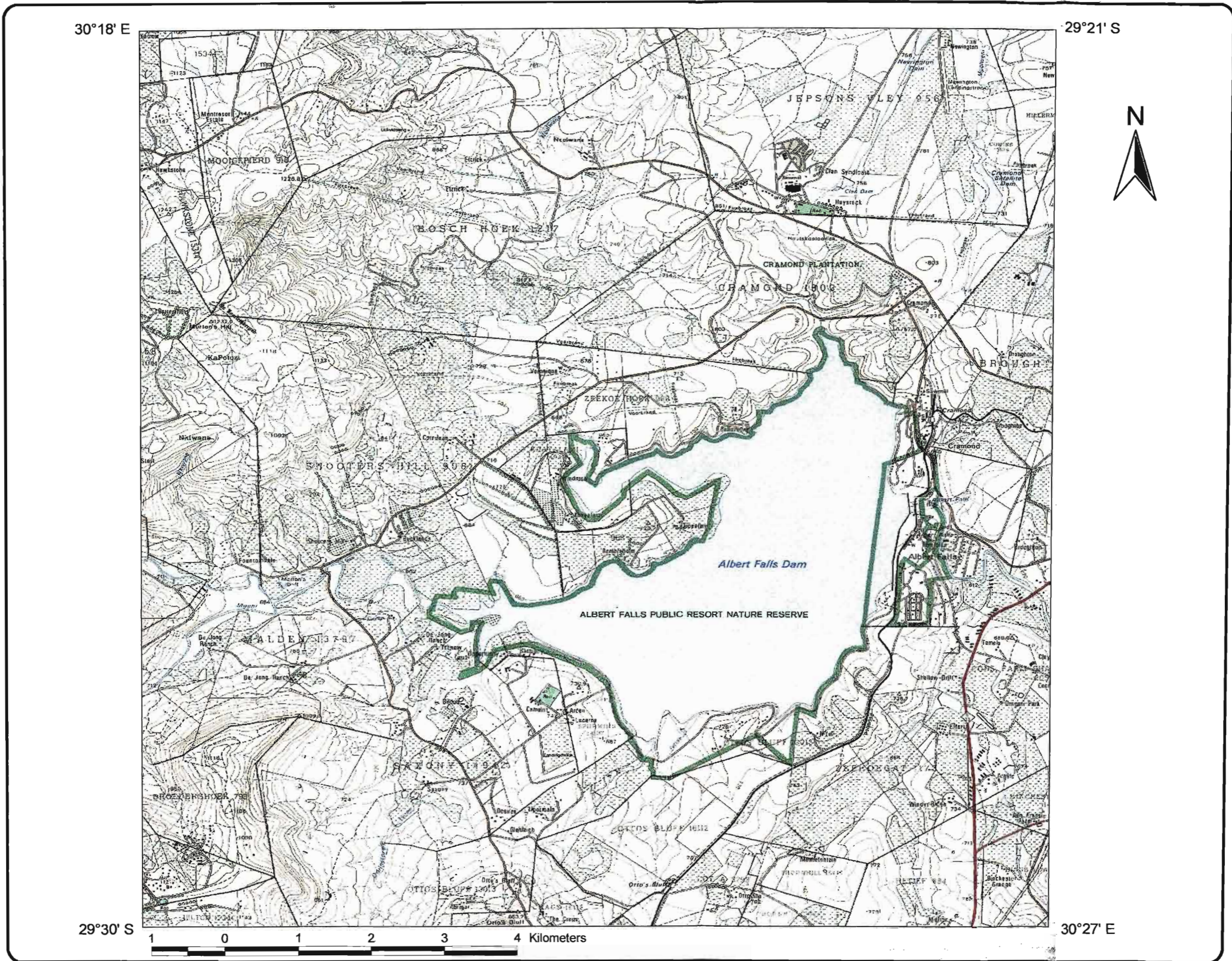
Fig 3.2 Topo-Cadastral Map of Albert Falls Area (Source: Surveying and Mapping, Mowbray)
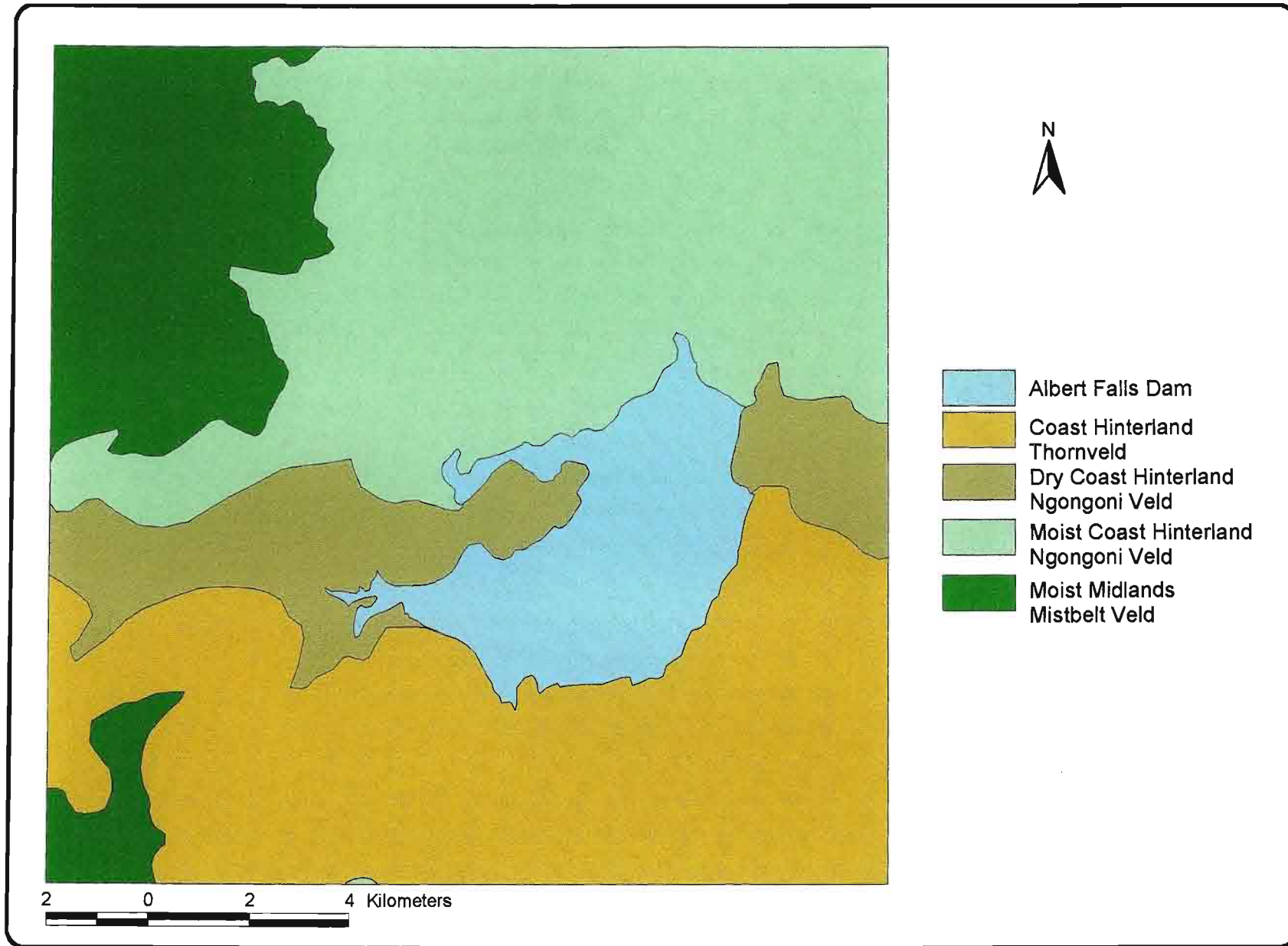
Fig 3.3 Bioresource Groups of Albert Falls Area (Source: Camp, 1999)

3.2.1 Climate

Latitude and altitude, together with oceanic influences are responsible for the wider range of climatic conditions in KwaZulu-Natal (Tyson, 1987). It is generally accepted that climate is a major influencing element in man's utilization of the land (Guy and Smith, 1998; Schulze, 1997). This applies more strongly under modern conditions to rural land use than to urban land use. Generally, in Albert Falls Area summers are warm and wet, and winters are cool to cold and dry, there being a two to three months dry period. Frosts may be moderate to severe (Camp, 1999).

Guy and Smith (1998) have classified KwaZulu-Natal into climatic capability classes for agricultural land potential. Accordingly, Albert Falls Area falls into four classes related to the Bioresource classification of Camp (1999), (Figure3.3). The Moist Coast Hinterland Ngongoni Veld and the Moist Midlands Mistbelt parts have C3 climatic capability class. This class has slightly restricted growing season due to the occurrence of low temperature and frost. The Dry Coast hinterland Ngongoni Veld has C4 climatic capability classes indicating moderately restricted growing season due to low temperature and severe frost. The Coast hinterland Thornveld has a climatic capability classification of C5 leading moderately restricted growing season due to low temperatures, frost and/or moisture stress. The various climatic factors affecting the environmental conditions of the area will be discussed individually.

3.2.1.1 Temperature

Temperature correlates with latitude and altitude in KwaZulu-Natal (Guy and Smith, 1998). Temperature determines the energy status of the environment and determines the rate of growth of plants (Schulze, 1982). Of importance to agriculture are the variations in temperature throughout the year, since it limits the growing season and, therefore, the type of farming suited to an area. The temperature requirement of crops is more conveniently expressed in heat units (Smith, 1997). In general, Albert Falls Area is free from extremely cold weather (Schulze, 1997, Camp, 1999). It has a mean annual temperature, where the range is 17.5 to 20.0 °C with some exception in the southern part

that drops from 17.0-16.0 °C. Mean monthly, daily maximum mean, and daily minimum mean temperatures of six climatic stations averaged over 8 to 68 years are given in climatic tables within the study area (Appendix I.a, I.b, and I.c).

3.2.1.2 Wind

Winds have a strong influence on temperature. During winter a cold wind may blow from a southern or south-western direction (Weyer, 2000). In spring Berg winds flowing from north and north-west are important ecologically because they have a strong desiccating effect on the vegetation, especially on the windward (north-west) facing slopes (Horwood, 1967; Moll, 1976). Fire hazard in the grassland areas is high during this time. Generally, the wind speed in the Albert Falls Area ranges from 92 to 114km/day (Camp, 1999).

3.2.1.3 Precipitation

Precipitation plays an important role in determining the resource situation, crop selection, yield and risk of agricultural production (Parry, 1990; Smith and Camp, 2002). Albert Falls Area falls in summer rainfall of South Africa (Natal Town and Regional Planning Commission, 1973; Camp, 1990). The maximum rainfall in the area tends to occur in February and March, towards the end of the rainy season, although the rain is distributed fairly evenly between the six summer months (Appendix I.d, I.e).

Mean annual precipitation of the study area ranges from 850 to 1300 mm. Rain is the result of both frontal activity and thunderstorms and there are on average 18.5 thunderstorms per year. Hailstorms are infrequent with an average of only 0.5 storms per year having been recorded (Moll, 1976; Camp, 1999). Part of the study area that falls in the mistbelt receives mists in summer which is agriculturally important (Natal Town and Regional Planning Commission, 1973; Weyer, 2000).

3.2.2 Topography

Topography is an important determinant of land utilization patterns both urban and rural. Topography plays an important role in the movements and settlements of people and their dynamic adaptation to the environment. A study of the topography is therefore, an important aspect of the background to people and their interactions within their surroundings (Archer *et al.*, 1995)

The topography of Albert Falls Area is generally undulating and in terms of relative relief varies from mountainous in south to relatively flat to the middle going to the northern boundary. It is relatively hilly in the western part and becomes relatively flat towards eastern and northern parts of the area (Figure 3.4).
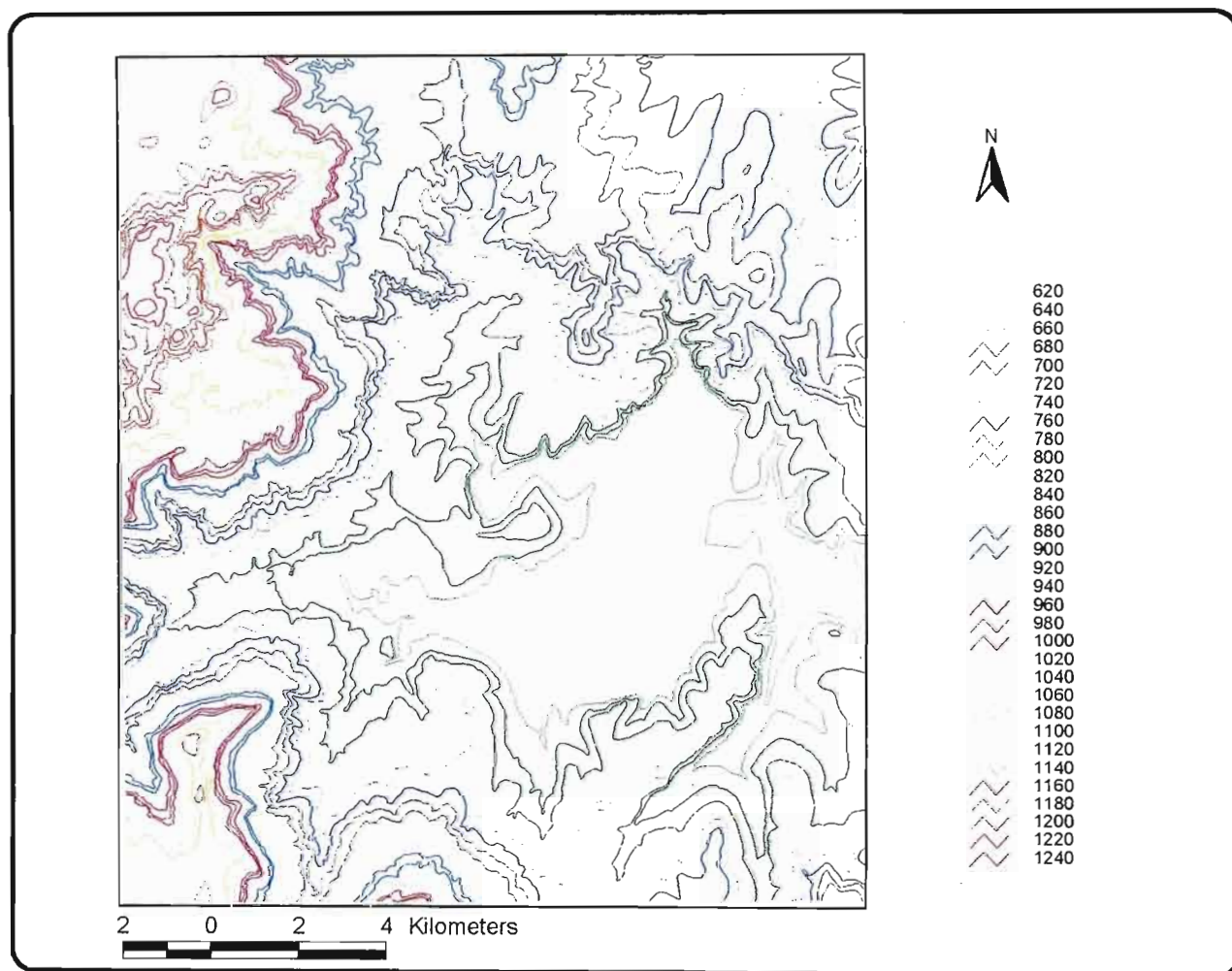
Figure 3.4 Topographical Representation of Albert Falls Area

Generally, Albert Falls Area has an altitude that ranges from 451 to 915m a MSL Some exceptions at the down stream of Albert Falls Dam also do occur reaching down to 305m a MSL (Camp, 1999).

3.2.3 Water Resources

The Umgeni River is a dominant feature in the study area. Three quarters of the mean annual run-off for the total Umgeni Catchment occurs in the Midmar and Albert Falls Dams (Natal Town and Regional Planning Commission, 1973). The Umgeni River is important from its strategic position as the water supply for the Pietermaritzburg-Durban complex providing water to over 3.6 million people and supports industry and agriculture that produce 20% of South Africa's gross national product (Natal Town and Regional Planning Commission, 1973) and 65% of the total economic production of KwaZulu-Natal (Tarboton and Schulze, 1990). Thus, Umgeni River is important for future development of the region, and the study area in particular.

The study area is dominated by large tracts of water, the most notable being the Albert Falls Dam. This dam was constructed to meet the increasing need and rising standards for water in the region in the nearby cities in particular and for the whole county in general (Natal Town and Regional Planning Commission, 1973; Tarboton and Schulze, 1990). It was completed in 1976 and flooded the former Peatties Lake area. It has a capacity of 289.0 M m^3 (Albert Falls Nature Reserve Brochure, 2001; KwaZulu-Natal Government, 1990).

Umgeni River in general and Albert Falls Area water resources in particular are relatively less polluted compared to other rivers in South Africa (CSIR, 2000). Umgeni Water, a local bulk water supplier, monitors the quality and quantity of water resources in KwaZulu-Natal. Umgeni Water is aware that land use activities in the Albert Falls catchment can have a significant effect on and in turn the availability and price of treated water (CSIR, 2000). This study might help provide information to develop appropriate

land uses to protect the catchment area or zone land use categories with allowable uses and take possible management actions.

3.2.4 Geology

Albert Falls Area lies within the Ecca group of KwaZulu-Natal geological formations. The Ecca group has a total thickness of about 7000m. Laid down in extensive bodies of fresh water during a cold temperature period, the Ecca shales and sandstones lie above the Dwyka (Moll, 1976). Sandstones of the Ecca group crown the prominent escarpment (Schulze, 1982).

Down stream of the Albert Falls Dam the Dwyka tillites are prominent. Above the dam the Dwyka tillites traverses alternating dark grey s hales of the volksrust formation and intrusive dolerite. Most of the area above Albert Falls Dam consists of horizontally bedded sandstones, s hales and mudstones belonging to Beaufort and Ecca series of the upper Karoo system. Most of the upper Karoo system has been intruded by dolerite dykes and sills (KwaZulu-Natal Government, 1990).

3.2.5 Soils

The interaction of geology and climate has resulted in a large number of different soils which are best described in association with the geology of KwaZulu-Natal (Scotney, 1978).

Sandstones and shales of the Ecca group comprise much of the bedrock over Albert Falls Area and these produce a variety of soil patterns (Moll, 1976; Camp, 1999). In relatively dry areas, the dominant soil on shale is Mispah, but it may occur in association with plinthic and duplex soils. Margalitic soils are also found in cool, moist upland landscapes; however, the Clovelly form is widespread on s hale. A wider spectrum of soils is found on sandstone (Camp, 1999).

Where dolerite has intruded into the sandstones, heavier textured soils of the Shortlands, Bonheim, Arcadia, and Rensburg forms are common, and in the moist interior basins Avalon and Longlands forms predominate. In the cool, moist Mistbelt and highlands areas, above 900 m a MSL, Dystophic and sandy clays of the Clovelly, Griffin and Katspruit forms are common (Camp, 1999).

The soils that fall in the Moist Coast hinterland Ngongoni Veld part of the area have 60% potential for cropping. The dry Coast hinterland Ngongoni Veld has a cropping potential of 20-30%. The Coast hinterland Thornveld has 40-50% cropping potential (Guy and Smith, 1998). The Moist Midlands Mist belt area has a cropping potential of 30-40% (Camp, 1999)

3.2.6 Biodiversity

South Africa ranks as the third most biologically diverse country in the world, and as such is of major global importance for biodiversity conservation (Government Gazette, 1998). Albert Falls Area is highly valued in terms of its natural habitats and the ability of these to support a large number and variety of flora and fauna. It is due to its ecological diversity that led to the establishment of Albert Falls Nature Reserve.

Albert Falls Nature Reserve is prolific with wild life, particularly birds. For example, within the Albert Falls Dam and some of the small farms on the edge of the dam area about 280 bird species were spotted (Appendix II). The dam is also rich in fish and other fauna and flora among which it is renowned for fish eagle and raptors (Albert Falls Nature Reserve Brochure, 2001).

3.2.7 Natural Vegetation

The natural vegetation of an area may be regarded as integrating climatic and soil conditions (Acocks, 1988). Since climate is strongly correlated with altitude in KwaZulu-Natal, the vegetation also varies with altitude (Camp, 1999).

According to Acocks (1988) South African vegetation classification most of the vegetation types of Albert Falls Area were included within the Ngongoni Veld with the exception of the area that falls into the Moist Midlands Mistbelt (Figure3.3) being classified as Natal Mist Belt Ngongoni Veld (Acocks, 1988).

Moll (1976) recognized the following forest types in broad vegetation categories. The vegetation types in the Moist Coast hinterland Ngongoni Veld and Dry Coast hinterland Ngongoni Veld (Figure3.3) were identified as *Acacia sieberana* Wooded Grassland with Secondary *Aristida juniciformis* Grassland. Whereas the Vegetation types in the Coast hinterland Thornveld were categorized as *Acacia sieberana* Wooded Grassland Dry Valley Scrub and Bushland Mosaic including Kloof Forest and Fringing Forest. The Moist Midlands Mistbelt vegetation was classified as Moist Transitional *Themada-Hyparrhenia* Grassland Mistbelt *Themada-Aristida* Grassland (Camp, 1999).

The dominant natural vegetation pattern in Moist Coast hinterland Ngongoni is secondary Grassland influenced by unpalatable Ngongoni grass *Aristida juniciformis* (Acocks, 1988; Moll, 1976). This veld is poor in quality due to injudicious burning coupled with selective overgrazing. Plant indicator species of this veld are *Aristida juniciformis*, *Digitaris ariantha*, *Lantana camara*, *Rouvolifa caffra*, *Syzygium cordatum*, *Solanum mauritanium*, and *Albiza adianthifolia* (Camp, 1999).

Dry Coast hinterland Ngongoni Veld is also dominated by *Aristida juniciformis* (Acocks, 1988; Moll, 1976). Dry Coast hinterland Ngongoni Veld has resulted in a poor quality due to burning at any time of the year, coupled with selective overgrazing. Plant indicator species of this veld are similar to those of Moist Coast hinterland Ngongoni but with the abundance of *Aristida juniciformis* and *Acacia Karoo* (Camp, 1999).

The Coast hinterland Thornveld is dominated by undesirable *Aristida juniciformis* (Acocks, 1988; Moll, 1976). The common practice of burning followed by selective overgrazing had deteriorated this veld (Acocks, 1988; Moll, 1976). Plant indicator

species of this veld are *Acacia karoo, Acccia nilotica, Accacia sieberiana, Aristida juniciformis, Pancium maximum, Sporobolus pyramidalis, Lantana camara,* and *Zyziphus murinata* (Camp, 1999).

The Moist Midlands Mistbelt has remains of the former *Themada thriandra*. Like others this veld is deteriorated due to excessive burning, followed by continuous selective overgrazing (Acocks, 1988; Camp, 1999; Moll, 1976). The dominant plants in this veld include *Themada trindra, Tristachia leucothrix, Trachypogon spicatus, Eragrostis capensis, Eragrostis racemosa,* and *Monocymbium ceresiiforme* (Camp, 1999).

Albert Falls Area has several exotic weeds such as black wattle (*Acacia mearnsii*) and silver wattle (*Acacia dealbata*), American bramble (*Rubus cuneifolius*), *Lantana camara,* and triffid weed (*Chromolaena odorata*) (Camp, 1999). Indigenous plants that pose a problem include Currys Post weed (*Athanasia aerosa*) which is invasive on over grazed veld and Serecio species and Tuli (Moraeo *spathulata*) which are toxic to stock (Camp, 1999).

3.3 Socio-economic Settings of the Study Area

Albert Falls Area reveals, in a general way, physical, climatic and other characteristics sufficiently different to affect the growing of crops and livestock. This in turn influences the land use patterns and hence the economy of the area.

The north and northeast of the study area with favorable climate and good soils is an area of high agricultural potential (Smith, 1997). Most of it is under commercial timber, including Eucalyptus, Pine, Wattle and Poplar (Camp, 1999). In a small strip in the middle part of the study area running east-west direction sugarcane is grown but supplementary irrigation is needed. Cattle and goats are farmed but the condition of the veld limits the potential for the development of this farming line. The southern part covering one third of the study area with suitable soils and climate has a potential for the production of sugarcane, maize and vegetables (Camp, 1999). Most of the northwest and

a small portion to the southwest of the study area are intensively farmed to annual crops, in addition to dairying, forestry and sugarcane (Camp, 1999).

3.3.1 Economic Growth in the Study Area

The economic source of Albert Falls Area is more or less related to agriculture and tourism. Sugarcane, commercial forestry, dairying, and chicken farming are some of the major agricultural activities in the area.

Forestry is ecologically suitable and is the most widespread land use form with gum, pine, and wattle and little poplar predominating the area. The Forestry industry is and always has been a predominantly export-oriented one (Edwards, 1990; Horwood, 1967; Natal Town and Regional Planning, 1973).

Dairy farming is an important enterprise in the study area. In the outlying areas some cattle ranching is also found. The dairy industry is not an export-oriented industry, but caters for the needs of the populace within the region (Horwood, 1967). The proximity of markets has been a dominant factor for the development of the dairy industry. Thus, it is not a direct earner of foreign exchange for the region as are sugarcane and commercial forest plantations. Nevertheless, dairying plays a dominant role in the agricultural economy of the region (Natal Town and Regional Planning, 1973).

Sugarcane is also one of the main agricultural enterprises in the study area. Sugarcane production is affected by national and international affairs; world market prices, and the high tariff walls behind which the industry has developed have had a major bearing on the development of the sugar industry (Ortman, 1974; Hudson, 1990).

Chicken farming is one of the economic enterprises in the study area. Chicken farming might be economically feasible, but the fowl house and the smell of the chicken's droppings create an aesthetic problem to the scenic Albert Falls Area. In addition to the

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above four major enterprises crops such as maize, potatoes, and sweet potatoes are the main crops grown in the area (Camp, 1999).

Tourism is also a major economic factor for development in Albert Falls Area. The natural vegetation and the rural farming activities impart a high visual quality adding a unique character to the landscape which attracts visitors to the area (Albert Falls Nature Reserve Brochure, 2001). Albert Falls Dam is important both as a water storage reservoir and as a focus of prime water-based recreation (Butler-Adam, 1982; Albert Falls Nature Reserve Brochure, 2001). It is also known for fishing. Albert Falls Nature Reserve, Game Valley and other tourism ventures have contributed to the area acquiring many of the characteristics for which the Midlands Amble of KwaZulu-Natal has become well known for tourism (Albert Falls Nature Reserve Brochure, 2001). Therefore, Albert Falls Area is important for the economic development of the region in particular and the whole country in general.

3.3.2 Human Resources

The population within the Albert Falls Area is almost as diverse as the scenic and cultural attractions. In addition to the historically important Zulus, there are fully integrated populations of former immigrant groups including English, Irish, Indian, German, Scottish as well as a sprinkling of European nationalities (South Africa Bureau of Statistics, 1968; Statistics South Africa, 1998; Albert Falls Nature Reserve Brochure, 2001).

In an area that is not well endowed with natural resources of some or other kind, the skills and capacities of the human population become critical in the process of economic growth (Horwood, 1967). The composition of the population in Albert Falls Area has been important to the economic growth of the region. This is because of the availability of different types of skills that vary among the racial groups, and because growth rates and other demographic factors differ sufficiently markedly, as between one racial group and another, to have a material bearing on the course of economic growth in the region.

The population growth in Albert Falls Area trend during 1944 to 2000 is evident (South Africa Bureau of Statistics, 1968; Statistics South Africa, 1998), but due to the fall of Albert Falls Area into different enumerating areas at different census years it makes it difficult to analyze the demographic data with any confidence.

3.4 Summary

Albert Falls Area with high agricultural potential soils, suitable climate, and well-developed infrastructure is an important farming area in KwaZulu-Natal. Albert Falls sub-catchment in Umgeni catchment which is one of the important catchments in South Africa. Moreover, the study area is one of main tourism attractions in the KwaZulu-Natal Midlands.

In South Africa there has been competition over land use between agriculture, recreation, conservation and other land uses (Rivers-Moore, 1997). Due to improper land use planning there has been inefficiencies, inequities and environmental degradation (DWAF, 1996). Like in other parts of South Africa there have been major land use/cover changes in Albert Falls Area trend during 1944 to 2000. In order to support a wide range of social, ecological, and aesthetic values of the area sound land use planning is needed.

One of the prime prerequisite for making sound land and land resource policies; developing more appropriate land use systems is information on land use/cover patterns as well as their changing proportions through time (Anderson *et al.* 1976; Pontius *et al.*, 2001). Assessment of change in land use/cover patterns in the Albert Falls Area can assist in developing sustainable land use systems.

The aim of this study was to create a series of historical land use/cover databases for the years 1944, 1967, 1989 and 2000, in order to assess the changes in land use/cover patterns in Albert Falls Area. Chapter four will discuss the materials and methods employed to develop the historical land use/cover databases.

Chapter Four: Materials and Methods

4.1 Introduction

The patterns of resource use and resource demand are constantly changing. Fortunately, the capability to obtain data about land uses/cover related to resource development is improving because of recent technological improvements in remote sensing equipment, interpretation techniques, and data processing (Heathcote, 1998).

Land use/cover mapping incorporates four basic stages in the compilation of land use/cover maps: initial field visits for land use/cover identification, aerial photograph interpretation and annotation, digitization of annotated land use/cover data, and both field and aerial photograph verification for map accuracy assessment (Westinga, 1998). This chapter will discuss the methods involved in developing the historical land use/cover databases and other methods employed in this study.

4.2 Land Use/Cover Classification

Concepts concerning land use and land cover are closely related and in many cases have been used interchangeably (Turner *et al.*, 1993; Meyer, 1995). The purposes for which lands are being used commonly have associated types of cover, whether they are for forest, agricultural, residential, or industrial.

For the purpose of land use/cover mapping a classification was required for consistency in terms of the degree of generalisation that was used. There is no uniform land use/cover classification system to date. Moreover, there is no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use/cover patterns change in keeping with demands for natural resources (Anderson *et al.*, 1976).

The majority of land use/cover classifications that did exist had typically been developed around specific user objectives, and had often been influenced by geographical location and actual data capabilities (Jansen *et al.*, 2000).

The problem of inventorying and classifying multiple uses occurring in a single parcel of land is also an additional problem in land use/cover classifications (Meerkerk, 1997, Anderson *et al.*, 1976). Multiple uses may occur simultaneously, as in the instance of forestland used for recreational activities such as hunting or camping (Arnold, 1997; Lillesand and Kiefer, 2000). Although each of these activities is detectable at some time using remote sensing, many other multiple-use situations cannot be interpreted with the same degree of success (Lillesand and Kiefer, 2000).

In developing a classification system, every effort has been made to provide as much compatibility as possible with other classification systems currently being used by various departments involved in land use/cover inventory and mapping in South Africa. The land use/cover classification used in this study was based on that defined by Thompson (1999) for South Africa (Appendix III). The South African classification system is a hierarchical framework designed to suit the South African environments and is designed to conform with internationally accepted standards and conventions (Thompson, 1999).

After a number of visits to the study area and reading relevant literature each land use/cover classes of the study area were identified. The first step followed in classifying the study area was to distinguish among the Level I classification classes (Appendix III). In this stage Albert Falls Area was found to comprise major land use/cover classes including Indigenous Forests, Grasslands, Commercial Forestry, Cultivated Lands, Built-Up Land, Waterbodies, and Barren Land (Table 4.1).

The next step was to classify the level I land use/cover classes into level II land use/cover classes. At this level of classification, land use/cover classes of the South Africa Classification System (Appendix III) were used with slight modifications to suit to this study (Table 4.1).

Table 4.1 Land use/cover classification system used in this study

Land Use/Cover Classes		A Brief Description of Level II Land Use/Cover Classes
Level I	Level II	
Indigenous Forests	Woodland	Tree canopy cover between 40-70%
	Wooded Grassland	Tree canopy cover between 10-40%
	Valley Thicket/Bushland	Multi-Layered community with interlocking communities found in riversides
Grasslands	Grassland	Improved and Unimproved grassland with less than 10% tree and/or canopy cover
Commercial Forestry	Forest Plantations	All areas of systematically planted, man-managed tree resources
	Clear Felled	Clear felled fields/compartments
Cultivated Lands	Cultivated Land	Areas of land under crop, fallow and land being prepared for cultivation
	Sugarcane	Cultivated lands under sugar cane plantations
Built-Up Land	Residential Area	Areas used for residence including formal and Informal settlement areas
	Non-Residential Area	Areas (buildings) used for non-residencial use mostly for commercial agriculture
	Transportation Routes	Areas used for transportation routes including roads and railways
Waterbodies	Dams	Reservoirs used for storing or impounding water with a safety risk
	Farm Ponds	Reservoirs used for storing or impounding water with less safety risk than dams
	River Water	Water bodies occuring in rivers
Barren Lands	Bare Lands	Natural areas of exposed sand, soil or rock with no or very little vegetation cover
	Degraded Lands	Permanent or seasonal, man-induced areas of very low vegetation cover

* Land use/cover classes will subsequently be refered to as described in this table (e.g.Degraded Lands (level I), and Degraded Land (leve II)

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The natural vegetation areas consisting of indigenous and alien vegetation was classified into Woodland, Wooded Grassland, and Valley Thicket/Bushland (Appendix III). The river valley vegetation was classified as Valley Thicket/Bushland. As differentiating between the Bushland and Thicket was not easy, the author preferred to use a combined definition.

The definition of Grassland was based on the South African land use/cover classification system. However, no differentiation was made between Improved and Unimproved Grasslands.

In this study Commercial Forestry area includes both forests under plantations including young and mature plantations, woodlots/windbreaks of sufficient size, and clear felled fields.

The Cultivated Lands was difficult to further subdivide into level II as cultivated patches included a mosaic of various crops, vegetables, and fruits. However, Sugarcane was treated as a separate class due to its economic importance.

Built-Up Land was classified into Residential Area, Non-Residential Area and Transportation Routes. In this study Non-Residential Area includes areas used for commercial farming such as dairying, chicken, and cattle farming. Transportation Routes were classified separately and included roads and railways. Further classification of the Transportation Routes was not made as only an indication of accessibility to transport was required in the study

Waterbodies were classified into three level II classes including Dams, Farm Ponds, and River Water in order to try and explain the mode of use according to proximity to water supply. Since detailed information on all dams (e.g. capacity and dam wall height) in Albert Falls Area was not available, the author used aerial coverage impounded by Waterbodies to differentiate Dams from Farm Ponds. Farm Ponds in this study implies any impoundment used for providing water for agriculture and domestic purposes such as

livestock and poultry watering, irrigation of crops, recreation, and conservation, for the owner or occupant of the farm.

The Barren Land sub-divided into Bare Lands and Degraded Lands. Although Thompson (1999) recommended subdividing Degraded Land according to level I classes (e.g. Degraded Grasslands, Degraded Woodlands), but this study grouped all degraded lands as Degraded Lands.

4.3 Land Use/Cover Mapping

4.3.1 Aerial photography

Aerial photography is the original form of remote sensing and is still widely used in topographic mapping and environmental studies. Aerial photographs are the most common remote sensing product that allows the rapid acquisition of accurate, up-to-date information about the size, location, and character of objects on the earth's surface (Carver, 1981; Campbell, 1993). Their format lends itself to the compilation of maps since they are concise representations of the patterns on the ground (Campbell, 1983, 1993).

Vertical aerial photographs are useful for mapping purposes (Carver, 1981; Mitchel, 1981). Vertical photographs are easier to use in locating objects and measuring the distance between objects than oblique photographs and can be compared to old photographs to depict changes over time (Mitchel, 1981, Campbell, 1983). Due to these advantages this study used vertical aerial photographs to assess the land use/cover change patterns in Albert Falls Area.

Since historical land use/cover databases were required and the relevant aerial photographs of Albert Falls Area were available, it was more cost-effective to use aerial photographs than field surveys, although ground truthing was still necessary. The best available quality black and white aerial photographs covering the Albert Falls Area for four years including 1944, 1967, 1989, and 2000 were obtained from Surveys and Mapping in Mowbray, Cape Town. Table 4.2 gives a general description of these aerial

photographs and the supplementary orthophotos used in this study. These Aerial photographs were to be used in conjunction with orthophotos (1:10000). High quality orthophotos (Duraster Copies) covering Albert Falls Area of 1996(2930AD 12, 13, 14, 17,18, 19) and 1981(29AD, 22, 23, 24) were also obtained from Surveys and Mapping in Mowbray, Cape Town.

Table 4.2. Description of Aerial Photographs and Orthophotos used to develop historical land use/cover databases.

Year	Scale	Job Number	Type	Strip No.	Photographs	Quantity
2000	1:50 000	1031/2000	Contact Print	9	3992,90	2
				8	3695, 97	2
1989	1:50 000	933/1989	Contact Print	6	1874, 76. 78	3
				7	1899, 1901, 1903	3
1967	1:30 000	573/1967	Contact Print	3	5883, 85, 87, 89,	4
				4	5930, 28, 26, 24	4
				5	6021, 19, 17, 15	4
				6	7861, 63, 65, 67	4
1944	1:20 000	60/1944	Contact Print	29	11906, 08, 10, 12, 14, 16, 18	7
				30	11943, 41, 39, 37, 35, 33	6
				31	12068, 70, 72, 74, 76, 78, 80	7
				32	2106, 04, 02, 00, 2098, 96	5
				33	12162, 64, 66, 68, 70, 72	6
				34	2198, 96, 94, 92, 90, 88, 86, 84	8
				35	12250, 52, 54, 56, 58, 60, 62	7
Orthophotos						
Year	Scale	Topomap I.D.	Orhtophoto number			Quantity
1981	1:10 000	2930AD	12, 13, 14, 17, 18, 19			6
1995	1:10 000	2930AD	22, 23, 24			3

Aerial photographs are subjected to distortion from the variations in ground relief, curvature of the camera lens and the tilt of the aircraft, leading to inaccurate representations of the earth surface (Carver, 1981; Mitchel 1981; Campbell, 1983). Another problem with aerial photography is resolution of the aerial photographs (Arnold, 1997). Resolution, the accuracy at which a given map scale can depict the location and shape of geographic features, is impacted on by contrast, colour and tone of the aerial photographs (Hohl, 1998). This can lead to changes in interpretation of the land use patterns.

To keep the inaccuracies due to resolution and distortion to a minimum the aerial photographs of the study area for each year were scanned using a Hewlett-Packard ScanJet 5370C Scanner at 600dpi to retain the optimal resolution. The scanned aerial photographs were georectified using a point-to-point rectification using the georeferenced and mosaicked orthophoto as a background by Smart Image Software (RockWare Inc. 2002). At least nine tic points were used to georectify each aerial photograph. Then each set of aerial photographs was mosaicked using Smart Image Software to produce a complete coverage of the study area. Finally, as the mosaicked images covered areas beyond the study area, these areas were clipped out using Smart Image Software to produce a complete coverage of the study area only. This process was repeated for all sets of aerial photographs producing a complete coverage of mosaicked aerial photographs for each year.

4.3.2 Aerial Photo Interpretation

Devices that capture remotely sensed images do not record activity directly. The remote sensor acquires a response, which is based on many characteristic of the land surface, including natural or artificial cover (Arnold, 1997). The interpreter uses patterns, tones, shapes, and site associations to derive information about land use activities from what is basically information about land cover (Carver, 1981, Mitchel, 1981).

In most land use applications, we are most interested in the minimum size of an area, which can be recognized as having an interpretable land use or land cover type (Westinga, 1998). Such a minimum area depends on the type and characteristics of the imagery system involved and partially on the scale and resolution of the aerial photograph (Andersen et al., 1976; Westinga, 1998). Moreover, the interpretation also depends on the scale of data compilation as well as the final scale of the presentation of the land use information (Campbell, 1993, Westinga, 1998). In some cases, land use cannot be identified with the level of accuracy approaching the size of the smallest mappable unit, while in others, specific land uses can be identified which are too small to be mapped (Campbell, 1983; Lillesand and Kiefer, 2000)

When maps are intended as the format for presenting land use/cover data, it is difficult to represent any unit smaller than 0.10 inch (2.54 mm) on a side (Andersen *et al.*, 1976, Westinga, 1998). In addition, smaller areas cause legibility problems for the map-reader (Campbell, 1983). For this reason it was necessary to limit the size of the mappable unit to 127m X 127m, as the aerial photograph of the smallest scale and the proposed final map were all of a 1:50 000 scale. Since the degree of generalization is under the subjective control of the interpreter (Campbell; 1993), the degree of detail employed in this study was set by the classification used (Table 4.1).

A number of visits to the study area were made to identify the land use/cover classes occurring in the study area. From these visits it was easy to interpret the aerial photographs of the 2000. The earlier aerial photographs (1944, 1967 and 1989) were interpreted based on the experience gained in interpreting the 2000 aerial photographs and consultation of the farmers as there were no ancillary data such as agricultural census and land ownership documents that might help for interpretation.

For land use/cover data needed for planning and management purposes, the accuracy of interpretation at classification levels I and II is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time (Lillesand and Kiefer, 2000; Fairbanks and Thompson, 1996). In this study every effort was made to reduce the errors that might have occurred due to misinterpretation. First, the interpretation was based on the ground truthing made before interpreting the land use/cover classes of the study area. In addition, to arrive at consistent interpretation the author interpreted all the scanned aerial photographs before establishing the historical land use/cover databases. So, the land use/cover databases developed in this study can be used for planning and management purposes as great precautions were taken in preparing them.

4.3.3 Digitizing

Digitizing of vectors refers to the creation of vector data from hardcopy materials or raster images that are traced using a digitizer keypad on a digitizing tablet or an on-screen

displayed image (Hohl, 1998). Digitizing enables us to digitize certain features of a map or a photograph, such as land use/cover classes, voting districts, soil class boundaries and so forth.

On-screen digitizing is an interactive process in which a map is created using previously digitized or scanned information as a background (ESRI, 1998). On-screen digitizing is more comfortable, accurate, faster, less expensive, and enables to get more information relative to digitizing tablet (MiraMon, 2002). In this study on-screen digitizing using ArcView 3.2 (ESRI, 1998) was used to trace land use/cover features from the scanned and mosaicked aerial photographs. For every year (1944, 1967, 1989, and 2000) the mosaicked aerial photographs were digitized separately to create accurate polygons of carefully interpreted land use/cover classes.

4.3.4 Projecting the Land Use/Cover Maps

Map projections refer to the representation of a spherical earth onto a flat medium (paper or computer screen) (ESRI, 1998; Department of land Affairs, 1997b). One of the ways of assessing changes in land use/cover pattern is to calculate the areal coverage of the land use/cover classes at different periods. Thus selection of suitable map projection was needed to assess the land use/cover change patterns in Albert Falls Area.

From 1999 the National Mapping in South Africa was decided to be based on a Gauss Conform Projected Coordinate System based on the hartesbeehoek94 (Hart94) datum which uses WGS84 as a reference ellipsoid (Wonnacott, 1997). The South African National Mapping is based on 2° to minimize the distortions in the areas of features as the distance from points of 'zero distortion' (central meridian for each mapping zone) is relatively small. Thus, the National Mapping system of South Africa was used in this study as it can be used comfortably to measure areas with negligible repercussions.

4.3.5 Editing

Once the digitizing was complete in ArcView 3.2 it was necessary to close the arcs to form polygons of related land use/cover classes. PC ArcInfo 3.5.1 (ESRI, 1996) was used

to build topology of the digitized polylines. When the topology was built the digitizing errors including overshoots, undershoots and other error were identified using PC ArcInfo 3.5.1 (ESRI, 1996). Then the ArcInfo coverage was converted to ArcView shapefile to fix the digitizing errors. Setting a snap tolerance of 5m all the errors were fixed manually. Finally the land use/cover databases were created in both ArcInfo coverage and ArcView shapefile.

Most of the editing including entering new attribute tables, mathematical calculations, and modification of the land use/cover polygons were done in ArcView shapefiles. But the final land use/cover databases were created in both ArcInfo coverage and ArcView shapefiles for ease of using the data for further applications.

4.4 Mapping Errors and Accuracy Measures

Maps created using GIS may possess significant amounts of errors (Hohl, 1998). If certain precautions are taken some errors can be avoided, minimized or corrected by accepting high standards in preparation and editing maps (Chrisman, 1991; Campbell, 1993). In spatial data errors generally concerns mistakes or variations in the measurement of position and elevation, in the measurement of quantitative attributes and in the labeling or classification of features (Veregen, 1999; Fisher, 1991;Weir *et al.*, 2001).

In remotely sensed data, a considerable effort is required to assess the accuracy of the interpretation and classification procedures (Campbell, 1993). The purpose of accuracy assessment is to allow a potential user determine the map's fitness for use for their particular applications (Fisher, 1991). The extent to which the errors and other shortcomings of a dataset affect decision-making depends on the purpose for which the data is to be used (Veregen, 1999; Weir *et al.*, 2001;). Therefore, any spatial dataset of a lesser accuracy can be accepted as long as the errors are within acceptable limits (standards).

The classification or labeling error were minimal as every land use/cover type in the study area was identified, and interpreted before digitizing guided by the orthophoto and

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use of a Global Positioning System, and farmers consultation. Moreover, a routine checking of labels was done in coding the attributes.

There is no detailed South African land use/cover map accuracy standard (Clarke *et al.*, 1988) of acceptable positional error relative to the scale of aerial photography used. In this study the possible sources of positional errors were georectification and mosaicking of the aerial photographs. The positional error from georectification and mosaicking was not significant as the total Root Mean Square error of the different years was in the range of 5 to 20m relative to the Orthophoto of the same area.

The positional error that arises from converting spatial data to digital format was so minimal as on-screen digitizing was used to delineate the boundary of the land use/cover classes on maps. This positional error of this study was considered negligible relative to the scale of the aerial photograph used and the detail of land use/cover classification employed in this study.

In this study except errors resulting from the complexity of the landscape (Mitchel, 1981; Carver, 1981), which demanded great efforts to georectify the aerial photographs, every effort was made to keep the accuracy of the historical databases developed to make them useful for decision makings and further studies.

4.5 Land Use/Cover Change Analysis

Once the mapping of land use/cover of Albert Falls Area was complete, the total area of each land use/cover class was calculated by running the summary function in ArcView 3.2 (ESRI, 1998). The summary tables were exported to Microsoft Excel for further analysis where changes in land use/cover over the study period were quantified.

This chapter described all the materials and methods employed to develop the historical land use/cover maps of Albert Falls Area. The overall procedures followed in this study are summarized in a flow chart diagram shown in Figure 4.1. Chapter five will present the results of the study and provide relevant discussions.
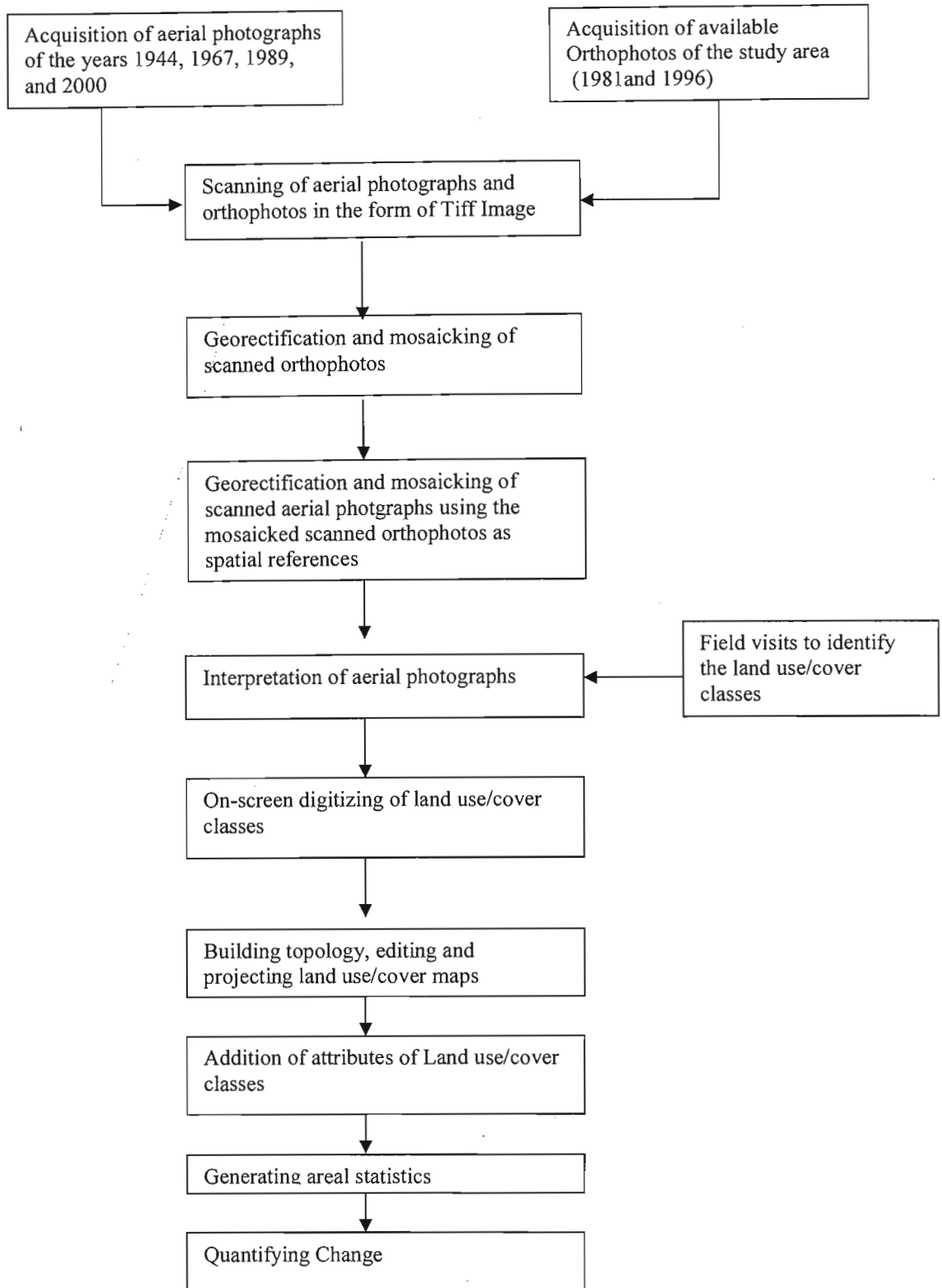
```
┌─────────────────────────────┐                    ┌─────────────────────────────┐
│ Acquisition of aerial       │                    │ Acquisition of available    │
│ photographs                 │                    │ Orthophotos of the study    │
│ of the years 1944, 1967,    │                    │ area                        │
│ 1989, and 2000              │                    │ (1981and 1996)              │
└─────────────────────────────┘                    └─────────────────────────────┘
              │                                                    │
              │           ┌──────────────────────────────┐        │
              └──────────▶│ Scanning of aerial photographs│◀───────┘
                          │ and orthophotos in the form of│
                          │ Tiff Image                    │
                          └──────────────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ Georectification and mosaicking│
                          │ of scanned orthophotos        │
                          └──────────────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ Georectification and mosaicking│
                          │ of scanned aerial photgraphs  │
                          │ using the mosaicked scanned   │
                          │ orthophotos as spatial        │
                          │ references                    │
                          └──────────────────────────────┘
                                       │
                                       ▼                        ┌──────────────────────┐
                          ┌──────────────────────────────┐      │ Field visits to       │
                          │ Interpretation of aerial      │◀─────│ identify the land     │
                          │ photographs                   │      │ use/cover classes     │
                          └──────────────────────────────┘      └──────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ On-screen digitizing of land  │
                          │ use/cover classes             │
                          └──────────────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ Building topology, editing and│
                          │ projecting land use/cover maps│
                          └──────────────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ Addition of attributes of Land│
                          │ use/cover classes             │
                          └──────────────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ Generating areal statistics   │
                          └──────────────────────────────┘
                                       │
                                       ▼
                          ┌──────────────────────────────┐
                          │ Quantifying Change            │
                          └──────────────────────────────┘
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Figure 4.1 Summary of the steps followed to develop the historical land use/cover databases and maps

Chapter Five: Results and Discussion

5.1 Introduction

Aerial photographs of different scales have been used for the development of the historical land use/cover databases of Albert Falls Area for the years 1944, 1967, 1989, and 2000. Level I Land use/cover maps of the study area produced from these databases are shown in Figure 5.1 (1944), Figure 5.2 (1967), Figure 5.3 (1967), and Figure 5.4 (2000). The various interpreted land use/cover classes, their areal extents and percentage coverages in the study area over the specified years are presented in Table 5.1.

Commercial Forestry, Cultivated Lands, and Barren Lands covered Albert Falls Area dominantly in 1944. These classes collectively were covering more than three-fifth of Albert Falls Area. In 1967 Commercial Forestry covered almost one-third of Albert Falls Area at the expense of Barren Lands and Cultivated Lands. The encroachment of indigenous forests to Grasslands had almost doubled the areas covered by Indigenous Forests in 1989. Areas covered by Waterbodies increased dramatically in 1989 thus reducing areas covered by Cultivated Lands. In 2000 there were only slight changes in the different land use/cover classes compared to the 1989 land use/cover classes.

A description of the changes in land use/cover patterns will follow accompanied by discussions of the observed trends.

5.2 Changing Patterns of Level I Land Use/Cover Classes

The major land use/cover level I classes showed tremendous changes from 1944 to 2000 (Table 5.1). The coverage of Indigenous Forests, Commercial Forestry, and Waterbodies had increased since 1944 (Figure 5.5). On the other hand, the areal coverages of Grasslands, Cultivated Lands, Built-Up Lands, and Barren Lands showed decreasing trends (Figure 5.6). However, it is possible that an overall increase in level I land use/cover classes my obscure a decreasing trend in one or two level II classes and vice versa.
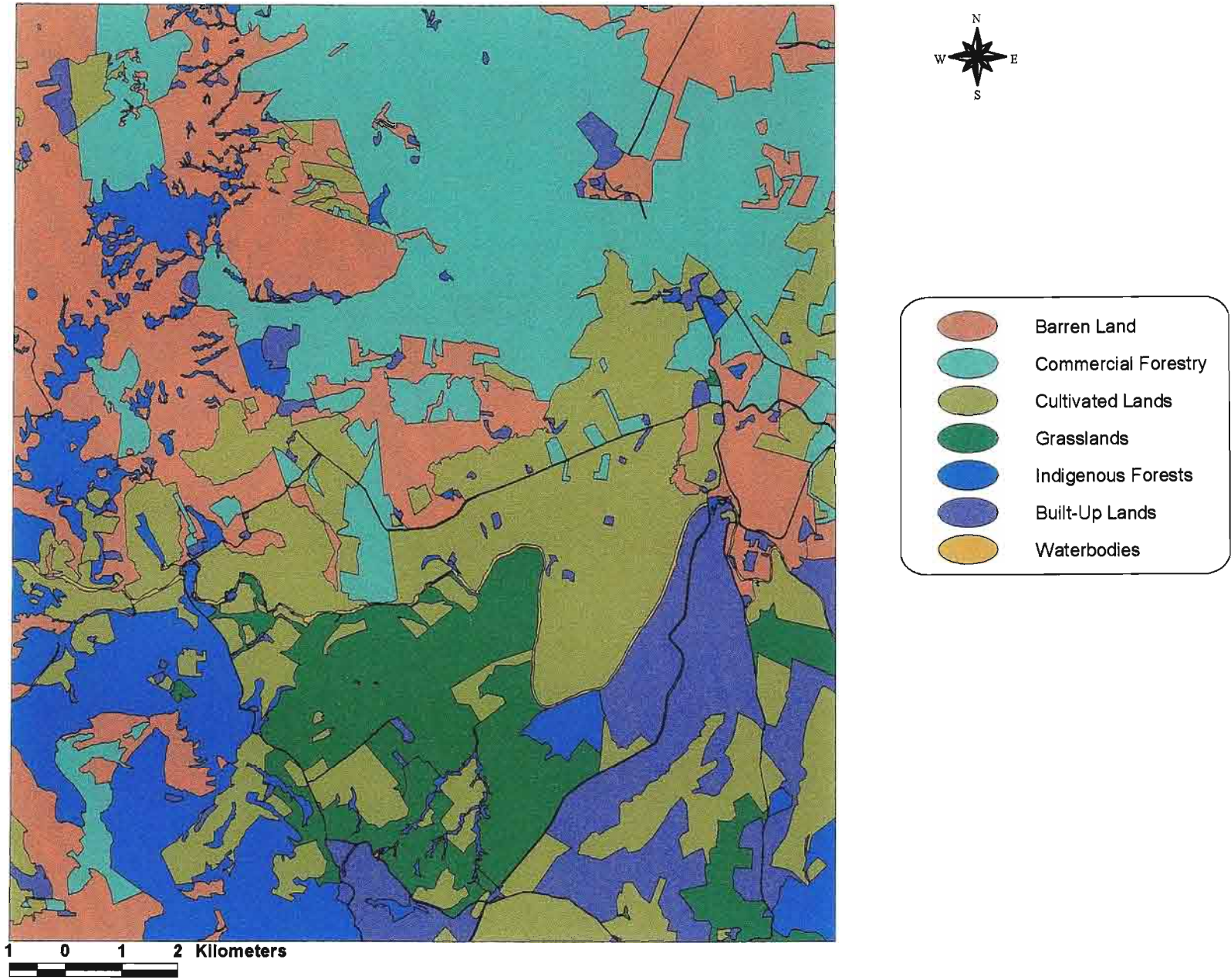
Fig 5.1. 1944 Level I Land Use/Cover Map

Fig 5.2 1967 Land Use/Cover Map
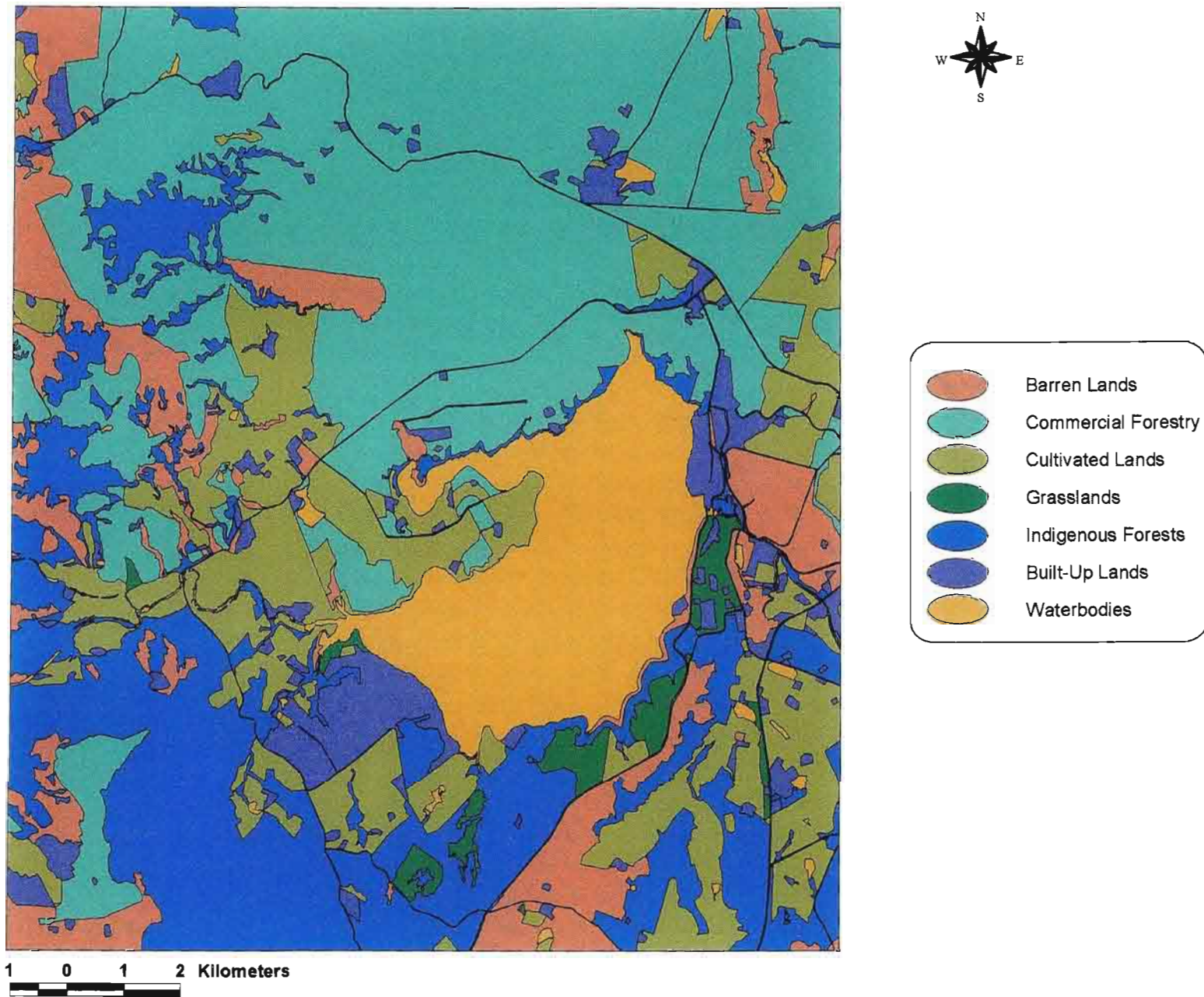
Fig 5.3. 1989 Land Use/Cover Map
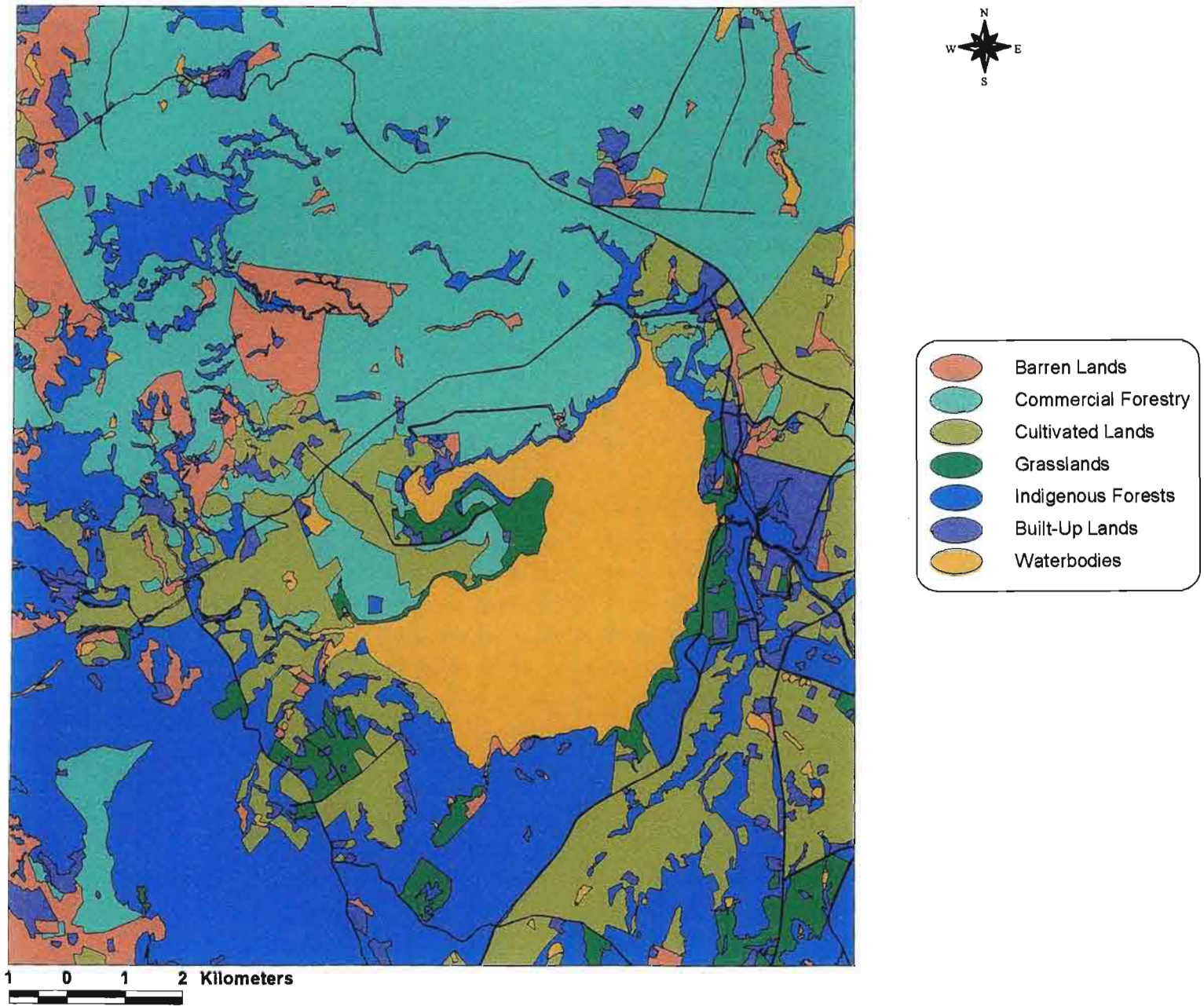
Fig 5.4. 2000 Land Use/Cover Map

Table 5.1 Summary areal coverages and percentages of level I land use/cover classes

Land Use/Cover classes	Years							
	1944		1967		1989		2000	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Indigenous Forests	2923.26	11.85	2573.99	10.43	4963.11	20.11	6088.31	24.67
Grasslands	2280.60	9.24	2773.51	11.24	396.70	1.61	823.38	3.34
Commercial Forestry	6034.58	24.45	8898.29	36.06	8940.00	36.23	8526.79	34.55
Cultivated Land	5688.42	23.05	4143.66	16.79	3943.23	15.98	3879.68	15.72
Built-Up	2246.84	9.10	1289.24	5.22	1487.25	6.03	1143.97	4.64
Waterbodies	106.31	0.43	323.18	1.31	2519.95	10.21	2533.55	10.27
Barren Lands	5398.96	21.88	4677.09	18.95	2428.66	9.84	1683.27	6.82

The increase of Indigenous Forests could be attributed to the establishment of Albert Falls Nature Reserve and the policies adopted by governmental departments to protect the remaining indigenous forests. The increase of Commercial Forestry might be attributed to the economic importance of the forestry industry. The increase of Waterbodies could be attributed to the construction of dams.

The decrease of Grasslands might be due to the gradual transformations of some areas into Indigenous Forests or other land use/cover activities. Cultivated Lands and Barren Lands showed a decreasing trend probably due to the conversion of the land areas either to Commercial Forestry or being impounded by Waterbodies. The decreasing trend in Built-up area could be attributed to the agricultural structuring that had occurred in the area.
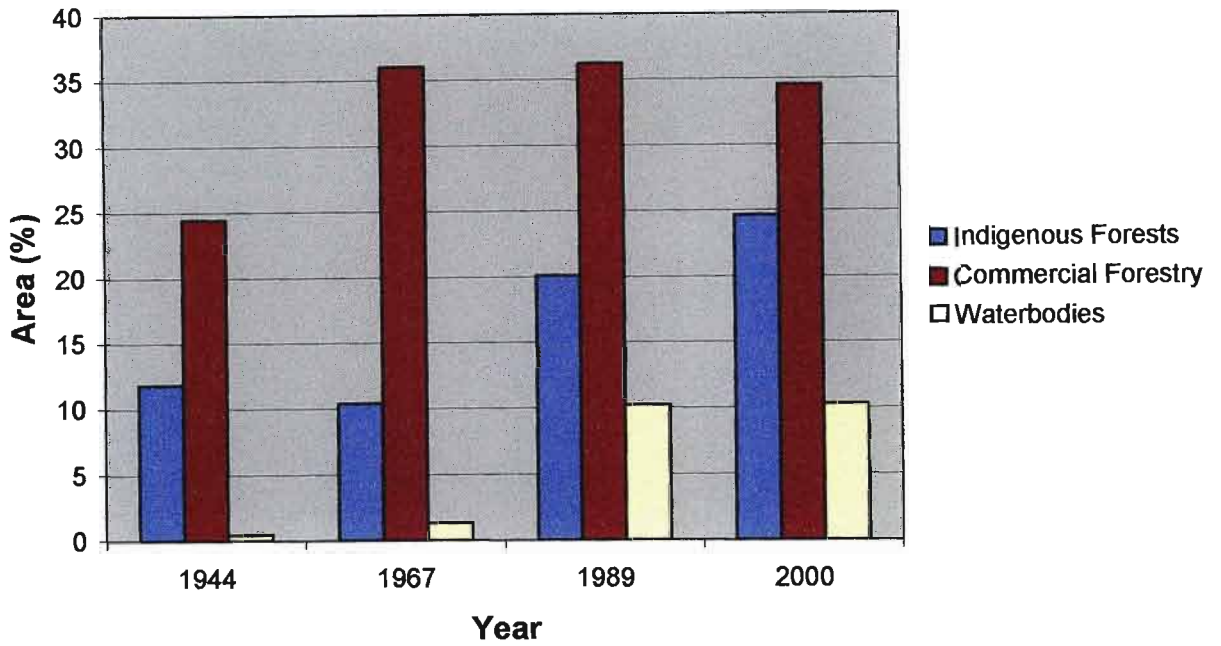
Figure 5.5 Percentage coverages of level I land use/cover classes that showed increasing trends
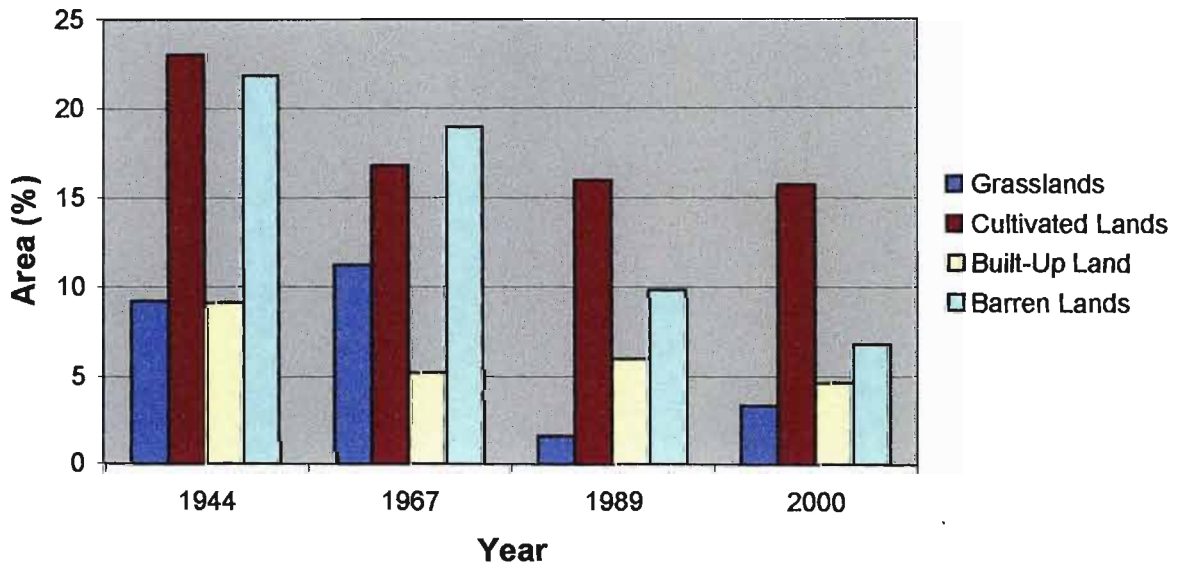
Figure 5.6 Percentage coverage of Level I land use/cover classes that showed decreasing trends

5.3 Changing Patterns of Level II Land Use/Cover Classes

Aerial photographs of different scales have been used for the development of the historical land use/cover databases of Albert Falls Area for the years 1944, 1967, 1989, and 2000. Level II Land use/cover maps of the study area produced from these databases are shown in Figure 5.7 (1944), Figure 5.8 (1967), Figure 5.9 (1967), and Figure 5.10 (2000). The various interpreted land use/cover classes, their areal extents and percentage coverages in the study area over the specified years are presented in Table 5.2.

Legend:
- Bare Land
- Clear Felled
- Forest Plantations
- Cultivated Land
- Dam
- Degraded Land
- Farm Pond
- Grassland
- Woodland
- Non-Residential Area
- Residential Area
- River Water
- Valley Thicket/Bushland
- Transportation Routes
- Sugarcane
- Wooded Grassland

Scale: 1 0 1 2 Kilometers

Figure 5.1 1944 Land use/cover map of the study area

Bare Land
Clear Felled
Forest Plantations
Cultivated Land
Dam
Degraded Land
Farm Pond
Grassland
Woodland
Non-Residential Area
Residential Area
River Water
Valley Thicket/Bushland
Transportation Routes
Sugarcane
Wooded Grassland

Figure 5.2 1967 Land Use/Cover Map of the study area

Legend:
- Bare Land
- Clear Felled
- Forest Plantations
- Cultivated Land
- Dam
- Degraded Land
- Farm Pond
- Grassland
- Woodland
- Non-Residential Area
- Residential Area
- River Water
- Valley Thicket/Bushland
- Transportation Routes
- Sugarcane
- Wooded Grassland

1 0 1 2 Kilometers

Figure 5.3 1989 Land Use/Cover Map of the study area

N

Legend:
- Bare Land
- Clear Felled
- Forest Plantations
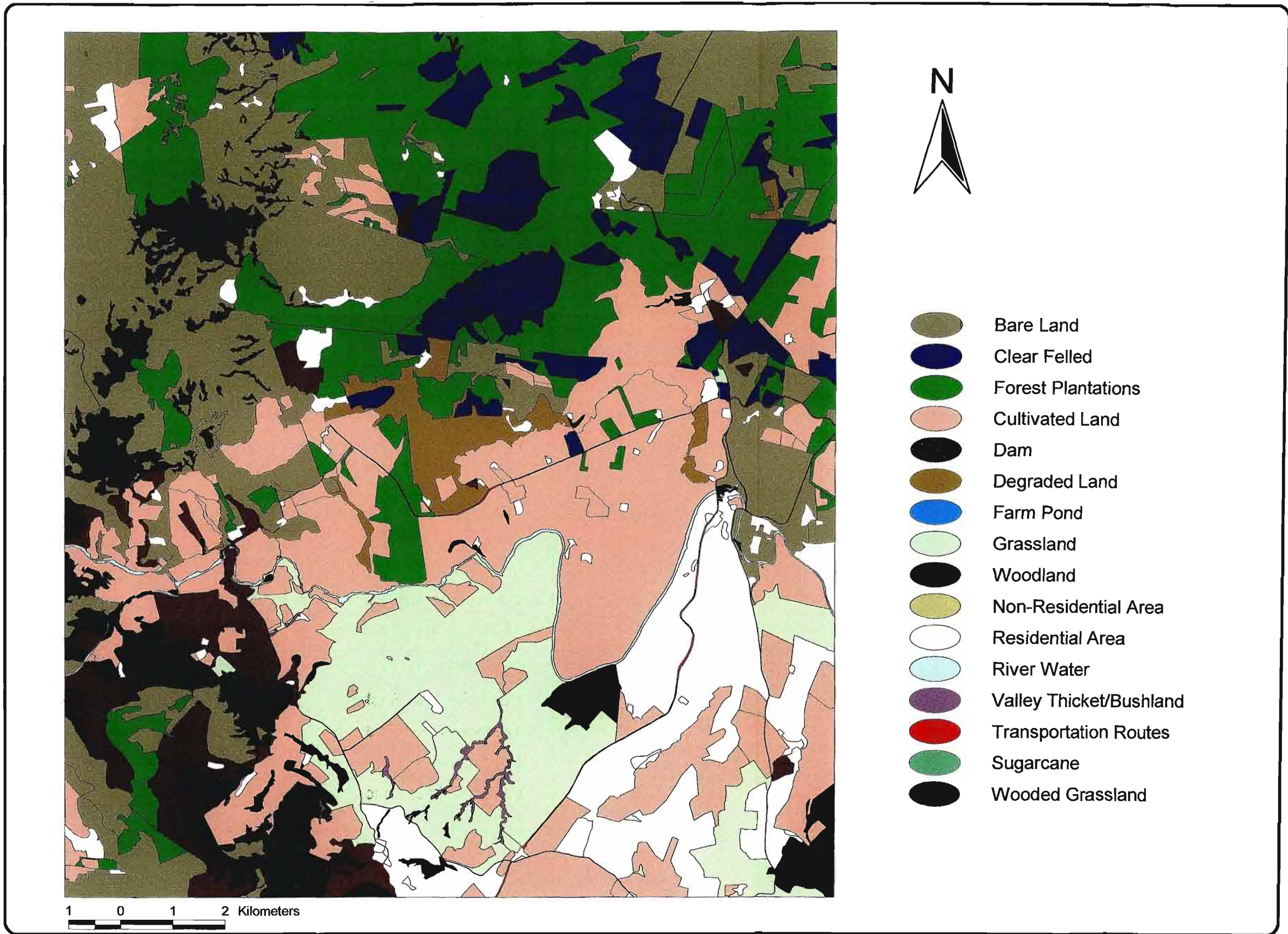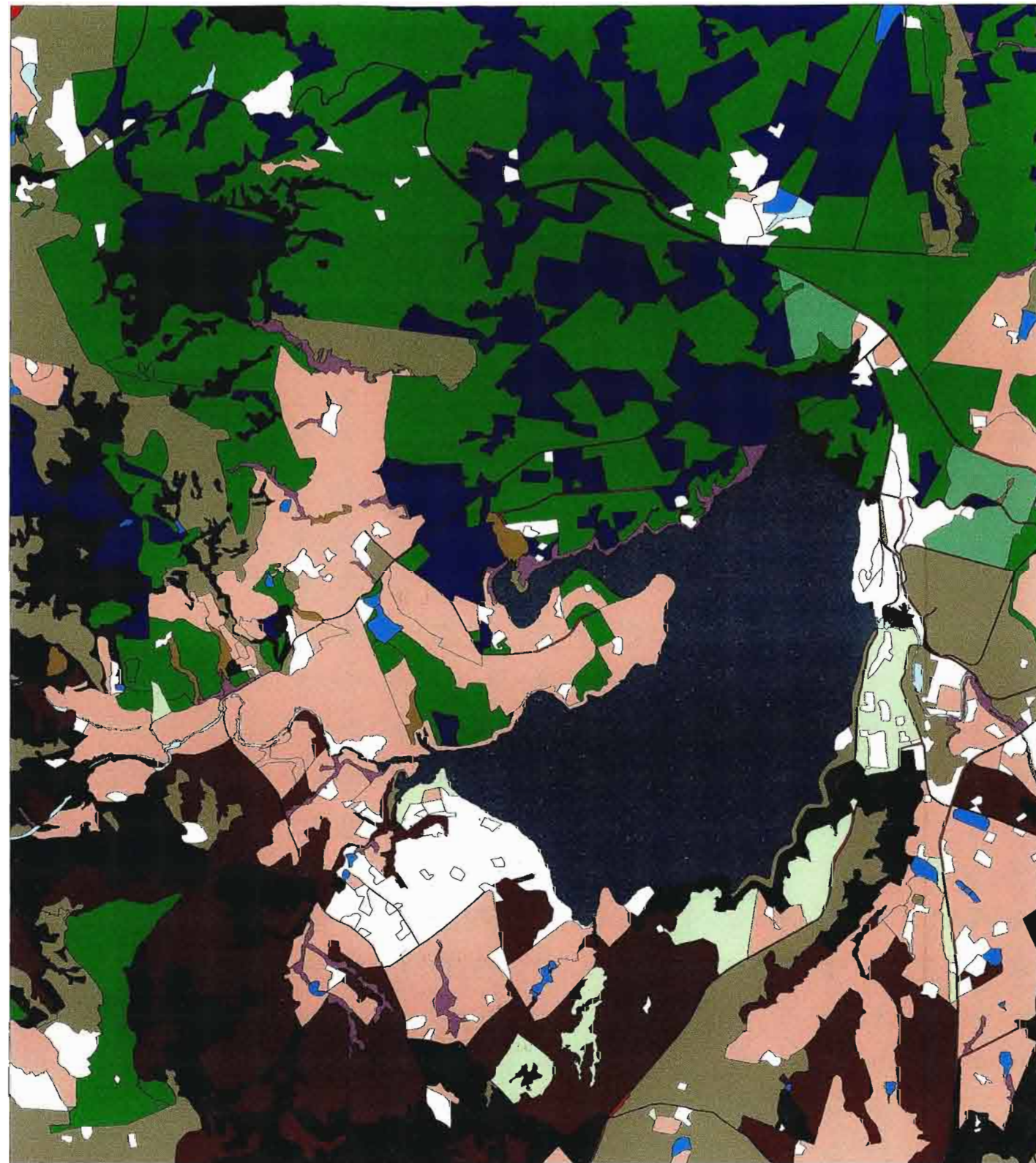- Cultivated Land
- Dam
- Degraded Land
- Farm Pond
- Grassland
- Woodland
- Non-Residential Area
- Residential Area
- River Water
- Valley Thicket/Bushland
- Transportation Routes
- Sugarcane
- Wooded Grassland

1   0   1   2 Kilometers

Fig 5.4 Land Use/Cover Map for 2000 of the study area

Table 5.2 A summary table of areal coverage and percentage of the interpreted land use/cover classess

Land use/cover classess		Year							
		1944		1967		1989		2000	
Level I	Level II	Area(ha)	Percentage	Area(ha)	Percentage	Area(ha)	Percentage	Area(ha)	Percentage
Indigenous Forests	Woodland	1797.8603	7.28	1302.71	5.28	2443.89	9.90	4597.98	18.63
	Wooded Grassland	1072.26	4.34	1180.69	4.78	2301.96	9.33	1455.51	5.90
	Valley Thicket/Bushland	53.14	0.22	90.59	0.37	217.25	0.88	34.81	0.14
Grassland	Grassland	2280.60	9.24	2773.51	11.24	396.70	1.61	823.38	3.34
Commercial Forestry	Forest Plantation	4535.71	18.38	6765.20	27.41	6105.89	24.74	7141.68	28.94
	Clear Felled	1498.86	6.07	2133.09	8.64	2834.11	11.48	1385.11	5.61
Cultivated Land	Cultivated Land	5688.42	23.05	4143.66	16.79	3699.00	14.99	2234.49	9.05
	Sugarcane	0	0.00	0.00	0.00	244.23	0.99	1645.19	6.67
Built-Up Land	Residential Area	2158.08	8.74	1163.97	4.72	1268.81	5.14	938.31	3.80
	Non-Residential Area	10.84	0.04	1.46	0.01	57.22	0.23	43.97	0.18
	Transportation Routes	77.92	0.32	123.81	0.50	161.21	0.65	161.70	0.66
Waterbodies	Dams	0	0.00	26.19	0.11	2344.59	9.50	2342.13	9.49
	Farm Ponds	0	0.00	2.80	0.01	112.76	0.46	120.49	0.49
	River Water	106.31	0.43	294.19	1.19	62.66	0.25	70.94	0.29
Barren Lands	Bare Lands	4916.97	19.92	4171.37	16.90	2359.41	9.56	1470.03	5.96
	Degraded Lands	481.98	1.95	505.70	2.05	69.25	0.28	213.24	0.86
Total		24678.96	100	24678.96	100	24678.96	100	24678.96	100

5.3.1 Indigenous Forests

For the purposes of this study the indigenous forests have been classified into three classes (Table 5.3). These are Woodland, Wooded Grassland, and Valley Thicket/Bushland.

Table 5.3 A summary table of areal coverages and percentages of Indigenous Forest in Albert Falls Area.

Land use/cover classes	Year							
	1944		1967		1989		2000	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Woodland	1,797.86	7.28	1302.71	5.28	2443.89	9.90	4597.98	18.63
Wooded Grassland	1072.26	4.34	1180.69	4.78	2301.96	9.33	1455.51	5.90
Valley Thicket/Bushland	53.14	0.22	90.59	0.37	217.25	0.88	34.81	0.14

5.3.1.1 Woodland

Woodland occupied 1797.86 ha (7.29%) of Albert Falls Area in 1944 (Table 5.3). The Woodland composition decreased slightly to 1302.71 ha (5.28%) cover in 1967, but occupied an area of 2443.89 ha (9.90%) of the total area in 1989. Woodland forest was almost doubled by the year 2000 covering an area of 4597.98 ha (18.63%) compared to its coverages in 1989. This dramatic increase could be attributed to the development of Woodlands in Albert Falls Nature Reserve and policies adopted by the government to protect the remaining indigenous forests. A typical example of Woodland is shown in Plate 1.

Moll (1976) identified Woodland Vegetation as occurring in the north and northeast of the study area and around Albert Falls Dam. Moll (1976) also identified the following plants as common tree species in the area: *Acacia sieberana, Apodytes dimidiata, Fagara capensis, Rubus cbirin, Cussonia spicata, Albizia adiantbifolia,*

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Plate 1. Woodland area in the eastern side of Binchester Grange

Croton sylvaticus, Turraeaida, Sclerocarya caffra, Acacia gerrardii, Ekebergia capensis, Erithrina caffra, Ficus capensis, Ziziphus mucronata and *Millettia grandis*. However, Camp (1999) repeated that much of the woodland had been encroached by species such as *Acacia karoo, A. nilotica, Ziziphus mucronata, Maytenus heterophylla, Brachylaena elliptica, Erythrina latissima, Cussonia spicata, Aloe candelabrum, Euphorbia ingens, Rhus pentheri, Grewia occidentalis* and *Ehretia rigida*. It appears that woodlands did not just increase in size over the years, but they also experienced an increase in species composition.

5.3.1.2 Wooded Grassland

Wooded Grassland (e.g. Plate 2) in Albert Falls Area occupied 1072.26 ha which was 4.34% of the total area in 1944 (Table 5.3). This proportion increased to 1180.69 ha in 1967 which was 4.78% of the total area. This increase might be due to the encroachment of Wooded Grassland into Grassland. The proportion of Wooded Grassland almost doubled occupying an area of 2301.95 ha in 1989 which covered 9.33% of the total area. The establishment of Albert Falls Nature Reserve and government policies directed to protect the indigenous forests had contributed to this increase. The Wooded Grassland coverage in Albert Falls Area was reduced to 1455.51 ha in the year of 2000 covering

5.90% of the total area. This change could be attributed to the transformation of Wooded Grasslands to Woodlands.
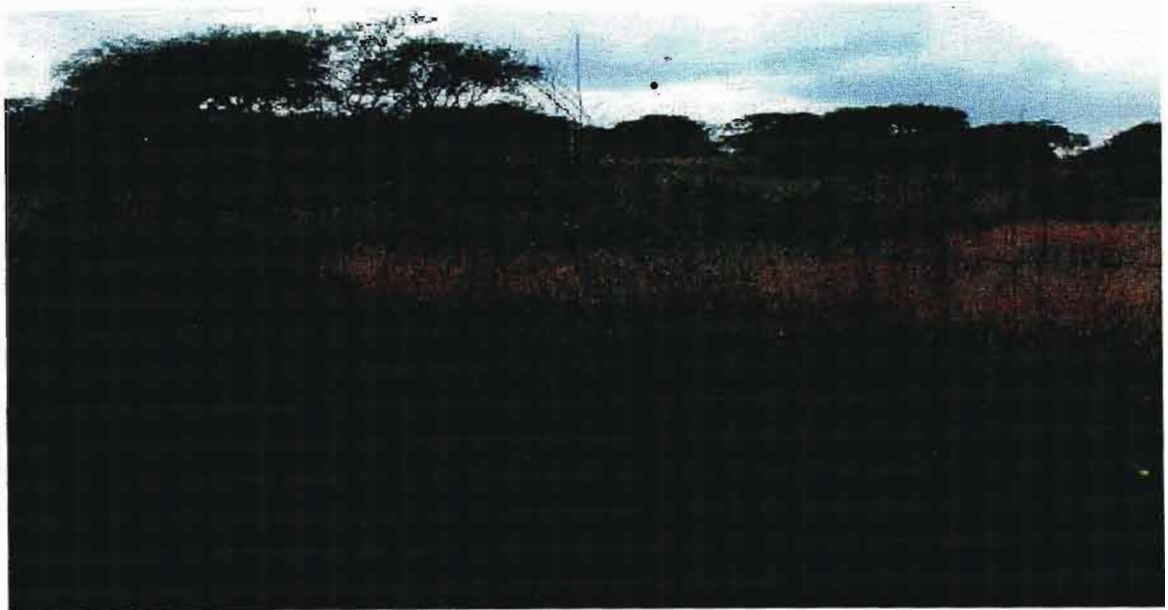
Plate 2. A closer view of Wooded Grassland in Wind Ridge

Moll (1976) identified Wooded Grassland in the southern part of the study area as Acacia Wooded Grassland and scrub. Whereas those in the north and northeast of the study area and around Albert Falls Dam area comprised of *Acacia sieberana* Wooded Grasslands with secondary *Aristida juniciformis* understorey. He claimed there had been changes in the type of species in these vegetation classes attributed to either increase in the density of the woody plant species, reduced intensity of grass either by fires or overgrazing, and/or soil erosion resulting in encroachment of woody species, mainly Acacia species. Camp (1999) identified patterns of Wooded Grassland in the study area to be characterized by the following dominant species: *Paperbark acacia, Acacia sieberana, Acacia karoo* and *Acacia nilotica.*

5.3.1.3 Valley Thicket/Bushland

The Valley Thicket/Bushland (Plate 3) covered an area of 53.14 ha in 1944 which is 0.22% of the total area (Table 5.3). This cover was increased to 90.59 ha (0.37%) in

1967. The aerial coverage of Valley Thicket/Bushland increased to an area of 217.25 ha (0.88%). This continuous increase could be attributed either to the encroachment of woody plants from the nearby indigenous forests or encroachment of alien vegetation types in the riverbanks due to the development of commercial forestry in the study area. The percentage of this vegetation type was decreased by the year 2000 to 34.81 (0.14%). The encroachment of Woodland around the river valleys had contributed to this decrease (Plate 4).

Plate 3. Valley Thicket/Bushland invaded by alien species in the upstream side of Albert Falls Dam

Moll (1976) identified the Valley Thicket/Bushland as Fringing Forest (Valley Bushveld) occurring in the northern and northeast of the study area, and around Albert Falls Dam area. Typical trees representing the Valley Thicket/Bushland were *Celtis africana, Ficus capensis, Bridelia micrantba, Combretum erytbropbyllum, Syzygium cordatum, Combretum kraussii, Macaranga capensis* and *Rauvolfia caffra* (Moll, 1976).
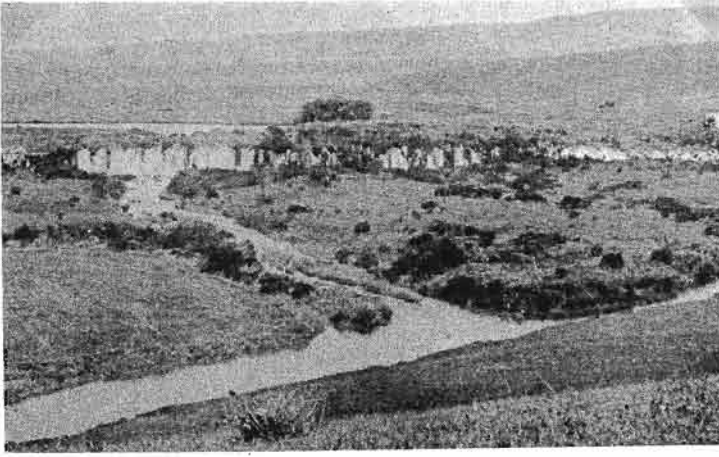
Plate 4. The increase of Woody plant communities in downstream of Albert Falls Dam (a) 1917; (b) 1953; (c) 1965 (Source: Moll, 1976)

According to Camp (1999) the Valley Thicket/Bushland were invaded by some problem plants both alien and indigenous that occur in the study area which include *Lippia javanica, Dichrostachys cinerea, Lantana camara* and *Solanum mauritianum.*

Generally the level II classes of Indigenous Forests showed increasing trends during the period 1944 to 2000 (Figure 5.11). This increase could be attributed to the efforts made by different governmental departments, and policies formulated to protect the small patches of indigenous forests in the country (Porter, 1990). Moreover, the development of commercial forestry that helped to substitute the timber requirements of the area might have contributed towards protection of indigenous forests (Cooper, 1990).

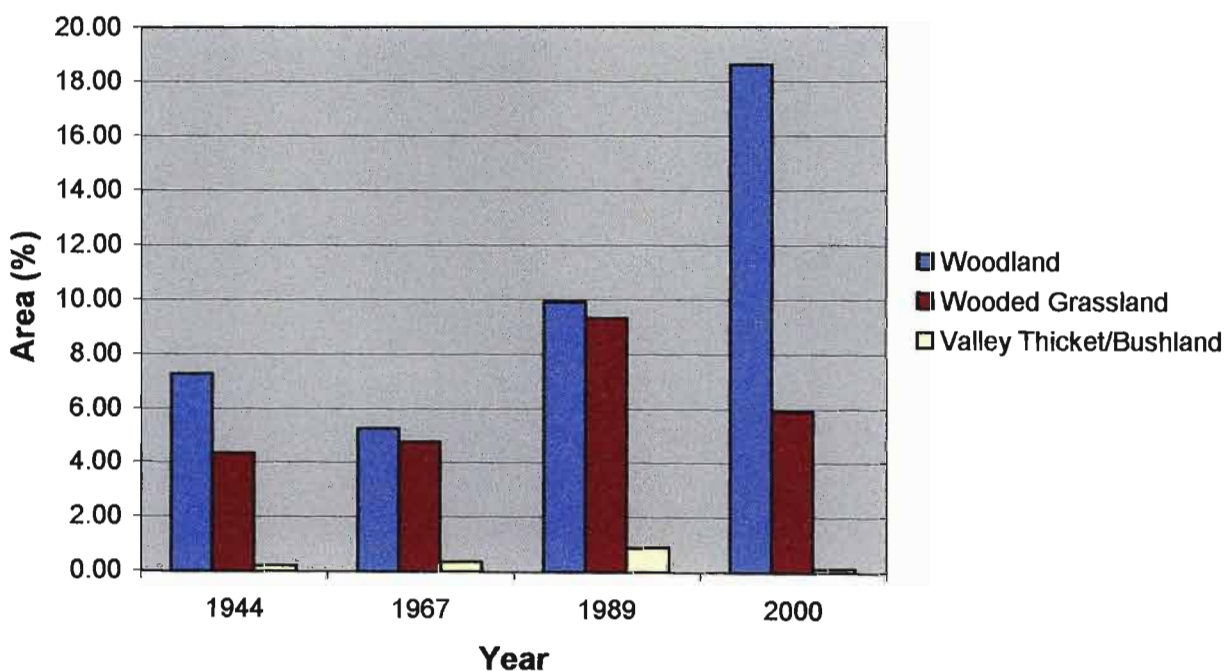Figure 5.11 Historical changing patterns of areal percentages covered by Indigenous Forests

The development of formal conservation areas by the South African National Parks also played a greater role for the conservation of indigenous forests (Cooper, 1990). Albert Falls Nature Reserve is one of the conservation areas that contributed towards higher percentage coverage of indigenous forests in the Albert Falls Area.

5.3.2 Grassland

According to South African land use/cover classification system Grassland is categorized into Improved (e.g. Plate 5) and Unimproved Grassland. In this study Improved and Unimproved grassland were grouped in the same class.

Plate 5. Domestic animals grazing on Improved Grassland in De Jong Ranch

Grasslands in 1944 occupied an area of 2280.60 ha which was 9.24% of the total area (Table 5.2). This proportion increased in 1967 to 2773.51 ha or 11.24% which could be attributed to the increase of dairy farming and ranching in the area (Horwood, 1967, Natal Town and Regional Planning Commission, 1973). The Grassland area decreased to 396.70 ha which was 1.61% of the total area in 1989. The possible reasons for this decrease could be due to the conversion of some Grassland either to Commercial Forestry or Cultivated Land. The aerial coverage of Grassland was 823.38 ha, i.e. 3.34% of the whole Albert Falls Area, in 2000.

Moll (1976) identified Grassland in the northwest and small portion of the southwest of the study area as Mistbelt *Themeda-Aristida* Grassland. In the northern and northeast of the study area, and around Albert Falls Dam area, Moll (1976) stated that *Aristida*

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junciformis dominates in severely disturbed grasslands. Similarly, Camp (1999) identified the grassland in Albert Falls Area to be characterized by secondary Grassland dominated by unpalatable Ngongoni grass, *Aristida junciformis* although some palatable species occur under good condition veld.

Moll (1976) and Camp (1999) claimed the development of poor quality Grassland in the study area was a result of poor management practices which included excessive burning, followed by continuous selective over-grazing. These practices have resulted in the replacement of the palatable grass species by hardy pioneer species such as *Aristida junciformis, Eragrostis plana, Sporobolus africanus* and *Hyparrhenia hirta*.

5.3.3 Commercial Forestry

Forest plantation has been the largest land use/cover class in Albert Falls Area. Wattles, gums (Plate 6), pines, and little poplar are some of the commercial plantations grown in the area (Horwood, 1967; Camp, 1990). Commercial Forestry has been a revenue-earning enterprise and is also used to fulfill domestic demands (e.g. building materials and fuel wood). Thus Commercial Forestry plays an indirect role in protecting the available indigenous forests (Edwards, 1990; Cooper, 1990).

Forestry Plantation covered an area 4535.71 which is 18.38% of the total area, while Clear Felled occupied 18.38 (6.07%) in 1944 (Table 5.4). In 1967 the area coverage under Forest Plantation occupied 6765.20 ha (27.41%) while Clear Felled compartment occupied 2133.09 ha (8.64%). Since Commercial Forestry had been predominantly export oriented and affected by world markets the increase in 1967 might be attributed to the high prices received in the export market (Horwood, 1967). The total area covered by Commercial Forestry slightly increased around 1989 from which areas covered by Forest Plantations amounted to 6105.89 ha (24.74%) whereas the areas under Clear Felled forest occupied 2834.11ha(11.48%).
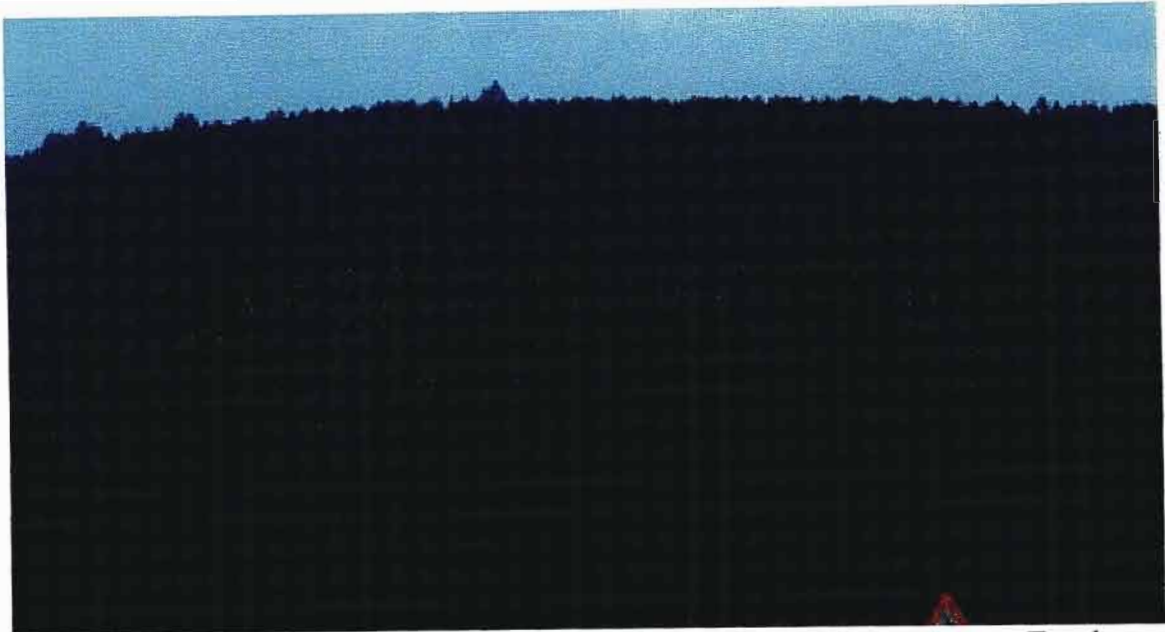
Plate 6. An example of a newly cleared felled compartment near a Eucalyptus plantation in the upstream side of Albert Falls Dam

Table 5.4 A summary table of areal coverages and percentages of Commercial Forestry in Albert Falls Area

| Land use/cover classes | Year | | | | | | | |
| | 1944 | | 1967 | | 1989 | | 2000 | |
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Forest Plantation	4535.71	18.38	6765.20	27.41	6105.89	24.74	7141.68	28.94
Clear Felled	1498.86	6.07	2133.09	8.64	2834.11	11.48	1385.11	5.61

The coverage under Forestry Plantation increased slightly in 2000 to 7141.68 ha (28.94%) of the total area. The Clear Felled area decreased to 1385.11 ha (5.61%). Generally areas under Commercial Forestry decreased slightly in 2000. This decrease in Commercial Forestry was not in line with the call by the Forestry Council in its Strategic Forestry Development plan (1989) to increase the area under forestry by 40,000 ha per annum from 1995 and by 35, 000 ha per annum thereafter until the year 2010 (Tarboton and Schulze, 1990). Generally areas under forestry showed an increasing trend during the period 1944 to 2000 (Figure 5.12).

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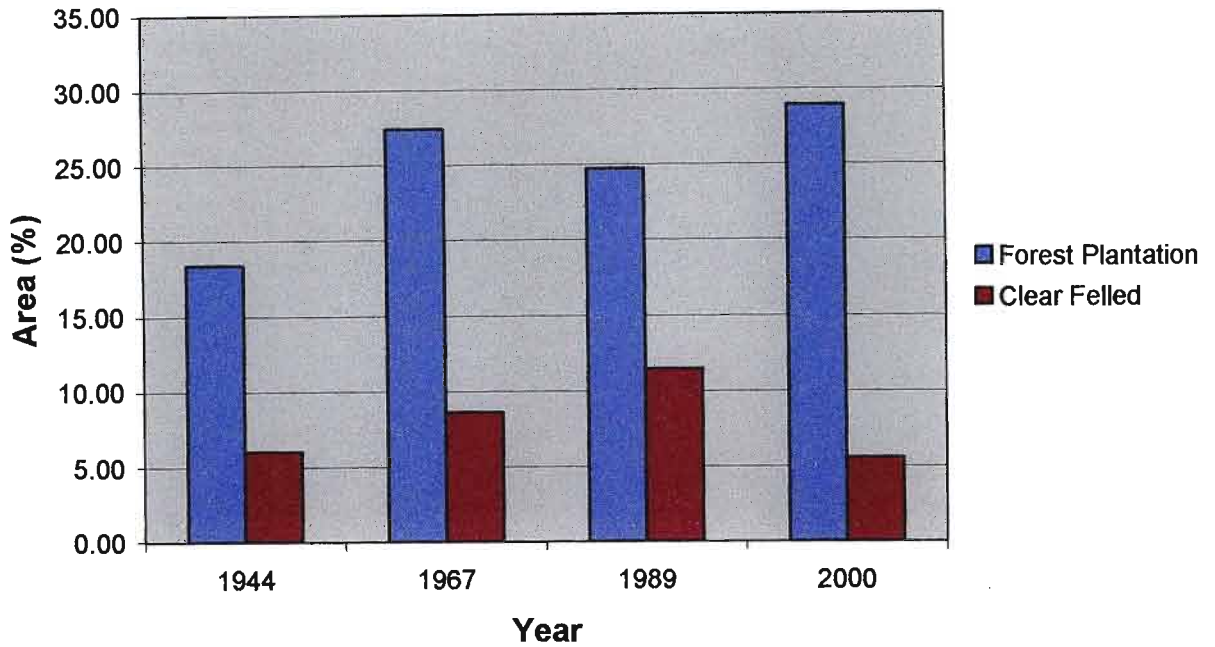
Figure 5.12 Historical changing patterns of areal percentages covered by Commercial Forestry

The popularity of Albert Falls Area for forestry plantations is due to its favorable climate and suitable soil, well developed transportation infrastructure, and proximity to Durban port for export (Edwards, 1990). Based on these factors the development strategy of the forestry industry has been focused on KwaZulu-Natal in general and Natal midlands in particular (Edwards, 1990). These forest plantations have enabled South Africa to be self-sufficient in its requirements for wood and timber in which only certain specialized timbers are imported; and become one of the main exporters of timber and other forest products (Cooper, 1990).

5.3.4 Cultivated Lands

5.3.4.1 Cultivated Land

In this study areas of land that are ploughed and/or prepared for raising crops with definite geometrical boundaries were categorized as Cultivated Land. The Cultivated Land class boundaries were defined to encompass the main areas of agricultural activity that include small inter-field cover types as well as farm infrastructure.

Cultivated Land occupied an area of 5688.42 ha during 1944 which was 23.05% of the total area (Table 5.5). This coverage dropped to 4143.66 ha or 16.79% in 1967. This trend continued and the total Cultivated Land decreased to 396.70 ha (1.61% of the total area) in 1989. The Cultivated Land increased dramatically and occupied 2234.49 ha or 9.05% of the total area in 2000. The results show that Cultivated Land generally reduced from the year of 1944 to 2000 (Figure 5.13). This decrease of Cultivated Land might be attributed to the conversion of these lands either to Commercial Forestry or Sugarcane plantations which are economically important; and impounding of lands by large water bodies like Albert Falls Dam and/or reserving the land for natural environment protection as in Albert Falls Nature Reserve.

Table 5.5 A summary table of areal coverages and percentages of Cultivated Lands in Albert Falls Area of area

Land use/cover classes	Year							
	1944		1967		1989		2000	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Cultivated Land	5688.42	23.05	4143.66	16.79	396.70	1.61	2234.49	9.05
Sugarcane	0	0	0	0	244.23	0.99	1645.19	6.67

5.3.4.2 Sugarcane

Sugarcane could have been classified as a Cultivated Land, but due to its economic importance it was classified as a sub-class of Cultivated Lands.

Sugarcane is grown on higher ground that is free of severe frost (Camp, 1999). Sugarcane entered the Natal Midlands in 1952 and it has since developed to a position where it produces a considerable percentage of the sugar industry's output (Ortman, 1974). However, in the assessment of the land use/cover changes of the area in 1944 and 1967 the author didn't identify any area as a sugar growing land. The interviews with the farmers confirmed that there were little or no Sugarcane plantations prior to 1967.
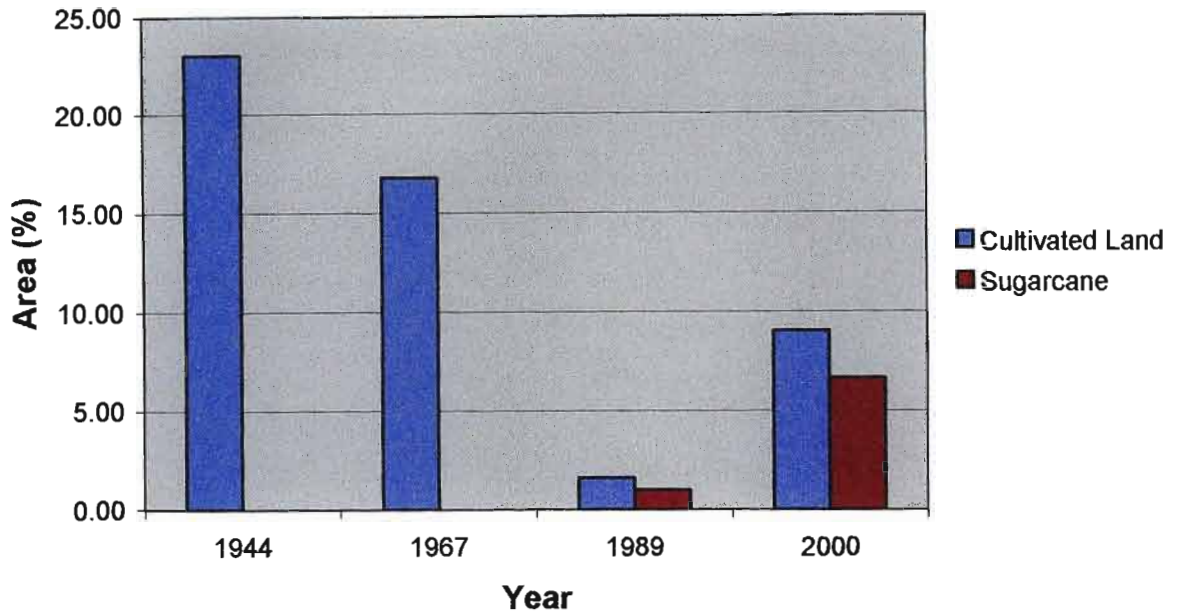
Figure 5.13 Historical changing patterns of areal percentages covered by Cultivated Lands

In 1989 areas under Sugarcane (Plate 7) identified by the author occupied a total area of 244.23 ha which is 0.99% of the total area (Table 5.5). This coverage increased to 1645.19 ha (6.67%) in 2000. This increase might be attributed to the economic importance of Sugarcane relative to other growing crops (Figure 5.13).

Sugar growers, along with all the other growers in South Africa are affected by national and international affairs, world market prices and the high tariff walls behind which the industry has developed (Ortman; 1974; Hudson, 1990). Consequently the expansion of Sugarcane plantation in Albert Falls Area could be attributed to the low prices paid for other alternative commercial farming for example wattle products, and the favorable economic trends in the sugar industry.

Plate 7. Sugarcane plantations near Crammond informal settlement area

5.3.5 Built-Up Land

In this study the Built-Up Land was subdivided into three classes: Residential Area, Non-Residential Area, and Transportation Routes (Table 5.6).

Table 5.6 A summary table of areal coverages and percentages of Built-Up Lands in Albert Falls Area

Land use/cover classes	Year							
	1944		1967		1989		2000	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Residential Area	2158.08	8.74	1163.97	4.72	1268.81	5.14	938.31	3.80
Non-Residential Area	10.84	0.04	1.46	0.01	57.22	0.23	43.97	0.18
Transportation Routes	77.92	0.32	123.81	0.50	161.21	0.65	161.70	0.66

5.3.5.1 Residential Area

The classification of this land use/cover class was based on the South African land use/cover classification systems. This class included both formal and informal settlement areas, ranging from high to low building densities.

As Albert Falls Area is an agricultural area, the relative coverage of Residential Area is small compared to the other land use/cover classes. The Residential Area showed a decreasing trend from the year 1944 to 2000 (Figure 5.14). Residential Area occupied 2158.08 ha which was 8.74% of the total area by the year of 1944 (Table 5.6). This coverage decreased to 1163.97 ha (4.72%) in 1967. This decrease could be attributed to the conversion of the scattered Residential Areas of 1944 to large-scale Commercial Forestry. The Residential Area coverage increased by a small proportion in 1989 occupying 1268.81 ha (5.14%).
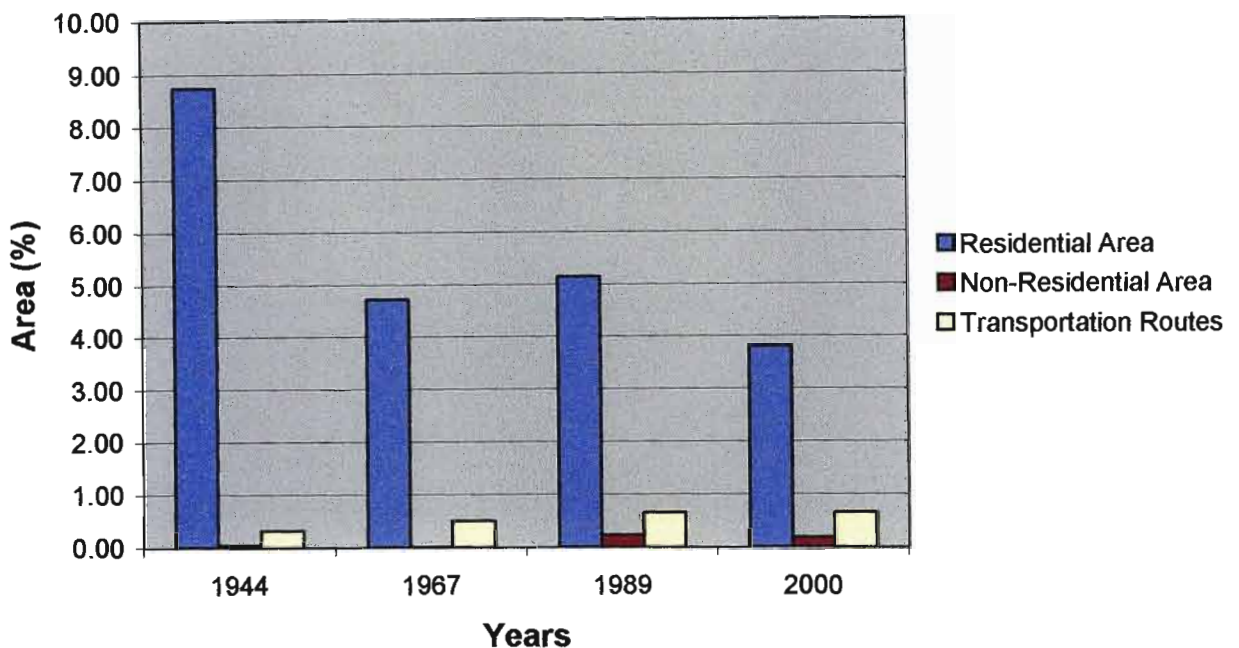
Figure 5.14 Historical changing patterns of areal percentages covered by Built-Up Land

Although there had been informal settlements around the urbanized areas the Residential Areas decreased to 938.31 ha which was 3.80% of the total land area in 2000. The decrease in Residential Area could be attributed to transformation of scattered settlements to concentrated residential areas and restructuring in the agricultural sector. For instance, there had been shifts in commercial agriculture from cultivation to commercial forest plantations, where the scattered settlements around the cultivated lands disappeared and were replaced by large commercial forestry plantations.

The informal settlements around Crammond (Plate 7) could be attributed to these activities in which the residents could have been farm workers displaced by agricultural restructuring.

5.3.5.2 Non-Residential Area

This class included Non-Residential Areas with major commercial agricultural activities (i.e. the manufacture and/or processing of goods or products). Examples would include chicken farming, dairying (Plate 8), and cattle ranching areas. Non-Residential Areas were treated as a sub-class due to their economic importance.
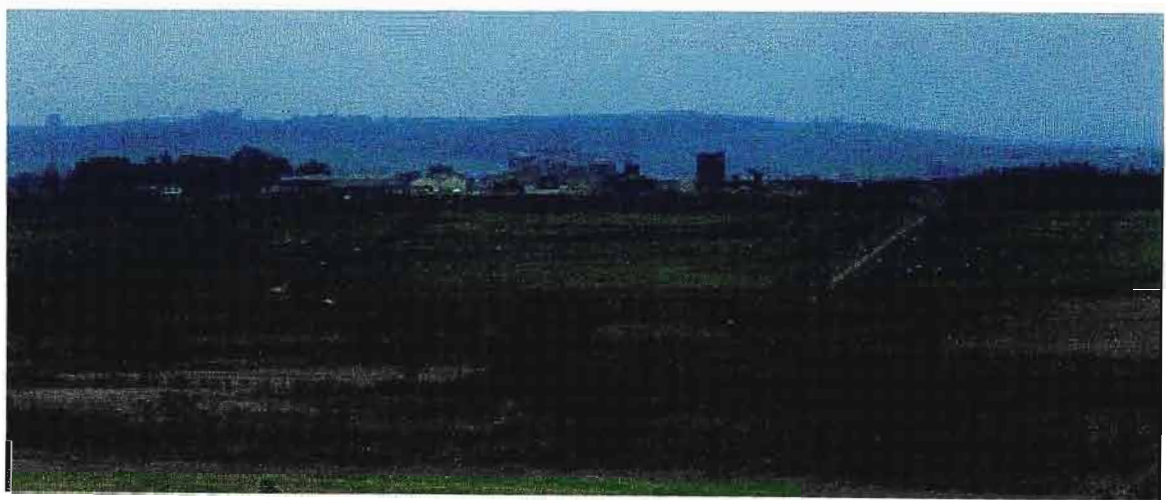
Plate 8. Dairy Farm in Umgeni Park (see Figure 3.2 for location)

Non-Residential Area occupied an area of 10.84 ha in 1944 constituting 0.04% of Albert Falls Area (Table 5.6). This proportion was decreased to 1.46 ha (0.01% of the total area). This reduction could be due to interpreting some of the Non-Residential Areas as Residential Areas. This land use/cover class increased slightly in 1989 covering an area of 57.22 ha (0.23%). The proportion of this land was decreased in 2000 to 43.97 ha (0.18%) of the total area.

Generally, Non-Residential Area showed a slight increasing trend (Figure 5.14) although this increase was relatively insignificant. This insignificant increase for Non-Residential

Area could be attributed to the proximity of Albert Falls Area to local markets, as most of these dairy and chicken farming enterprises cater for the needs of the populace within the Durban and Pietermaritzburg region (Horwood, 1967). The presence of cultivated pastures, crops growing for feeding purposes such as maize and the use of veld grasses for hay also contributed to the development of dairying and cattle ranching in the area (Camp, 1999).

5.3.5.3 Transportation Routes

This level II class includes transport related infrastructure. The main infrastructures captured during the land use/cover assessment include roads and railways present in the area. Transportation Routes covered an extremely small portion of the study area but treated as a separate class due to its importance for most developments in the study area.

Areas covered by Transportation Routes occupied 77.916 ha of which is 0.32% of the total area in 1944. This coverage increased to 23.81 ha (0.50%) in 1967 (Table 5.6). This increasing trend continues slightly occupying an area of 161.21 ha (0.65%) in 1989. Land used for Transportation Routes slightly increased in 2000. The increasing trend in Transportation Routes area could be attributed to development of commercial farming which includes commercial forestry, dairying, and sugar plantations. Generally, Transportation Routes showed a very slight increase during 1944 to 2000(Figure 5.14).

5.3.6 Waterbodies

The definition of water body in this study was based on South African land use/cover classification system. In this study Waterbodies were classified into three level II classes: Dams, Farm Ponds, and River Water including lakes (Table 5.7).

5.3.6.1 Dams

In 1944 there was no dam in the Albert Falls Area. In 1967 a dam called Satellite dam had been constructed impounding 26.19 ha which is 0.11% of the total area (Table 5.7). The coverage impounded by Dams increased to 2344.59 ha (9.50%) in 1989 and 2000 with the construction of Albert Falls Dam in 1976. The Albert Falls Dam has total

catchment area of 1640 km^2 and a total capacity of 2907 × 10^6 m^3 (Albert Falls Nature Reserve, 2001).

Table 5.7 A summary table of areal coverages and percentages of Waterbodies in Albert Falls Area

Land use/cover classes	Year							
	1944		1967		1989		2000	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Dams	0	0	26.19	0.11	2344.59	9.50	2342.13	9.49
Farm Ponds	0	0	2.80	0.01	112.73	0.46	120.49	0.49
River Water	106.31	0.43	294.19	1.19	62.63	0.25	70.94	0.29

Generally the coverage of area impounded by Dams increased after 1967 (Figure 5.15). The increased dam construction in the area was means to meet the increasing needs and rising standards for water in the region (Natal Town and Regional Planning Commission, 1973). Albert Falls Dam is not only a water supply reservoir but also it is used for water related recreational activities (Butler-Adams, 1982; Albert Falls Nature Reserve, 2001). However, there is a possibility that water-based recreation may cause a possible increase in managerial and treatment costs which would be incurred by all the consumers (Bauman, 1969).

5.3.6.2 Farm Ponds
Similar to Dams there was no evidence of Farm Ponds in Albert Falls Area prior to 1944. In 1967 Farm Ponds covered an area of 2.80 ha which is 0.01% of the total Albert Falls Area (Table 5.7) were developed. The proportion of areas impounded by Farm Ponds increased to 112.73 ha (0.46%). This increase in the areal coverages impounded by Farm Ponds was due to the construction of Farm Ponds for irrigation in order to respond to the increased demands for food production, improved technology (Tarboton and Schulze, 1990); and the dry periods experienced during the early 1980's (Huntley et al, 1989).
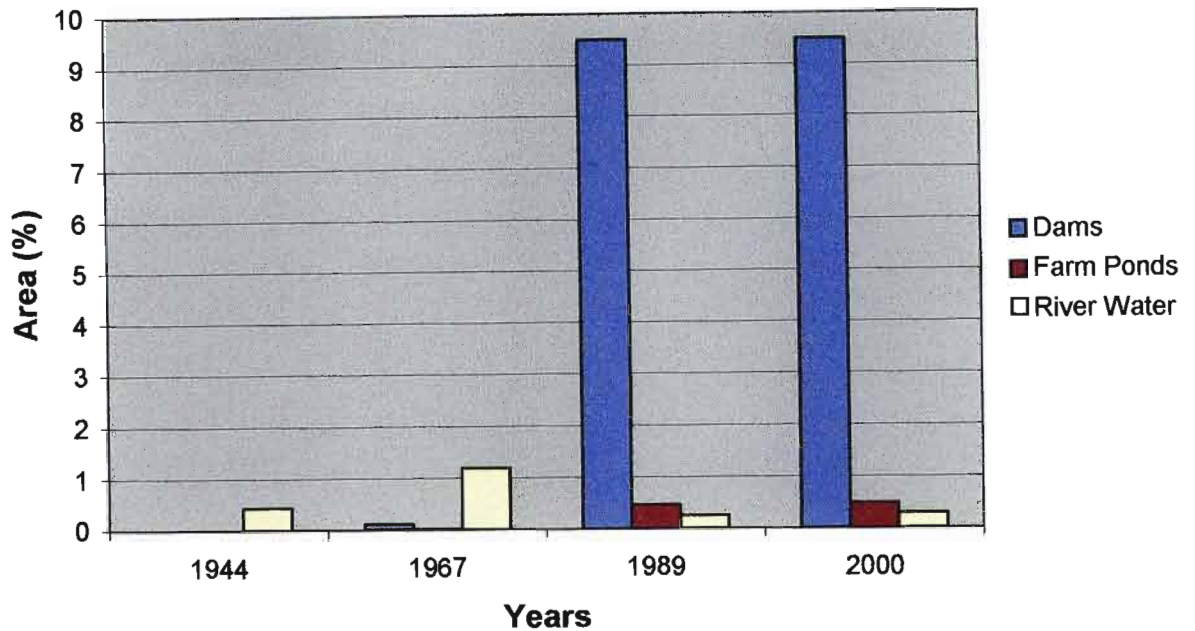
Figure 5.15 Historical changing patterns of areal percentages covered by Waterbodies

5.3.6.3 River Water

Umgeni River is the main water resource for the Durban-Pietermaritzburg region (Tarboton and Schulze, 1990). Although the coverage of this water resource varies with the rainy season and water abstractions made from the catchment, it was treated as a sub-class of Waterbodies.

The proportion of Waterbodies covered by River Water in 1944 was 106.31 ha or 0.43% of the total area (Table 5.7). This coverage increased to 124.00 ha (0.50%) in 1967. The proportion of land covered by River Water was reduced dramatically to 62.63 ha (0.25%) in 1989 due to the construction of Albert Falls Dam that impounded the former Peatties Lake which constituted a large proportion of river water. The areal coverage of the River Water increased slightly to 70.94 ha (0.29%) of the total area in 2000.

5.3.7 Barren Lands

The Barren Lands class was subdivided into Bare Land and Degraded Land (Table 5.8).

Table 5.8 A summary table of areal coverages and percentages of Barren Lands in Albert Falls Area

Land use/cover classes	Year							
	1944		1967		1989		2000	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Bare Lands	4916.97	19.92	4171.37	16.90	2359.41	9.56	1470.03	5.96
Degraded Lands	481.98	1.95	505.72	2.05	69.25	0.28	213.24	0.86

5.3.7.1 Bare Land

Bare Land differs from the Degraded Land in its exclusion of degraded vegetation types and erosion scars. Bare Land occupied a large proportion in 1944 covering an area of 4916.97 ha or 19.92% of the total area (Table 5.8). However, with the development of forest industry and other agricultural activities in the area, Bare Land coverage decreased dramatically to 4171.37 ha in 1967 which constituted 16.90% of the total area. The decreasing trend of Bare Land continued with the development of other agricultural activities including the expansion of sugar plantation reaching to 2359.41 ha (9.56%) of Albert Falls Area. Bare Land in 2000 occupied only 1470.03 ha (5.96%) of the total areas. Generally, Bare land decreased steadily during the years 1944 to 2000 (Figure 5.16).
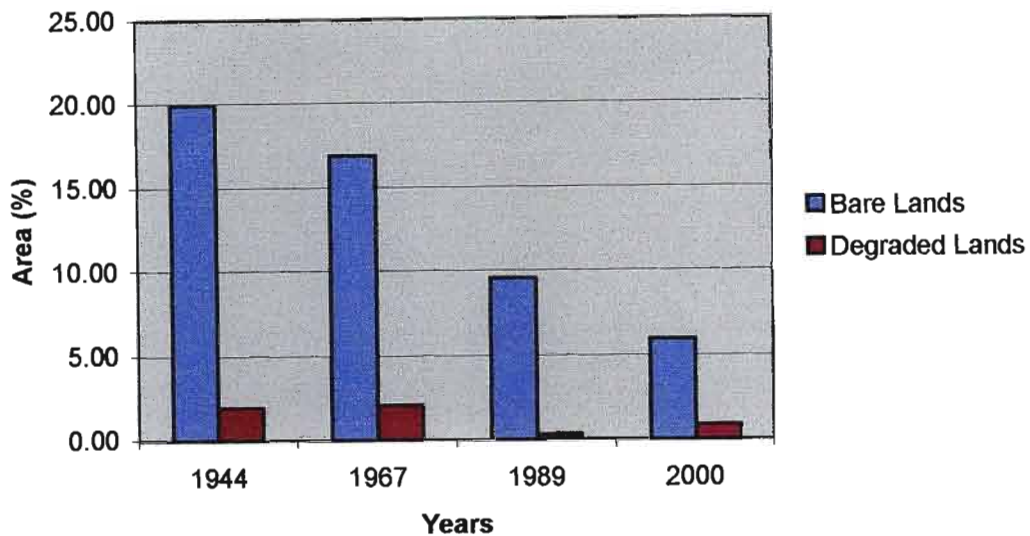
Figure 5.16 Historical changing patterns of areal percentages covered by Barren Lands

As the land demand for different land use activities in South Africa in general and KwaZulu-Natal in particular is high (Edwards, 1990; Marcus *et al.*, 1996) the continued decrease in the areal coverages of Bare Land portrays this condition.

5.3.7.2 Degraded Land

The results show that Albert Falls Area had Degraded Land covering 481.98 ha which is 1.95% of the total area in 1944 (Table 5.8). This could be attributed to the mountainous nature of the area (see Figure 3.4) which may induce erosion; or unsuitable land use and inappropriate land management practices applied to the land. The proportion of land covered by Degraded Land increased in 1967 to 505.72 ha (2.05%). The trend reversed and the land covered by Degraded Land was only 69.25 ha (0.28% in 1989). The type of farming which was practiced and the attitude of the farmers towards soil conservation might have contributed to the reduction of Degraded Land (Tarboton and Schulze, 1990). However in 2000 the Degraded Land coverage occupied bout 213.24 ha which was 0.86% of Albert Falls Area.
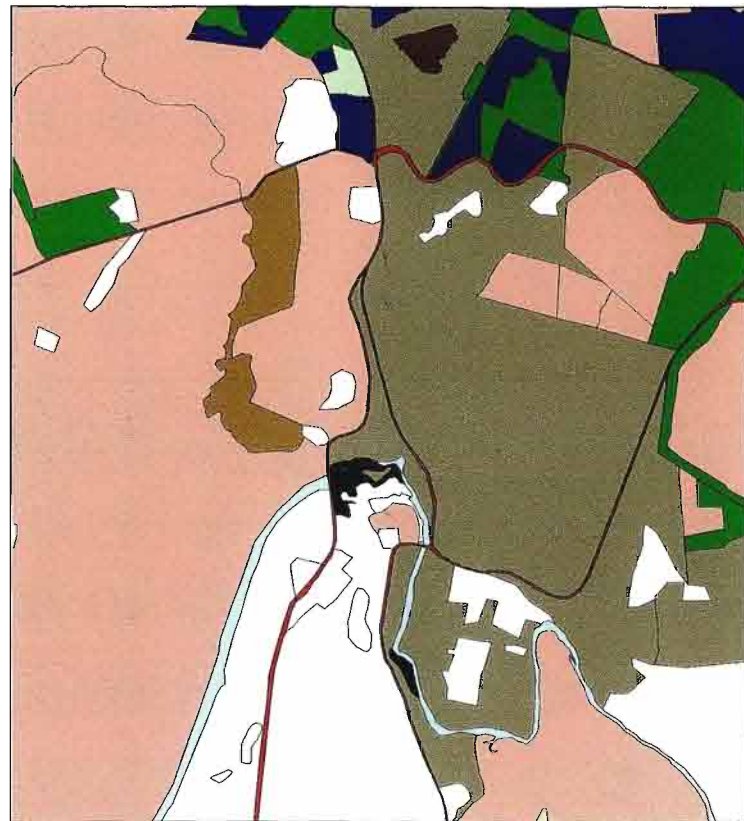
Generally human induced land degradation in South Africa is wide spread particularly in rural areas (National Botanical Institute South Africa, 2000). In KwaZulu-Natal a land

degradation survey was done based on the assessment of the resources at magisterial district level. Although the detail of the survey was not available, the report asserts that there had been a land degradation that varies greatly across the province (Forbes, 2002). But KwaZulu-Natal as a whole was found to have the second highest provincial soil degradation index in South Africa (National Botanical Institute South Africa, 2000).

5.4 An Example of Detailed Land Use/Cover Change

Crammond, Albert Fall (Figure 3.2) is a typical example in Albert Falls Area that had experienced a dramatic land use/cover change patterns during 1944 to 2000. A small portion of Albert Falls Area surrounding Crammond, Albert Fall was clipped (Figure 5.17) to portray a closer view of changes in land use/cover patterns in Albert Falls Area.

A closer view of the clipped area shows that some of the Bare Lands were encroached by residential area mostly informal settlements in 2000. On the contrary the scattered residential area in 1944 was abandoned in 1967 and classified as Grassland. With the construction of Albert Falls Dam and establishment of Albert Falls Nature Reserve the residential area decreased and was converted to Grassland in 1989 and 2000. Most of the Cultivated Land in 1944 was impounded by Peatties Lake in 1967 and Albert Falls Dam in 1989 and 2000. Some of the cultivated land was also converted to Sugarcane in 1989 and 2000. Indigenous Forests increased dramatically in 2000 with the establishment of Albert Falls Nature Reserve. The encroachment of indigenous forests in Crammond, Albert Falls was observed by Moll (1976) as is shown in plate 4 (see page 69). Commercial Forestry had covered a substantial area in 1967 which was later converted to Sugarcane in 1989 and 2000.
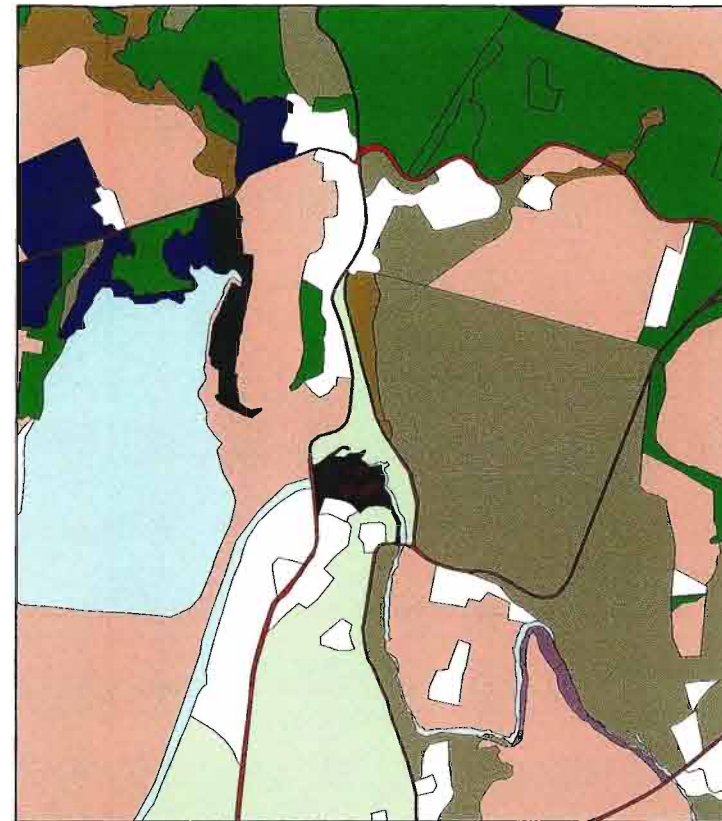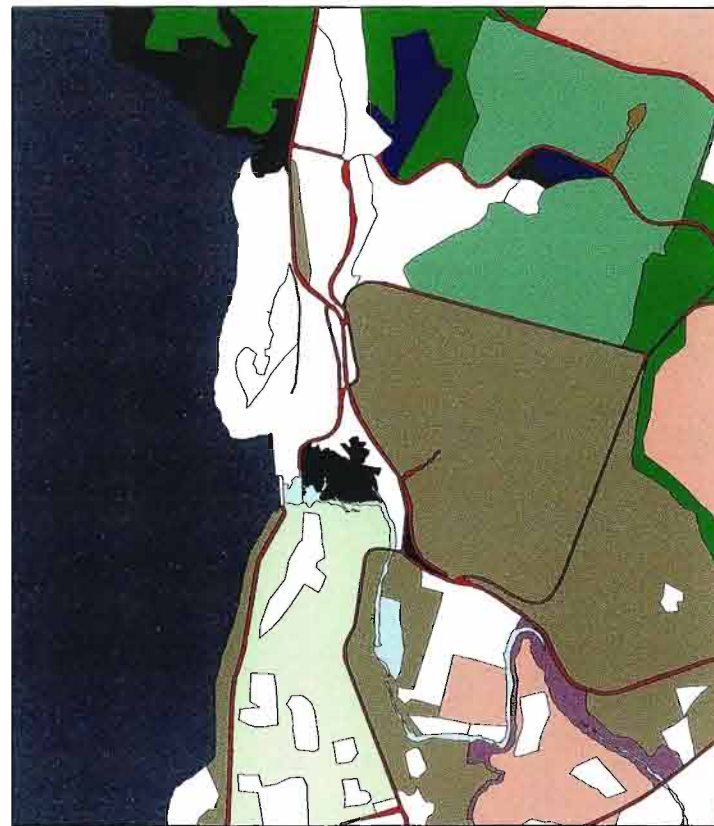
Legend

- Bare Land
- Clear Felled
- Forest Plantations
- Cultivated Land
- Dam
- Degraded Land
- Farm Pond
- Grassland
- Woodland
- Non-Residential Area
- Residential Area
- River Water
- Valley Thicket/Bushland
- Transportation Routes
- Sugarcane
- Wooded Grassland

a. 1944

b. 1967

c. 1989

d. 2000

Figure 5.13 Crammond, Albert Fall environs that experienced a dramatic land use/cover change

5.5 Prediction of Future Land Use/Cover Changes in the Study Area

To project land use/cover patterns in Albert Falls Area in the near future, a model that combines socio-economic and biophysical data is needed. Since all the desired socio-economic and biophysical data were not available, the possible near future forecasting of the probable land use/cover changes was not attempted. However, given the broad trends of land use/cover changes and analysis of the historical databases, some general remarks could be made. The common underlying assumption here is that the mechanisms responsible for land use changes in the study area remain the same. Then, it could be postulated that in the coming few years Indigenous Forests will probably increase due to the governments policy to protect the remaining indigenous forests and farmers awareness regarding conservation of natural resources. Commercial Forestry will also probably increase, as there is a Strategic Forestry Development Plan by the Forestry Industry (1989) to develop the total areas under forestry from 1995 to 2010 focused in KwaZulu-Natal. Sugarcane might also increase if the market value favors it relative to Commercial Forestry. Built-Up land might increase in the coming few years due to the encroachment of informal settlements that might be expanded due to the movement of people from rural areas.

Cultivated Lands and Barren Lands will probably decrease in the near future at the expense of the high economic values land use/cover classes such as Commercial Forestry and Sugarcane and the higher land demand in the area. As the abstraction of water from the catchments will be under the supervision of Umgeni Water there might not be any major changes in areas covered by Waterbodies in the near future.

Chapter Six: Conclusions and Recommendations

6.1 General Conclusion

Land use/cover pattern in Albert Falls Area during the period 1944 to 2000 may be described as being mainly agricultural. However, within the agricultural use there had been tremendous changes from one land use/cover class to another. Although biophysical factors played a role in land use/cover change, institutional policies regulating natural resource use, access to technological information, access to markets and agricultural price policies as well as incentives provided by the government were the driving forces of the changes in land use/cover patterns in the study area. Other Socio-economic factors e.g. demographic trends were found to have little influence in land use/cover transformations in the study area.

The assessment showed a dramatic increase of indigenous forests which is of importance as Albert Falls Area had little indigenous forests in 1944. Weyer (2000) also noted a similar increase in the nearby karkloof catchment. The increase of the areas covered by indigenous forest is likely to continue, as there is a movement to increase formal conservation areas for recreation, and tourism ventures in the study area.

Grassland dramatically decreased during 1944 to 2000 showing minor fluctuations. If the fire burning practices and selective overgrazing continues, Grasslands may not only deteriorate in quality but the number of grass species may also be reduced, as most of the Grasslands in the area are now dominated by unpalatable species like *Aristida junciformis* (Moll, 1976; Camp, 1999).

Commercial forestry predominated throughout the period 1944 to 2000. Although Commercial Forestry is economically important, it creates monoculture that reduces the aesthetic value of the study area. This might affect the tourism industry, which is one of the main economic drivers in Albert Falls Area. Commercial Forestry is also the cause for the invasion of indigenous forests by alien species around river courses. Forest plantations might increase in the near future as the forestry industry plan to expand forest

plantations in KwaZulu-Natal (Tarboton and Schulze, 1990). Thus, a sound land use planning is needed for future land use/cover developments. This planning should integrate all social, economic and environmental factors and hence leading to sustainable land use.

One of the main developments in the study area is the introduction of Sugarcane. Sugarcane production might increase where the land is agriculturally suitable at the expense of the remaining patches of cultivated land for maximum economic return. There could be shift between sugarcane and forestry as both industries had strategies to expand their agricultural lands in KwaZulu-Natal (Edwards, 1990; Hudson, 1990). International market values and other socio-economic factors may also play a decisive role in the shift of land either to Sugarcane or Commercial Forestry in the near future.

The land covered by Waterbodies showed a dramatic increase with the construction of Albert Falls Dam and numerous small Farm Ponds within the agricultural farms. Albert Falls Dam is used both as a water source and for water-based outdoor recreation in the region, thus contributing to the economic growth of the area (Butler-Adams, 1982; Albert Falls Nature Reserve, 2001). Flourishing of Farm Ponds as observed in the study area might decrease surface runoff available into Umgeni River (Tarboton and Schulze, 1990), although abstraction of water from Umgeni River is no longer possible without permission of the Umgeni Water (KwaZulu Government, 1990).

Built-Up land showed a fluctuating decreasing trend during the period 1944 to 2000. Residential Area was decreased irrespective of the encroachment of informal settlements e.g. around Crammond, Albert Fall. Agricultural restructuring is primarily responsible for the decrease in Residential area. Non-Residential Area and Transportation Routes generally increased with the development of commercial agriculture in the area. The movement of people from rural areas in search of employment in the Albert Falls Area will probably lead to the expansion of informal settlements in the area.

Land demand in Albert Falls Area is high due to its favorable climate and suitable soil conditions. Consequently, agricultural activities had showed to expand on Barren Lands some of which are considered marginal for cultivation, for instance, expansion of Commercial Forestry on steep slopes. Consequently, like in other parts of KwaZulu-Natal currently there is almost no unused land in the area. Therefore it is not expected to find Bare Lands in the Albert Falls Area.

The demand for land and its products in Albert Falls Area will continue. The influence of the above mentioned factors would also continue to play a dominant role in shaping the land use/cover patterns in the study area.

6.2 Future Applications of the Study

This study has provided a spatial and descriptive historical land use/cover databases of Albert Falls Area. This baseline information will assist in planning sustainable land use systems and developing improved environmental management plans. Specifically the land use/cover databases developed in this study can be used in the various applications inclusive of the ones described below:

- The results of this study can be used for environmental management such as analysis of habitat fragmentation in the study area. Chen *et al*. (2001) and Rao and Pant (2001) have employed historical land use/cover databases to analyze habitat fragmentation to reflect biodiversity status in Northern Plateau of China and Central Himalaya of India respectively. The databases developed in this study can be useful for KwaZulu-Natal Conservation Boards who require information on the changing land use/cover patterns of the area to plan for corridors between conservation areas.

- The historical land use/cover databases can be utilized in environmental planning work. For instance the latest land use /cover databases can be overlayed with some biophysical and other factors to determine suitable land uses. For instance, Cox and Madromootoo (1998) used GIS to develop conservation-oriented watershed management in St. Lucia. Cox and Madromootoo (1998), used land use/cover map together with a soil erosion

model within a GIS environment to evaluate agricultural management strategies in terms of soil loss on agricultural fields.

- The databases can help Umgeni Water, a bulk water supplier in the region, to formulate policies for controlling water quality and quantity of the Albert Falls catchment in particular and Umgeni River catchment in general based on the land use/cover developments in the area. For instance Tarboton and Schulze (1990) using the ACRU model to simulate impacts of farm dams and Commercial Forestry on water resource found that the development of these land use activities reduced the potential stream flow into Midmar Dam.

- The land use/cover databases in conjunction with other similar studies undertaken in the adjacent Midmar Dam sub-catchment by Rivers-Moore (1997) and Karkloof sub-catchment by Weyer (2000) can be used to model land use/cover change in the region and project possible future changes.

Upon completion of this dissertation the historical land use/cover databases of Albert Falls Area will be made available to the researchers and decision makers interested in environmental management planning and sustainable land use system planning use in the study area.

6.3 Recommendations

The study has shown that there is a need for various conservation measures to be taken in the study area. Although the expansion of land area for agricultural production contributed to the overall growth of the economy, it also created some environmental problems.

The development of different land use/cover types can break the links between natural habitats blocking movements of species between them (Anon, 1994; Bennet, 1999). Such habitat fragmentation may cause radical habitat changes resulting in losses of populations of plant and animal species (Anon, 1994; Bennet, 1999). One of the options for reducing

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the impacts of habitat fragmentation is the creation of corridors/linkages between natural vegetation patches (Bennet, 1999). The results of this study indicate that there is evidence of habitat fragmentation irrespective of the increase of Indigenous vegetation in Albert Falls Area. Since analysis of habitat fragmentation was beyond the scope of this study, the extent and nature of this fragmentation was not investigated. But it is recommended that based on the changes in land use/cover patterns reported in this study, corridors/linkages between the remaining conserved indigenous forest patches are created.

The development of large scale farming e.g. replacing vast areas of land by commercial plantations reduces the aesthetic value of a landscape (Porter, 1990). Such development may reduce the tourism potential of the study area. As tourism is one of the contributors to the economic growth of the study area, it is recommended that a holistic conservation management plan be considered such that the diverse land use/cover types are included in the area as diversity enhances the aesthetic value of the environment.

Albert Falls Dam is used as outdoor water-based recreation place where hundreds of visitors fish for bass, enjoy recreational motor-boating among other activities (Butler-Adams, 1982; Albert Falls Nature Reserve, 2001). Such activities may deteriorate the water quality and hence increase the risk of health hazards to users (Bauman, 1969). Although technology is available to produce safe, potable water from such waters, recreation increases treatment costs and managerial responsibility (Bauman, 1969). Economically water-based recreation may be supporting but it should be done in ways that do not jeopardize the water quality of the already scarce national resource.

The results of this study would undoubtedly improve on the holistic catchment management plan of Umgeni River catchment which includes Albert Falls, and the adjacent Midmar and Karkloof sub-catchments among the other six sub-catchments (DWAF, 1999). Umgeni Water has a management plan to monitor the Mgeni Catchment water bodies. The holistic Mgeni Catchment plan current activities include: removal of alien species; the reduction of inappropriate afforestation; and limiting of agricultural

land use increases, especially afforestation and irrigated agriculture (DWAF, 1999). Thus, it is recommended that Umgeni Water consider the changes in the historical land use/cover pattern of Albert Falls Area in its implementation of the holistic Mgeni Catchment plan.

Large-scale forest plantations can increase invasion of natural vegetation particularly riparian vegetation by alien species. This invasion results due to increased disturbances to the land and the establishment of exotic species (Porter, 1990). South Africa has forest plantation guidelines and policies for regulating the forest industry to work in environmentally sustainable way (Roux, 1990; Forestry Industry Environmental Committee, 1995). For instance Cooper (1990) recommended that the impacts of forest plantations could be reduced if they are kept 30 meters away from the margins of all indigenous forests. Thus, the only recommendation to be made here is to implement and follow the well-drafted and formulated forest plantation guidelines and policies.

One of the main objectives of the Department of Agriculture is the promotion of optional utilization of the agricultural resources (Roux, 1990). The Department of Agriculture believes that land should be utilized to the maximum economic advantage in a way that does not lead to the long-term degradation of the resource (Roux, 1990). Thus, future land development in the study area can proceed in sustainable manner with environmental sound practices if the above stated objective is implemented.

Land use is framed not only in biophysical factors but also in an institutional and natural resource policy context, with property and land use rights, access to extension services and markets and agricultural price policies being additional relevant factors influencing these factors. As it was highlighted in the South African land use policy the land reform program needs to consider the environmental degradations that may occur during the land reform program. The land tenure system to be adopted needs to be aware of the system's impacts on sustainable use of the land. For instance, tenancy and open access tenure systems do not encourage farmers to invest in measures to conserve land resources if their future rights to use these resources are not secure.

Like other parts in South Africa, Albert Falls Area is likely to be affected by the new land and natural resource policies. For instance the movement of people to find employment in the study area may increase the already encroaching informal settlements. Thus, it is important that any future increase informal settlements in the area be considered when a holistic environmental management plan is implemented.

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Appendix I: Climatic Summary of Albert Falls Area

(Source: Computing Center for Water Research(CCWR, 2000)

a, MEAN MONTHLY TEMPERATURE (oC)

STATION NAME	LAT	LON	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Clansyndicate	2922	3025	20.5	22.5	21.5	19.5	16.5	13.5	13.5	15.5	17.5	19	20	22
Cramond	2924	3025	20.5	22.5	21.5	19	16.5	13.5	14	15.5	17.5	19	20	21.5
Cramond, Albert Fall	2924	3026	20.5	22.5	21.5	19.5	16.5	14	14	15.5	17.5	19	20	22
Cramond(Pol)	2925	3026	20.5	22.5	21.5	19	16.5	13.5	14	15.5	17.5	19	20	21.5
Solmon, Otto's Bluff	2926	3021	20.5	22.5	22	19.5	16.5	13.5	13.5	15.5	18	19	20.5	22
Rambelholm	2926	3023	20.5	22.5	22	19.5	16.5	14	14	15.5	18	19	20	22
Malden	2927	3020	20.5	22.5	22	19.5	16.5	13.5	13.5	15.5	18	19	20.5	22
Beggs and PMB	2927	3022	20.5	23	22	19.5	16.5	14	14	15.5	18	19	20.5	22

b, Daily Maximum Mean Temp (^{o}C)

Name	LAT	LON	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Clansyndicate	2922	3025	28	28	27	26	24	22	22	23	24	25	26	28
Cramond	2924	3025	28	28	28	26	24	22	22	23	25	25	26	28
Cramond, Albert Fall	2924	3026	28	28	27	26	24	21	22	23	24	25	26	27
Cramond(Pol)	2925	3026	28	28	28	26	24	22	22	23	25	25	26	28
Solmon, Otto's Bluff	2926	3021	28	28	28	26	24	22	22	23	25	25	26	28
Rambelholm	2926	3023	28	28	27	26	24	22	22	23	24	25	26	28
Malden	2927	3020	28	28	28	26	24	22	22	23	25	25	26	28
Beggs and PMB	2927	3022	28	29	28	26	24	22	22	23	25	25	26	28

c, Daily Minimum Mean Temperature (^{o}C)

Name	LAT	LON	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Clansyndicate	2922	3025	17	17	16	13	9	5	5	8	11	13	14	16
Cramond	2924	3025	17	17	16	13	9	6	6	8	11	13	15	16
Cramond, Albert Fall	2924	3026	17	17	16	13	9	6	6	8	11	13	14	16
Cramond(Pol)	2925	3026	17	17	16	13	9	6	6	8	11	13	15	16
Solmon, Otto's Bluff	2926	3021	17	17	16	13	9	5	5	8	11	13	15	16
Rambelholm	2926	3023	17	17	16	13	9	6	6	8	11	13	14	16
Malden	2927	3020	17	17	16	13	9	5	5	8	11	13	15	16
Beggs and PMB	2927	3022	17	17	16	13	9	6	6	8	11	13	15	16

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d, Mean Monthly Rainfall (mm)

Name	LAT	LON	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Clansyndicate	2922	3025	161.3	165.1	146.1	63.8	19.9	13.1	14.3	36.3	75.5	103.7	127.3	168.2
Cramond	2924	3025	202.7	187.4	156.5	73.6	21.8	14.3	15.4	37.8	79.5	116.7	147.9	177.3
Cramond, Albert Fall	2924	3026	152.3	141.8	124.4	64.6	25.9	14.9	14.2	27	55.5	86.9	119.9	141.2
Cramond(Pol)	2925	3026	135.5	114.4	95.7	34.7	13.2	8.9	10.3	24.4	50.9	83.3	97.5	132.6
Solmon, Otto's Bluff !	2926	3021	155	82.5	142.2	67.2	23.5	7	11.9	29.3	50.2	95.3	121.3	135.5
Rambelholm	2926	3023	120.6	125.7	97.6	54.2	22.9	12.3	17.4	21	40.7	67.6	88.2	130.1
Malden	2927	3020	149.4	129.2	87.9	59.9	29.1	13.7	13	25.2	49.2	84.7	129.6	134
Beggs and PMB	2927	3022	137.9	112.1	113.2	58.3	30.6	5.5	7.7	27.1	47.5	79.3	98.5	110.6

The Mean Monthly Rainfal is the average of the mean monthly rainfall of the six climatic data stations in Albert Falls Area.

e, Rainfall Summary (mm)

Name	LAT	LON	MAP	CV_Value	Concentration	Seasonality
Clansyndicate	2922	3025	1110.9	17	49	4
Cramond	2924	3025	1187.5	16	49	4
Cramond, Albert Fall	2924	3026	955.6	21	50	4
Cramond(Pol)	2925	3026	824	22	50	4
Solmon, Otto's Bluff !	2926	3021	898	21	50	4
Rambelholm	2926	3023	798.2	25	51	4
Malden	2927	3020	918.7	23	50	4
Beggs and PMB	2927	3022	826.4	23	49	4

The period of the rainfall data measurements made varies in all thestations.

Periods of Data Collection

Name	From	to	Complete data years
Clansyndicate	1970	1999	23
Cramond	1971	2000	28
Cramond, Albert Fall	1919	1989	68
Cramond(Pol)	1967	2000	12
Solmon, Otto's Bluff !	1976	1985	8
Rambelholm	1916	1961	32
Malden	1952	1965	12
Beggs and PMB	1966	1982	16

APPENDIX II

Albert Falls Nature Reserve Bird List (23/10/89)
Dabchic(*Tachybaptus Ruficollis*)
White Pelican(*Pelecanus Onocrotalus*)
Pinkbacked Pelican (*Pelecanus Rufescens*)
Reed Cormorant (*P halacrocorax Africanus*)
Darter (*Anhinga Melanogaster*)
Grey Heron (*Ardea Cinerea*)
Blackheaded Heron (*Ardea melanocep hala*)
Goliath Heron (*Ardea Goliath*)
Purple Heron (*Ardea Purpurea*)
Great White Egret (*Egretta Alba*)
Little Egret (*Egretta Garzetta*)
Yellowbilled Egret (*Egretta Intermedia*)
Black Egret (*Egretta Ardesiaca*)
Cattle Egret (*Bubulcus Ibis*)
Squacco Heron (*Ardeaola Ralloides*)
Blackcrowned Nightheron (*Nycticorax Nycticorax*)
Whitebacked Nightheron (*Gorsachius Leuconotus*)
 hamrkop (*Scopus Umbretta*)
White Stork (*Ciconia Ciconia*)
Black Stork (*Ciconia Nigra*)
Woolynecked Stork (*Ciconia epsicopus*)
Yellowbilled Stork (*Mycteria Ibis*)
Sacred Ibis (*Threskiornis Aethiopicus*)
Glossy Ibis (*Plegadis Falcinellus*)
 hadeda Ibis (*Bostrrychia hagedash*)
African Spoonbill (*Platalea Alba*)
Lesser flamingo (*Phoenicopterus Minor*)
Whitefaced Duck (*Dendrocygna Viduata*)
Whitebacked Duck (*Thalassornis Leuconotus*)
Egyptian Goose (*Alopochen Aegyptiacus*)
South African Shelduck (*Tadorna Cana*)
Yellowbilled Duck (*Anas Undulata*)
African Black Duck (*Anas Sparsa*)
Cape Teal (*Anas Capensis*)
Hottentot Teal (*Anas Hottentota*)
Redbilled Teal (*Anas Erythrorhyncha*)
Cape Shoveller (*Anas Smithii*)
Southern Pochard (*Netta Erythrophthalma*)
Pygmy Goose (*Nettapus Auritus*)
Knobbilled Duck (*SarkidiornisMelanotos*)
Black(Yellowbilled) Kite (*Milvus Migrans*)
Secretarybird (*Sagittarius Serpentarius*)
Blackshouldered Kite (*Elanus Caeuleus*)

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Black Eagle (*Aquila Verreauxii*)
Longcrested Eagle (Lop haetus Occipitalis)
Martial Eagle (*Polemaetus Berllicosus*)
Crowned Eagle (*Step hanoaetus Coronatus*)
African Fish Eagle (*haliaeetus Coronatus*)
Steppe Buzzard (*Buteo Buteo*)
Little Sparrow hawk (*accipiter Minullus*)
Black Sparrow hawk (*accipiter Melanoleucus*)
African Gos hawk (*accipiter Tachiro*)
European Marsh harrier (*Circus Aeruginosus*)
African Marsh harrier (*Circus Ranivorus*)
Black harrier (*Circus Maurus*)
Gymnogene (*Polyboroides Typus*)
Osprey (*Pandion haliaetus*)
Lanner Falcon (*Falco Biarmicus*)
Hobby Falcon (*Falco Subbuteo*)
Sooty Falcon (*Falco Concolor*)
Eastern Redfooted Kerstrel (*Falco Amurensis*)
Rock Kerstrel (*Falco Tinnunculus*)
Greater Kerstel (*Falco Rupicoloides*)
Coqui Francolin (*Franclinus Coqui*)
Shelleys Francolin (*Franclinus Shelleyi)*
Redwing Francolini (*Franclinus Levaillantii*)
Natal Francolin (*Franclinus Swainsonii*)
Common Quail (*Conturnix Conturnix*)
harlequin Quail (*Conturnix Delegorguei*)
Helmeted Guineafowl (*Numeida Meleagris*)
Kurrichane Buttonquail (*Nturnix Sylvatica*)
Blackrumped Buttonquail (*Nturnix Hottentotta*)

Wild Life List
Rhino
Giraffe
Zebra
Warthog
Wildebeest
Iland
Impala
Kudu
Nyala
Blesbok
Spring Buck
Water Buck
Red hartebeest
Oribi
Reed Buck
Source: Albert Falls Nature Reserve Office (January, 2001)

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APPENDIX:III Standardised South African land use/cover classification system and Associated Description (Source: CSIR, 2001)

1. FOREST and WOODLAND

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

1.1 Forest

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

1.2 Woodland

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

1.3 Wooded Grassland

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

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%, with canopy height between 2 - 5 m. 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). Typical examples are Valley Bushveld, Mopane bush, and tall Fynbos. Dense bush encroachment areas would be included in this category.

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% cover. A typical example would be Valley Bushveld.

2.2 Scrub Forest

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

2.3 Bushland

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

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

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

3. SHRUBLAND and LOW FYNBOS
Communities dominated by low, woody, self-supporting, multi-stemmed plants branching at or near the ground, between 0.2 - 2 m in height. Total tree cover < 1.0%. 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.

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.

3.2 Low Fynbos (Heathland)
Typically small-leaved (i.e. nanophyllous), sclerophyllous, evergreen plants growing on infertile soils. Proteaceae, Ericaceae and Restionaceae frequently dominate.

4. HERBLAND
Communities dominated by low, non-woody, self-supporting, non-grass like plants, between 0.2 - 2 m in height. Total tree cover < 1.0%. Typical vegetation examples are found in Namaqualand, and `weed' dominated degraded areas.

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

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

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

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, Levels 1 and 2 include clear-felled stands within plantations. Excludes all non-timber based 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.

7. WATERBODIES
Areas of (generally permanent) open water. The category includes natural and man-made Waterbodies, 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.

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 saltmarsh, pans (with non-permanent water cover), reed-marsh or papyrus-swamp and peat bogs.

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.

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.

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 problems.

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.

10.1 Permanent crops
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.

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.

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).

11.1 Residential Area
Areas in which people reside on a permanent or near-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).

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).

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.

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.