An investigation into changes in land use/cover patterns in Manganeng area, Limpopo, South Africa.

by

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PREFACE

The work described in this dissertation was carried out in the Centre for Environment and Development, University of KwaZulu-Natal, Pietermaritzburg from September 1999 to June 2001 under the supervision of Dr Fethi Ahmed (School of Applied Environmental Science).

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

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ABSTRACT

Manganeng area is a communal land with the local community relying on use of land for their livelihoods. Manganeng shows signs of continued land degradation due to inappropriate land use management, while land use and land cover offer low returns. Continued degradation of natural resources has led to an investigation into changes in land use patterns in the area. Past and present aerial photographs (covering the years 1950, 1964, 1977, 1983 and 1995), recorded and oral history were used as main data sources for investigating changes in land use patterns in the study area. A GIS was also used to quantify the rate of land use change. Data collected from this study aided in providing information about natural resources in the area, how these resources have changed over time and methods used to protect the environment.

This study established that from 1950 to 1995, residential land had increased significantly, while farmland and bare rock on Ntswelatau Mountain had increased slightly. Other land cover such as dongas and scattered trees had remained stable over time. Grazing land had decreased significantly while deposited sand and clustered trees decreased insignificantly. A visual change assessment conducted in 2003 indicated that no significant change had occurred in the area since the 1995 aerial photograph was taken.

Population growth in Manganeng has led to an increase in residential land use, which directly affected other land uses such as grazing and farmland. The communities' indigenous knowledge has helped in reducing and/or maintaining donga sizes over the past 54 years while restrictions on tree felling on Ntswelatau Mountain has conserved vegetation in the area. Cultivation methods applied in Manganeng are not environmentally sustainable and need to be improved.

It is recommended that further research be carried out to assess soil erosion, economic potential, and integration of political/governing powers, as well as levels of agricultural education and awareness among the community. This will ensure an improved understanding of the natural environment in Manganeng, and can provide coping and recovery strategies from stress and shocks of unsustainable resource use in order to preserve these resources for future generations. It is further recommended that the Sustainable Livelihood Framework be adopted in assessing an integrated view of issues related to community based resource management in the area so as to provide insight into priority development options for Manganeng.

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The study reported in this dissertation was undertaken in response to initiatives by the Environment and Development Agency (EDA) in association with the Council for Scientific and Industrial Research (CSIR) for developing Community Based Resource Management Programmes (CBRM) in rural areas. Gratitude also goes to Common Ground Consulting for providing funding for aerial photographs.

I would like to thank the following people and organisations for their assistance in compiling this mini dissertation:

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Table of Contents

List of Figures

List of Plates

List of Tables

List of Boxes

List of Acronyms

AMSL	Above Mean Sea Level
ANC	African National Congress
BNHR	Broad Natural Homogenous Region
CBRM	Community Based Resource Management
CCWR	Computing Centre for Water Research
CSIR	Council for Scientific and Industrial Research
DEM	Digital Elevation Model
EDA	Environment and Development Agency
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organisation
GIS	Geographic Information System
GPS	Global Positioning System
IGBP	International Geosphere Biosphere Programme
ISCW	Institute of Soil, Climate and Water
MAP	Mean Annual Precipitation
MAX	Maximum
MEC	Minister of Executive Council
MIN	Minimum
MMP	Mean Monthly Precipitation
NAD	Native Affairs Department
NEC	Native Economic Commission
NP	National Party
NT	Native Trust
PRA	Participatory Rural Appraisal
RMS	Root Mean Square
SLF	Sustainable Livelihood Framework
TIN	Triangulated Irregular Network

CHAPTER 1- Introduction

1.1 Background

Human use of natural resources has changed radically with the advent of agriculture, leading to clearance of natural vegetation and the creation of cultural landscapes (Roberts, 1996). This change has progressively expanded at the expense of wilderness, with an obvious decline of indigenous vegetation (Cocks and I've, 1996; Saunders and Briggs, 2002) and an increase in residential and agricultural land use (Pinchon, 1996; Keneley, 2002). This, in a way, has accelerated soil erosion which has made continued agricultural practices in some areas impossible (Dikeni *et al*, 1997).

Manganeng is typical of the former homelands in Limpopo, South Africa (Figure 1.1). It is a communal land with a population that consists of impoverished households that rely as part of their survival strategy on use of land. Demographically, women dominate with most employable men living and working elsewhere. Land shows obvious signs of continued degradation due to inappropriate use, while land use and land cover offers low returns. Land use administration and management of this area is not properly implemented.

In light of this, an investigation into possible changes in land use patterns was launched. Past and present aerial photography, recorded and oral history are the main data sources for such a study. Studies of change in land use patterns usually give an insight into the type, extent and rate of change and the mechanisms driving such change. Such information is vital for sustainable management of natural resources.

It is hoped that information arising from this study will be disseminated to the local community in Manganeng, to make them aware of the natural resources that are available in their area, how these resources have been depleted in the past five decades and how they could conserve those that remain. Information gathered from this study would then facilitate a means by which the community could practise resource conservation management, while at the same time increasing their opportunities of self-employment through appropriate agricultural practices.

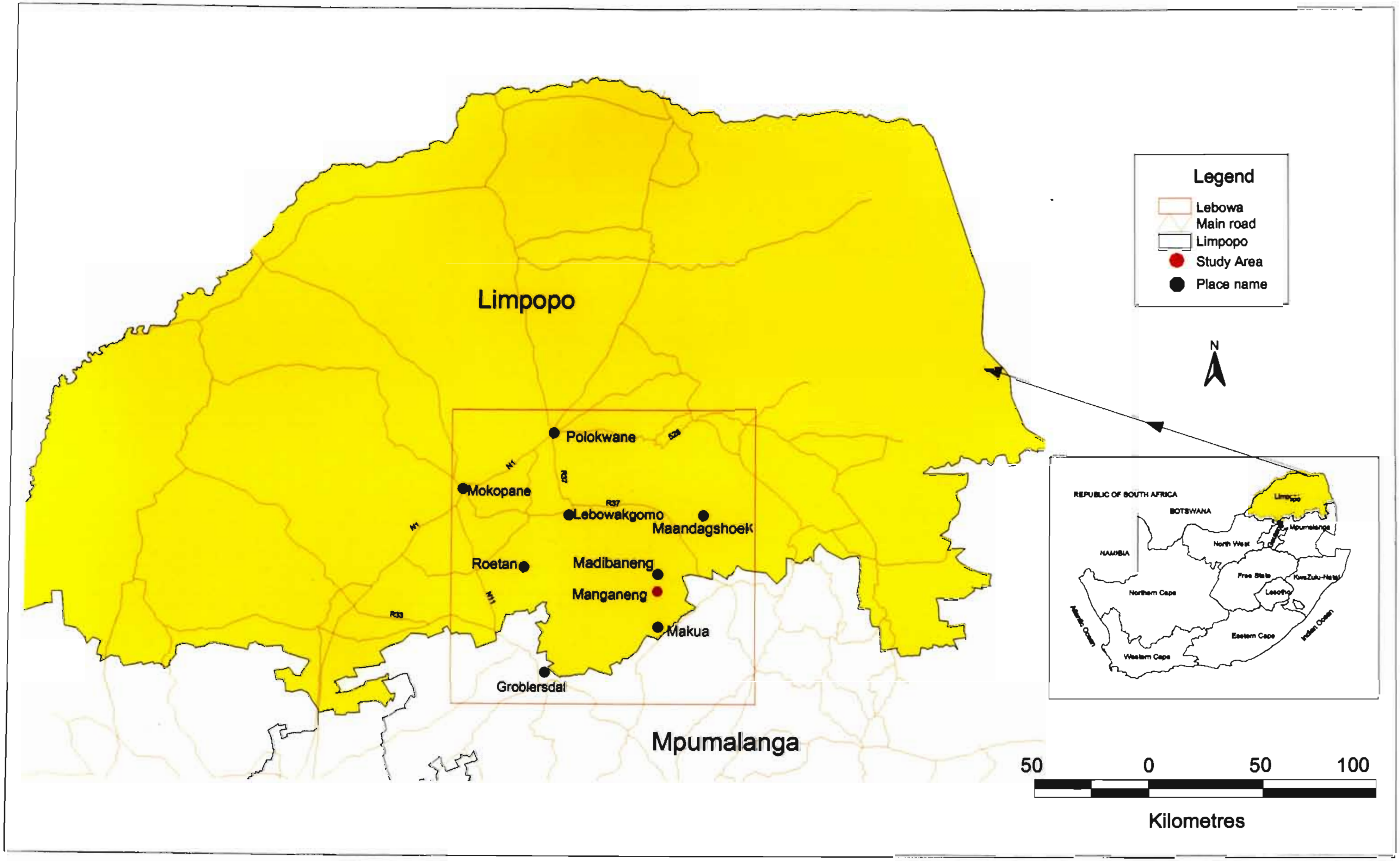

Figure 1.1 Map showing the location of the study area, Manganeng, Limpopo.
Inset: Map of the Republic of South Africa

1.2 Aim and objectives of the study

The aim of this study was to examine changes in land use patterns in Manganeng, Limpopo, South Africa over a period of 45 years. The following were the specific objectives of the study:

(a) Gathering oral and documented historical and present accounts of land distribution; and land tenure, as well as environmental changes that have occurred in Manganeng. This information obtained from interviews, a workshop, and including documented data, would provide insight into past and present land uses, causes and consequences of land use changes and indigenous knowledge applied to conserve natural resources.

(b) Producing land use maps. Aerial and orthophotographs assist in the identification and interpretation of land use patterns, while a ground truthing exercise confirmed the true location of features identified on these photographs. Digitizing these aerial and orthophotographs produces land use maps when using a Geographic Information System (GIS).

(c) Examining changes in land use over a period of five decades (1950-1995) using a GIS. Identification and interpretation of land use changes from the land use maps allows for the determination of whether change has occurred, while comparisons and quantification of these changes can also be made.

(d) Identifying the mechanisms responsible for possible land use changes. The use of an ecological time line, a GIS, participatory rural appraisal and interviews assist in the identification of whether socio-economic, political or cultural issues contributed to land use changes.

(e) Identifying potential future changes in land use that may occur due to continued resource utilisation.

(f) Proposing a framework that could be adopted to guide sustainable community-based resource management in Manganeng.

1.3 Choice of study area

Manganeng was selected as the study area for the following reasons:

(a) It is a relatively small area that could be adequately covered over the period allocated for this research.

(b) It contains all possible land cover types.

(c) It falls under the auspices of the Council for Scientific and Industrial Research (CSIR) and

Environment and Development Agency's (EDA) demarcated research boundary for community-based resource management within Sekhukhuneland, Limpopo[1].

1.4 Choice of time period for evaluation

This study evaluates changes in land use between 1950 and 1995. The decision to evaluate this period was solely based on available aerial and orthophotographs from the Surveyor General at the time this study was carried out. It is hoped that future research will evaluate and compare changes that would have occurred from 1995 and the time when that research is carried out.

1.5 Structure of the dissertation

Following this introductory chapter, Chapter 2 of this report contains a brief literature review. This is to familiarise the reader with various issues raised, including background information on general changes in land use patterns. Chapter 3 focuses on the geographical location, natural resources as well as the historical background of the study area. Chapter 4 provides a description of materials used, and explains the methods applied to collect and analyse data. The limitations of using these materials and methods are also considered. Chapter 5 describes and discusses the results obtained, while conclusions and recommendations are presented in Chapter 6.

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[1] This area has been identified by both agencies for conducting research and the implementation of Community Based Resource Management (CBRM) Programmes.

CHAPTER 2 – Literature Review

2.1 Land use and land cover change: an overview

Human activities have in recent years played a major role in shaping the biosphere. These human activities, coupled with population growth have caused an impact on biogeochemical cycles, and have also brought about modifications of the land surface (Figure 2.1). These activities, rather than natural forces, are the source of most contemporary changes in the state of the biosphere (Feoli *et al*, 2002). Land transformations which can be observed on the landscape can be caused by activities such as vegetation clearing which change land cover type and physical properties, while the application of fertiliser can change chemical flow in soils and ground water systems (Foth, 1990). Understanding these activities and the social forces that drive them is thus of crucial importance for understanding, modelling, and predicting local or global environmental change and for managing and responding to such change (Miller, 1998; Wu and Hobbs, 2002).

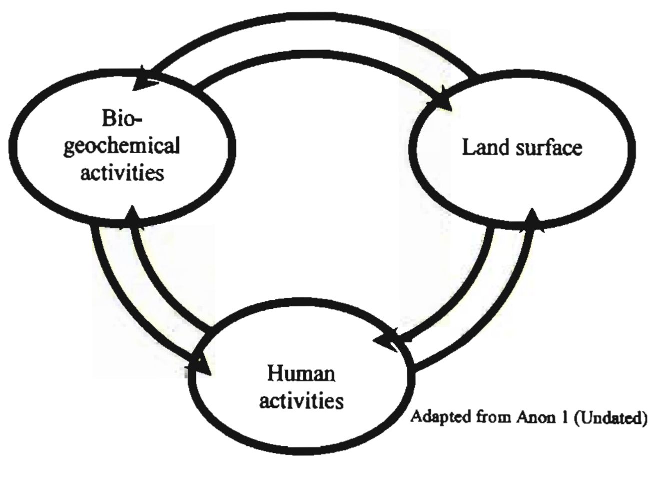

Figure 2.1 Conceptual framework used for global environmental change.

Land use denotes ***human employment of the land.*** It includes settlement, cultivation, pasture, rangeland, recreation, etc. Land use change can involve either a shift to a different use or an intensification of the existing one. Land cover can be described as *the physical state of the land.* It includes the quantity and type of surface vegetation, water and earth materials (Hugo *et al,* 1997). Land cover changes fall into two categories, namely conversion and modification. Conversion is a change from one land cover to another such as from grassland to agricultural land, while modification is a change in condition within a land cover category, such as the thinning of a forest or a change in its composition (Glendinning and Logan, 1959)[2].

A single land use may correspond to a single class of land cover. For example, pastoralism to improved grassland (Dikeni *et al*, 1997). On the other hand, a single class of cover may support multiple uses. These could include forests that are used for combinations of timbering, slash and burn agriculture, hunting and gathering, the collection of fuel wood, watershed and soil protection (Brannstrom, 2002; Feoli *et al*, 2002). A single system of land use may involve the maintenance of several distinct covers, such as farming systems, which combine cultivated land, wood lots, improved pasture and settlements. It has been noted that land use change is likely to cause land cover change, but that land cover may change even if land use remains unaltered. For example, a forest may shrink if a constant rate of timber extraction exceeding regrowth is maintained (Williams, 1994).

The realms of land use and land cover are connected by adjacent sources of change caused by human actions that directly alter the physical environment (Foster *et al*, 2003). It is through these proximate sources that the human goals of land use are translated into changed physical states of land cover (Ojala and Louekari, 2002).

Examples of these proximate sources are biomass burning, fertiliser application, species transfer, ploughing, irrigation, drainage, livestock pasturing and pasture improvement. These sources produce land cover changes or alter actions of the properties of the land surface. They can take the form of either conversion or modification, which can lead to secondary environmental impacts such as biodiversity loss, soil erosion and degradation, micro- climatic change as well as water flow and changes in water quality. On the social side, these sources reflect human goals mirrored in land uses which result in land use and

[2] In this document, land use and land cover will be referred to as land use unless specified exclusively.

land cover change, shaped by social, economic, political and cultural attributes (Johnson and Lewis, 1995). Figure 2.2 illustrates the land use and land cover change dynamics.

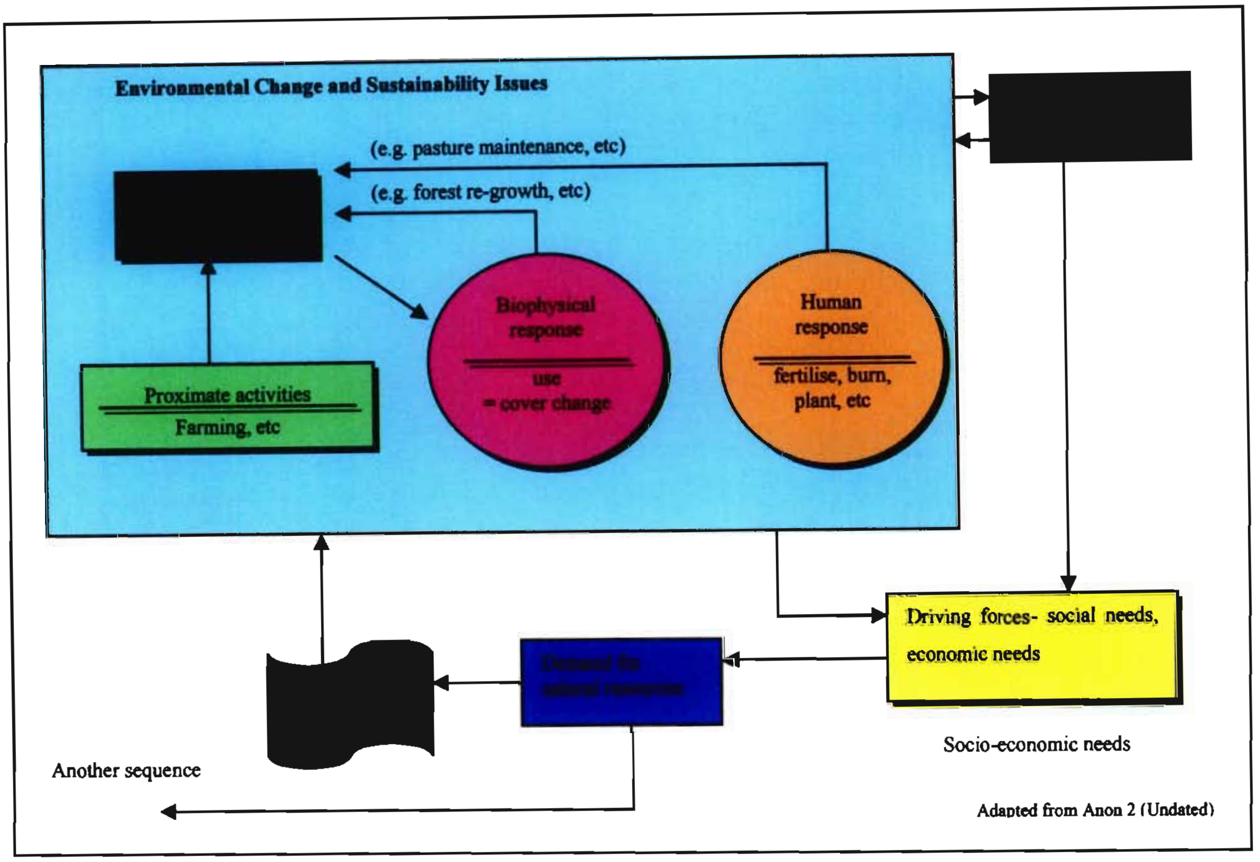

Figure 2.2 Land use and land cover change dynamics

This series of interactions is not unidirectional. Environmental changes may have feedback effects on land covers, land uses and human driving forces. These effects, real or perceived have a further set of human dimensions to the extent that they provoke societal responses intended to manage and mitigate harmful changes (Figure 2.3) (Acevedo, 1999; Szerszynski, 2002).

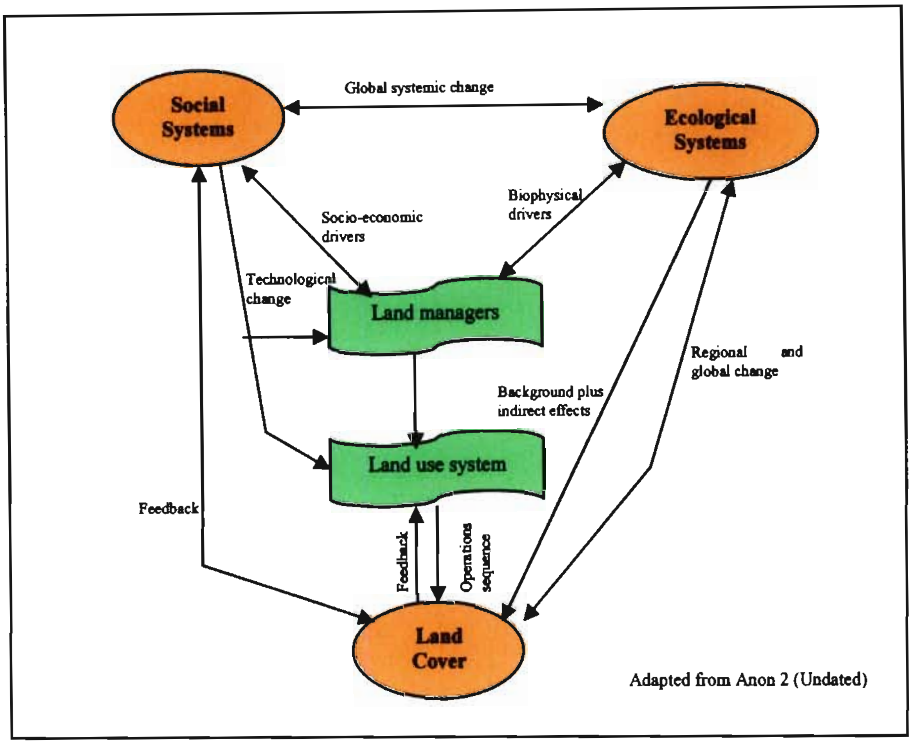

Figure 2.3 Framework for understanding land use and land cover situations.

2.2 Natural resource assessment

Natural resources are of utmost importance to any nation. The range of resources, their quantities and location are measures of any nation's potential, especially in the economic market. Natural resources can be classified according to the following categories: water, plants, soil, minerals, animals and the atmosphere. Knowledge of these resources, their status and condition, their availability and utilisation, as well as their cost and how the communities benefit from them is essential to ensure sustainable use (Boelter, 1959). All theories concerning the use of natural resources depend on the laws which govern the fundamental ecological variables which include energy, matter, space, time and diversity (Ramade, 1984). Figure 2.4 illustrates some of the variables and a classification matrix (not to scale) of the natural resources.

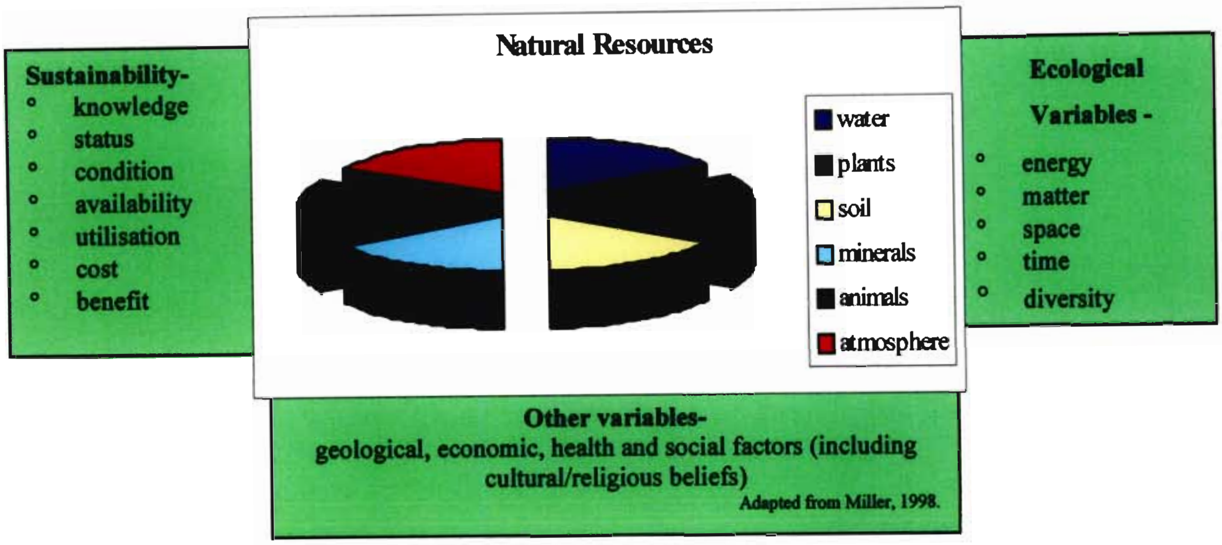

Figure 2.4 Natural Resource Assessment variables and classification.

The following subsections will focus mainly on the following resources: water, soil, plants and animals as they are usually altered by human-induced activities, which ultimately result in land use changes. Although minerals and the atmosphere are important environmental resources, they will not be discussed in detail[3].

2.2.1 Water as a resource

The role water plays in our lives is largely dependent upon its abundance and its physical and chemical characteristics. It is the most widely distributed inorganic liquid that exists in nature as a liquid, a gas, and a solid. The earth's water supply is largely in a state of flux. The natural system of water movement is normally termed the hydrological cycle. Water reaches the land surface in various forms such as snow, hail, rain and dew, and the total amount, intensity, and time of deposition differs from season to season as well as from one altitude to another (Brock *et al,* 1994; Miller, 1998).

As humans developed new uses for water, the demand for it increased. Irrigation is one use of water which is largely consumptive as water transpired by the plants and evaporated from the soil is lost to the atmosphere. Continued damming and silting of

[3] Both minerals and the atmosphere are aspects that lie outside the scope of this research.

rivers can contribute to the drying up of streams which serve as a major source for irrigation, thus resulting in a drought inflicted region if the area also receives limited rainfall (Ramade, 1984).

2.2.2 Soil as a resource

Soil is the basis of production and of the survival of humans. Its composition is very diverse. It consists of the eroded and partially eroded unconsolidated layer of material that covers the rocks that form the earth's crust. It also consists of a mineral fraction, eroded rock particles and the remains of plants and animals (Brady, 1990).

Erosion is one of the factors that result in the deterioration of soils, particularly because soil is a non-renewable resource. Riverbeds become shallower and flooding becomes prevalent and extends over a greater area due to this erosion (Evans; 2002, Ni and Li, 2003). As a result of increased run-off from eroded hill slopes, cultivated fields in valleys are flooded and extensive damage is caused to agricultural products (Hugo *et al*, 1997).

In South Africa, there have been several decades of serious attempts at soil conservation in those areas where the annual loss as a result of erosion was estimated at 400 million tonnes (Huntley *et al*, 1998). Fuggle and Rabie (1992) also stated that soil erosion has destroyed 25 percent of South Africa's original fertile soil reserves. This calls for further research, including investigations to improve ways of conserving our national heritage soil.

2.2.3 Flora as a resource

Without Flora (vegetation or plants), animal and human life as we know it today would not be possible. Plants are utilised on a large scale and in many ways by people (Hugo *et al*, 1997). From early times the use of wood including wood products has played an important role in human activities. Some plants have also been used for medicinal purposes. Because plants can be easily propagated from seed or by vegetative means they are described as renewable resources (Miller, 1998).

Approximately 12 percent of South Africa is under cultivation. The southern Cape (Overberg) has been cleared of approximately 75 percent of the indigenous *Renosterbush* and replaced by grain fields. The wetter portions of the interior grasslands have also been substantially replaced by maize, sunflower, wheat, lucerne and other crops (Hugo *et al*, 1997). Overgrazing in many areas of the country has given rise to bush encroachment (Acocks, 1988). The expansion of the Karoo vegetation eastwards, the increase in the density of trees in the Savannah biome, and the replacement of palatable grasses by unpalatable varieties of grasses are due to poor management and over-utilisation (Hugo *et al*, 1997). This removal of vegetation coupled with flooding causes a devastating increase in soil erosion as already discussed in Section 2.2.2.

2.2.4 Fauna as resources

Fauna (animals) are also very valuable to people, as they are an important source of food. They also play a role in environmental degradation when there is overgrazing, as large stocking rates alter the soil and cause erosion. Animals also contribute to land cover change as they alter different vegetation species during consumption and accelerate soil erosion especially next to water sources and hilly environments (Lange *et al*, 1998).

Once there is an alteration in vegetation, migration by wildlife tends to be inevitable, thus leading to an imbalance in the biosphere as they also contribute to the dispersion of seeds for regeneration of new plants.

2.2.5 The atmosphere and minerals as resources (brief overview)

The chemical composition of the atmosphere is constantly being modified by the injection of particles, gases and volatile substances. This hinders the renewal of certain natural resources, upsets the normal functioning of the atmosphere to varying degrees and runs the risk of inducing irreversible ecological changes on a world wide scale (IGBP, 1990). It was during the 1970s that various unexpected climatic fluctuations occurred such as drought in the Sahara during 1976 and extremely cold weather in central North America during 1977. These incidents made it clear how much agricultural production could be seriously affected by climatic change (BEPA, 2004).

Minerals, on the other hand, are not evenly distributed over the surface of the earth. Minerals are classified as non-renewable resources and as a result can never be replenished (Ayres *et al*, 1991). Their extraction also causes major changes in land cover and if not properly managed, further destruction of the environment may be experienced.

2.3 Land use types and their impact on the environment

Land use may involve the maintenance of several distinct covers such as cultivated land, woodlots, improved pasture and human settlements. These will be discussed as agricultural land, forestry and woodlands, natural rangelands and human settlements[4]. In the following subsections, each land use type will be discussed briefly including how changes in their composition impact on the environment.

2.3.1 Agricultural Land

It should be noted that during plant cultivation, small patches of vegetation such as forests are cleared and the underbrush burned to create agricultural land. Such extensive land clearing has degraded and destroyed the habitats of many plants and animals, causing their extinction. This has resulted in soil erosion and reduced forest cover which have converted many once productive landscapes into barren regions (Houghton, 1994).

Improper agricultural practices, in a form of extended fertiliser and pesticide applications, as well as the use of livestock for farming where there are no soil conservation methods applied to retain the soil in its natural state have also destroyed the habitat. Where fertilisers have not been applied, the soil is sometimes striped of its many properties, thus lowering agricultural production (Norse *et al*, 1991; Sands and Leimbach, 2003).

2.3.2 Forestry and woodlands

The durability of natural forests, woodlands and their resources depends on the manner and the intensity of their exploitation (Cablk, 2003). An example of a destructive form of forest exploitation is the felling of trees for timber by clear cutting forests, thereby

[4] Human settlements include housing and infrastructure.

unsettling fragile soil structure (Miller *et al*, 1996). Other practices that lead to the destruction of forests include the complete clearance of woodland for agriculture and other purposes, and itinerant farming where crop rotation is too rapid (Hester *et al*, 1996).

2.3.3 Natural rangelands

Whenever the growth of trees is hindered by insufficient rainfall or other climatic factors, forests give way to different types of biomes in which the dominant vegetation is herbaceous, with a ground cover principally of grasses. Areas that are predominantly grassland are barely capable of being transformed into arable land because of the shortage of water, poor soil structure and/or low temperatures. For these reasons, they are mainly used for extensive livestock rearing, a practice that has been in existence from the beginning of the Neolithic age (Veski et al, 2005).

When livestock is kept in excessive densities, overgrazing often occurs. This overpopulation can occur either deliberately or inadvertently from human activity and usually produces effects that are harmful to the environment. Trampling by closely packed herds wreaks havoc on the vegetation and removes soil along the tracks forming gullies which encroach on neighbouring land (McIntyre and Tongway, 2005). Fire, if not well managed, can remove some grass species and alter the diversity of available life forms in an area. Although fire is recommended for improving the available grass type and its palatability as mentioned above, it tends to remove some grass species, replacing them with others, and this indirectly alters the ecosystem (Dikeni *et al*, 1997).

2.3.4 Human settlement

The formation of villages and small towns has contributed to the removal of vegetation leading to a transformed environment. This has served as a positive attribute for humans as they are able to obtain shelter and housing. However, the environment has suffered the loss of its natural resources (Russel, 1997). Although this effect of continued destruction did not prove detrimental to the environment in the past, it has become so more recently due to continued land degradation caused by overpopulation and the overexploitation of resources. If deforestation is reduced and appropriate agricultural practices are implemented, then human settlement would not be regarded as a contributing factor to further environmental degradation, but could be viewed as a mutual relationship where humans benefit from the environment while the balance in the ecosystem is maintained (Russell, 1997).

2.4 Land use planning and control

Land use planning is the systematic assessment of land and water potential in order to select and adopt the best land use options available. Its main purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future (Acevedo, 1999). This planning is driven by the need for improved land management dictated by changing circumstances in a society (FAO, 1993).

Ecological land use planning involves the addition of various variables which are integrated into models designed to anticipate a region's present and future problems. This complex process takes into account geological, economic, health and social factors that also incorporate cultural beliefs (Miller, 1998; Bacon *et al*, 2002).

In most instances, governments have been able to influence decisions on land use planning through price signals, zoning and other regulatory measures (Norse *et al*, 1991; Trakolic, 2002).

Some attempts at implementing land use planning in the past have failed because of their insensitivity to local needs and perceptions. Emphasis has now been placed on sustainable resource management (Kakonge, 2002). The formulation of integrated land use plans as a framework for sustainable development is currently given higher priority (Hirst *et al*, 2000).

2.5 Interpreting land use change using aerial photographs

Photographs provide a more or less direct record of what is present. Sequential aerial photographs and orthophotographs of the same area permit the interpretation of landscape change (Poyato *et al*, 2003). Such photographs use technology first developed during the First World War (Russell, 1997). The variety of tones, patterns and spatial arrangements depicted on the photographs reflect the combined work of nature and cultural patterns of humans. Human activities in settling, cultivating, and exploiting various land resources have left characteristic marks upon the earth's surface. Many of the markings are unattractive, undesirable or completely out of phase with the concept of natural resource conservation (Avery, 1977). Much is still to be learned from these footprints, for certain land use patterns are repeated wherever humans contend with natural forces in shaping their environment (Burger *et al*, 2001).

2.6 Geographic Information Systems (GIS)

A GIS is a computer based tool for mapping and analysing features that exist and events that happen on the surface of the earth. The most commonly used and accepted definition is by Duecker (1979) who states that -

> "*A GIS is a special case of information system where the data consists of observations on spatial distributed features, activities or events, which are definable in space as points, lines and area. A GIS then manipulates data of these points, lines and areas to retrieve data for ad hoc queries and analysis*".

Burrough and McDonnell (1998), on the other hand, defined GIS as -

> "A *powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data from the real world for a particular set of purposes*".

GIS technology integrates common database operations such as query and statistical analysis with the unique visualisation and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes and planning strategies (ESRI, 2000; Clarke, 1997).

The geographical (or spatial) data represents phenomena from the real world in terms of:

- their position with respect to a known co-ordinate system;

- their attributes that are unrelated to position (i.e. temperature, pH, colour, rainfall, etc.); and,
- their spatial interrelations with each other which describes how they are linked together

(Maguire, 1991).

A GIS is therefore regarded as an organised activity by which people:

- measure aspects of geographical phenomena and processes;
- represent these measurements, usually in the form of a computer database, to emphasise spatial themes, entities and relationships;
- operate upon these representations to produce more measurements and to discover new relationships by integrating disparate sources; and,
- transform these representations to conform to other frameworks of entities and relationships

(Star and Estes, 1990; Chrisman, 1997).

It should not be understated how GIS contributes to decision-making. It is designed for more complex goals than simple efficiency (Hugo *et al*, 1997).

2.7 The use of GIS in land use change studies

The use of GIS in association with aerial photographs and satellite images can aid in giving measurements of available natural resources. The quantity of these resources can be measured and potential changes detected (Eastman *et al*, 1995). Understanding the mechanisms behind resource use allows for possible modelling of future projections of the state of these resources (Eastman *et al*, 1995; Hathout, 2002).

In most land use change studies, GIS is used extensively to examine the nature and patterns of change that have occurred. This is in order to develop informed decisions (for planning purposes) derived from data produced by a GIS which is used as a decision-making tool.

The following are some examples of research undertaken to evaluate land use change, how it inter-relates with socio-economic perceptions and how GIS could be used as a decision support tool:

(a) Simpson *et al* (1994) analysed the current and historical structure of two adjacent rural landscapes covering approximately 242 km^2 in central Ohio, USA using GIS. These landscapes showed differences in their physical environment, topography, soil capability, and socio-economic environment (i.e. agricultural policies and patterns of urbanisation). This research made it possible for land management planners to realise that socio-economic factors must be combined with the physical setting to fully understand patterns of change in human-dominated landscapes.

(b) Rivers-Moore (1997) examined changes in land use patterns in the Midmar Catchment, KwaZulu Natal, South Africa using a GIS. From this research, it became evident that afforestation, cropland, farm dams, human settlement and *Podocarpus* forests were increasing land uses while grasslands, wetlands, woodlots and subsistence land decreased. This researcher recommended that a corridor of grassland should be established to link patches of indigenous forests, and that the Lions River Wetland should be rehabilitated as both these land covers were encroached upon by other land uses and need to be either rehabilitated or replanted to protect them from extinction.

(c) Hunziker and Kienast (1999) investigated people's perceptions of land abandonment and spontaneous reforestation as either a loss or a gain in Central Europe. The researchers then developed a prototypical technique (using GIS) for rapid aesthetic assessment of reforestation scenarios for vast regions. This whole exercise aided in providing maps that clearly indicated that reforestation would not affect the scenic beauty of the area.

(d) Reid *et al* (2000) made an integrated assessment of driving forces and consequences that usually lead to land use and land cover changes with the aid of a GIS. In this study, ecological and social science tools were integrated to develop a way of identifying causes and consequences of change at the landscape scale in Ghibe Valley, south western Ethiopia. An ecological time line was developed to elicit landscape scale explanations for changes from long-term residents. This research revealed that the scale of causes and consequences in land use changes vary from local to sub-national (regional) to international, and the links between causes and consequences crosses scales. At the landscape scale, it was found that each cause affected the location and pattern of land use/land cover differently.

2.8 Land use classification

For many years, information on land use and land cover change has been collected and generated from a variety of physical and social science sources (The Chinese University of Hong Kong, 2001). The generation of data or images by various types of sensors flown aboard different platforms at varying heights about the terrain and at different times of the day and the year does not lead to a simple classification system (ISRO, 2002).

A land use classification system is an interpretation technique used in land use mapping. With the advent of the generation of data at different scales and times, it was noted that it is nearly impossible to aggregate the available data because of the differing classification systems used (Anderson *et al*, 1976).

While it is understood that there is no such thing as a universal classification system, appropriate classifications will need to consider the different dimensions of land use and land cover. A sound classification requires some of the following characteristics -

- It must be comprehensive
- The criteria must be based on inherent dimensions of land use and land cover in order to complement other classifications (e.g. soil, vegetation, farming, etc)
- The diagnostic criteria should be those associated with the land use over the long term (e.g. burning is one of the consistent characteristic of shifting cultivation even though the action takes place in a few hours or in a few days)
- The basic unit of land cover must be a geographically explicit unit (i.e. a unit of biophysical management). For instance, the field/parcel/plot is not a useful unit

while any unit of biophysical management can be applied to a range of land use. To the basic unit of land cover corresponds the unit of socio-economic management, which may be geographically different because it sometimes includes non-land use activities or non-geographically explicit units such as the household

- The diagnostic criteria must be a differentiating characteristic at the "field" or "land-user level", similar to the use of diagnostic horizons in soil classification
- The land use classification must be scale neutral, meaning that the classes at all levels of the classification should be applicable at any scale or level of detail
- The land use classification must be a multi-categorical system with only a few diagnostic criteria and classes at the highest level; at lower levels, the number of diagnostic criteria increases as does the number of classes; diagnostic criteria used at one level of the classification should not be used again at a lower level

(The Chinese University of Hong Kong, 2001)

The most successful attempt in developing a general purpose classification system compatible with remote sensing data has been attempted by Anderson et al, 1976, referred to as USGS Classification System. Other classification schemes available for use with remotely sensed data are basically modifications of the USGS Classification System (ISRO, 2002).

2.9 Multilevel land use classification system

The multilevel USGS land use and land cover classification system was developed because different sensors provide data at a range of resolutions dependant upon altitude and scale. Box 2.1 depicts the USGS multilevel data type characteristics.

Box 2.1 Multilevel USGS data type characteristics

Classification	***Type of data characteristics***
I	LANDSAT (formerly ERTS) type of data
II	High altitude data at 12,400 m or above (less than 1:80 000 scale)
III	Medium altitude data taken between 3,100 and 12,400m (1:20,000 to 1:80 000)
IV	Low altitude data taken below 3,100m (more than 1:20,000 scale)

Adopted from ISRO, 2002.

Although land use data obtained at any level of characterisation certainly should not be restricted to any particular level user groups nor to any particular scale of presentation, information at Levels I and II would generally be of interest to those who desire data on a national or regional basis. More detailed land use and land cover data such as those categorised at Levels III and IV usually will be used more frequently by those who need and generate local information within national, provincial and municipal level (ISRO, 2002).

2.10 Levels of land use analysis

Four levels of classification are suggested in the USGS classification system. Each level is useful at various information and decision making levels. This information can be used at-

Level I	inter state and state level planning
Level II	state level to regional level planning
Level III	regional to local level planning
Level IV	local or micro level planning

(ISRO, 2002)

When analysing changes in land use and land cover, one needs to identify the different spatial patterns, compare them, quantify significant differences and determine relationships between functional processes and landscape patterns (Crews-Meyer, 2004). Indexes of landscape richness, evenness and patchiness have been used widely by means of the size and distribution of the patches in the landscape. Patch size and arrangements may also reflect environmental factors such as topography or soil type (Forman, 1995). Information analysis can then be packaged and coded accordingly with reference to the four levels of classification as mentioned above.

2.11 Change detection techniques using aerial photographs and GIS techniques

There are many change detection techniques available to detect and record land use and land cover changes (i.e. using image differencing, ratios or correlation). Khorram *et al*, 1999 described change detection as "the from - to" analysis where information is generally required on the initial and final land cover types or land uses. The detection of image differences may be confused by problems with phenology and cropping, and such problems may be exacerbated by limited image availability and poor quality in temperate zones, the difficulties in calibrating poor images, calculating landscape metrics and using land use and land cover which not always that clear as super indicators (Brandt *et al,* 2002). Post classification comparisons of derived thematic maps go beyond simple change detection and attempt to quantify the different types of change. The degree of success depends upon the reliability of the maps made by image classification (Fuller et al, 2003).

There are three main categories that differentiate image processing for assessing change detection- these include pixels, features and object level image processing. Pixels level image processing refers to the numerical values of each image band, or simple calculations between corresponding bands such as image differencing or rationing. The feature level is a more advanced level of processing, which involves transforming the spectral or spatial properties of the image (e.g. principle components analysis (PCA), texture analysis or vegetation indices), thus the enhanced feature may have real meaning (e.g. vegetation indices in the radiometric domain, or lines/edges in the spatial domain) or may not. Object level image processing is the most advanced level of processing. All levels can involve symbolic identification in addition to pixel or feature change detection (Civco *et al*, 2002; Deer, 1998).

Most change detection based studies are based on objects. When comparing objects the problems of data set mis-registration are more complex than in per-pixel analysis. Major problems associated with data set registration have been observed in studies of change detection than are commonly undertaken within GIS. These studies typically aim to identify thematic changes that have occurred over time, sometimes involving temporal interpolation between the specific periods represented by the datasets used. Such data sets can have a significant impact on the analyses and interpretations made (Civco *et al*, 2002).

2.12 Summary

As already stated, natural resources can be used to measure any nation's potential, especially in the economic context. These resources are normally affected by the type of land use applied over time and how a shift from one land use to the other can cause resource depletion and degradation. In most rural areas where illiteracy, unemployment and poverty rates are high, there seem to be obvious signs of land degradation due to inappropriate land use management as well as complete dependency on natural resources for survival.

This study will investigate the possible causes and consequences of land use change in Manganeng over 45 years. The use of a series of aerial photographs, a GIS, interviews and a participatory rural appraisal workshop will aid in this investigation. All aspects concerning natural resource conservation and management, planning and control as well as mechanisms responsible for change will be evaluated and quantified. It is hoped that this information will provide a base from which a framework for developing a Community Based Resource Management Strategy can be established.

CHAPTER 3 – Study Area

3.1 Location

Manganeng is situated on the south-eastern corner of Limpopo (24° 40'S, 29° 58'E) in a former bantustan (homeland) previously known as Lebowa (Figure 1.1). Manganeng forms an arc around the Ntsweletau Mountain (altitude 1498 m AMSL) which is found at the southern tip of the Leolo Mountain range (Figure 3.5). As Limpopo is sub-divided into districts, the study area falls within the Nebo Magisterial District (Figure 3.1).

3.2 Hydrology

Manganeng is bordered by the Sebilwane and Pshirwa Rivers which drain into the Lepellane Dam (Figure 3.1). The Pshirwa River shows signs of having been well watered in the past, but due to present climatic conditions and the building of a dam, this aspect has changed. When there are no rains, there is usually a small amount of river water in the Pshirwa River while Sebilwane River tends to dry up (Figure 3.1). Most of the tributaries from the mountains have become dongas, rendering the area dry and disfigured by erosion.

3.3 Soils

Schulze *et al* (1997) produced an atlas which mapped climatic parameters (i.e. precipitation, temperature, and potential evaporation and soil types) for all of South Africa. From this atlas it was possible to classify the soil zone of the study area which was found to be Type 7 when using a Broad Natural Homogenous Region method (BNHR) delimited by the Institute of Soil, Climate and Water (ISCW). The soil depth (mm) ranged from 100- 400 (55%) and 600- 1000 (30%) while the soil texture was found to be SaClLm (55%) and SaLm (30%)[5]. It was also found that the plant available water was 39mm using methods developed by Schulze *et al* (1985) and Schulze and Kunz (1995) while the drainage rate index was very slow at less than 30% drainage of excess water per day.

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[5] Cl, Lm and Sa represent fine, medium and coarse texture soils respectively

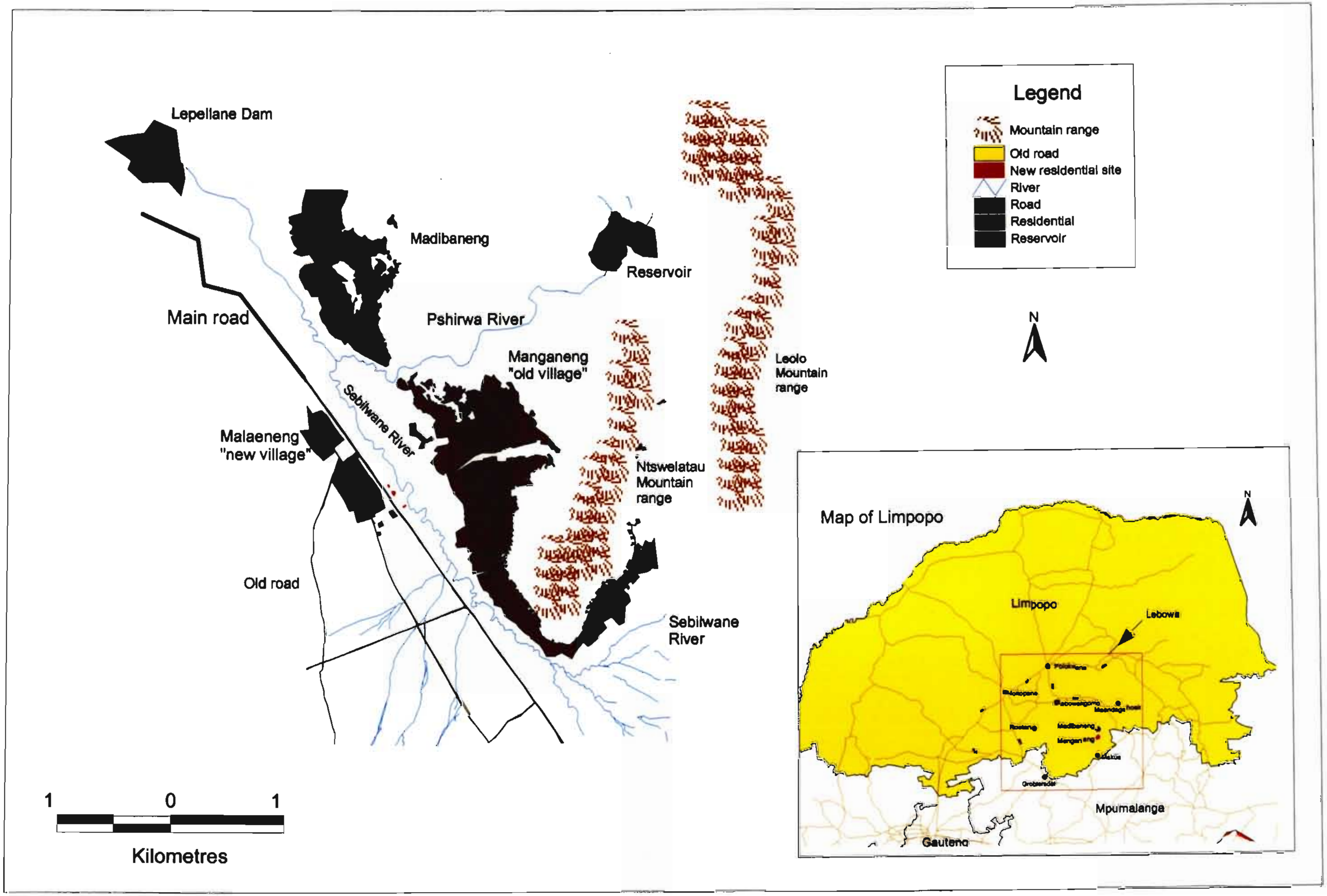

Figure 3.1 Map showing the study area around Ntswelatau at the foot of the Leolo Mountain range.
Inset: Map showing the location of the study area, Manganeng, Limpopo.

The soil form and series of the area was assigned typical day content values and base status indices to measure soil moisture and potential growing season. These values and indices were extracted from the 84 Broad Natural Homogenous Soil Zones identified by the ISCW using MacVicar *et al* (1977) and Schulze and Kunz (1995) as sources of information. These values/indices were then scored according to Fey's (1993) soil fertility criteria, and the soil fertility for this area ranged between 3-4 Low+[6]. Using the FAO (1978) method, the moisture-growing season of the area starts in October and ends in March.

This implies that the soil fertility rate in the area is very low at fertility rate between 3 and 4, with low moisture content as the area is dry with no proper irrigation system in place since the river and its tributaries are literally dry. It should be noted that agricultural activity and potential growing season are limited to the rainy season which is between October and March of each year.

3.4 Climatology[7]

As Manganeng has no meteorological station, rainfall data from 1924 to 1993 were collected from the nearest station in Maandagshoek (Figure 1.1): Station ID 0593126 Weather Bureau at 24 ° 36'S, 30 ° 05'E, 975m altitude, (Figure 3.2 - Data in Appendix A: Table A1. Annual Averages). This area experiences comparatively low and erratic rainfall with rainfall variations between 350-650mm (and increasing sometimes). The area receives 90 percent of its rainfall between October and March (Figure 3.3 - Data in Appendix A: Table A1. Monthly Averages). Due to this erratic rainfall pattern, the area has been found to have a coefficient variation of 25 - 30 percent

[6] Scores range from 0 (i.e. no fertility) to 10 (i.e. highest possible fertility potential).
[7] Climatic data were collected from stations near the area, as none were available from Manganeng itself. Available data was from 1924 to 1993 as obtained from the Computing Centre for Water Research

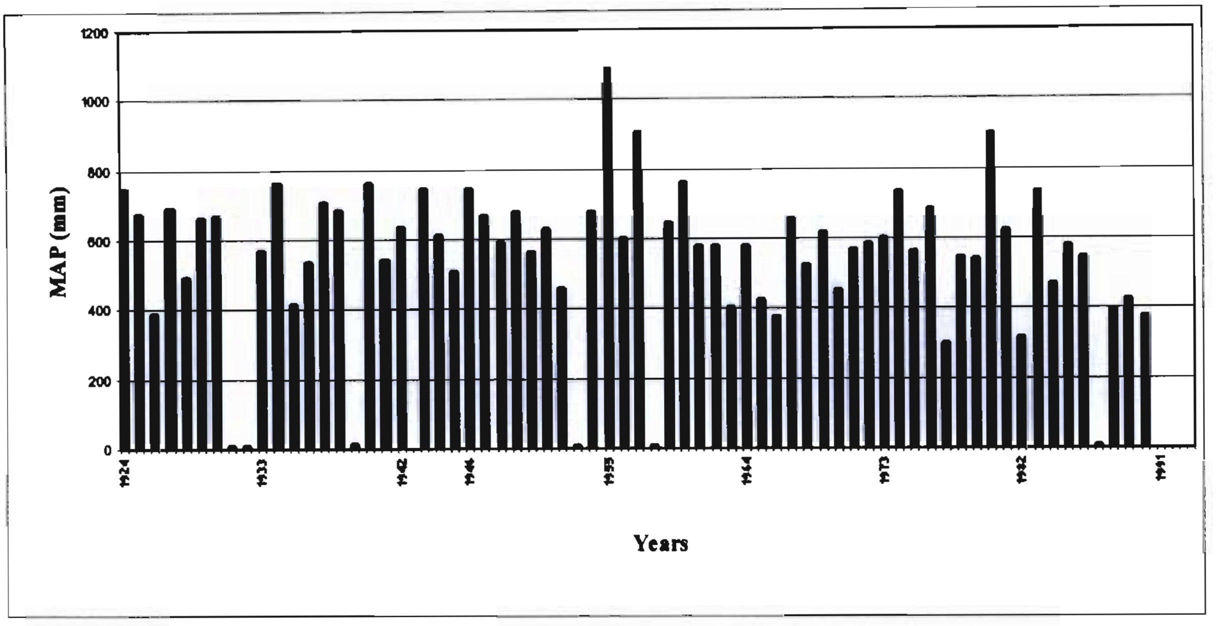

Figure 3.2 Rainfall data showing Mean Annual Precipitation (MAP) from 1924 to 1993 for areas located near the Mandagshoek meteorological station.

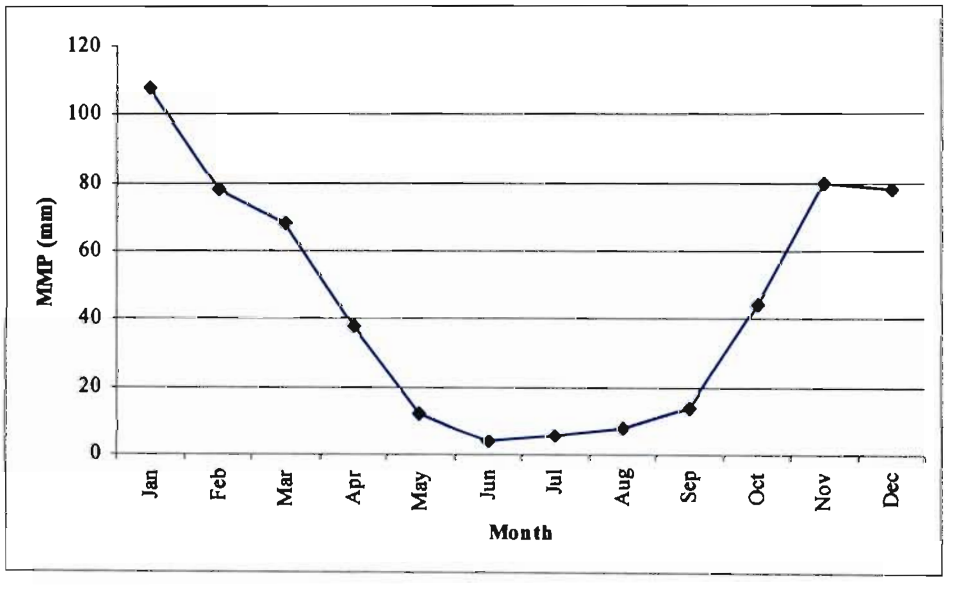

Figure 3.3 Rainfall data showing Mean Monthly Precipitation (MMP) from 1924 to 1993 for areas located near the Mandagshoek meteorological station.

Temperature data for the area was collected from the meteorological station in Roedtan (Figure 1.1): Station ID 0591124 Department of Agriculture at 24° 34'S, 29° 055'E, 1100m altitude, from 1983 to 1990 (Figure 3.4 - Data in Appendix A: Table A2. Monthly Averages). The temperature ranges from ± 8° C to ± 40° C with an annual average of ± 21° C.

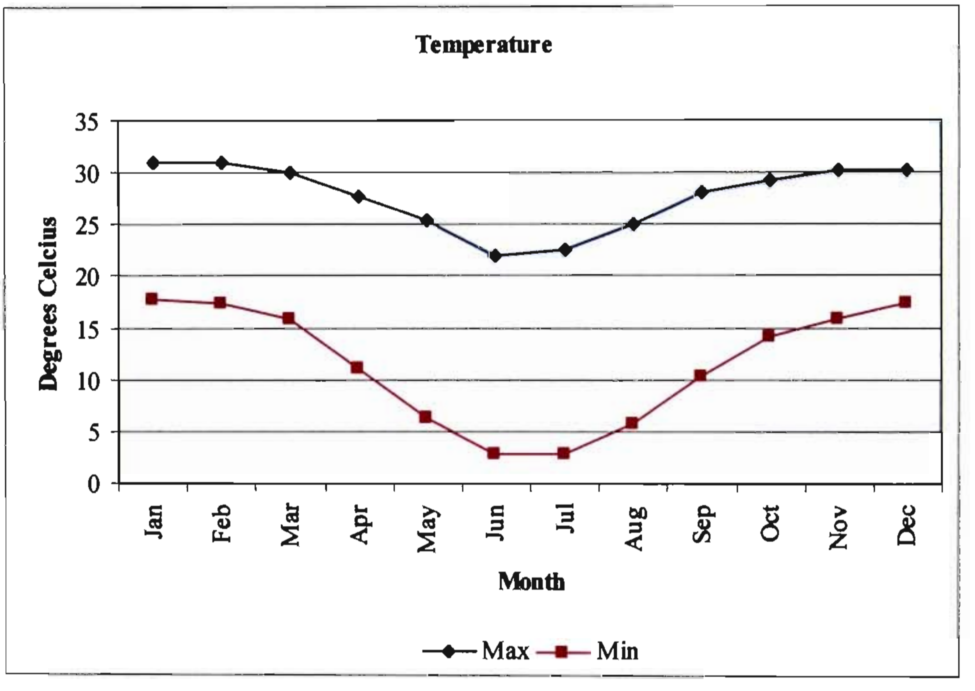

Figure 3.4 Temperature data showing Minimum (Min) and Maximum (Max) monthly averages from 1983 to 1990 for areas located near the Roedtan meteorological station.

3.5 Natural vegetation

Manganeng falls within the Savanna Biome of South Africa with a mixed bushveld vegetation. The bulk of the area to the west of the Steelpoort River (Figure 2.5) has been classified as mountainous bushveld. This area is dissected by numerous valleys (Delius, 1983). Acocks (1988) states the vegetation of Limpopo in the 1400s to the 1950s as bushveld, and projected that in 2050 it will remain as bushveld.

This mixed bushveld vegetation covers 28 percent to 82 percent of the total land area in Limpopo. It also varies from dense short bushveld to an open savanna. Acocks (1988) classified it as *Acacia nigrescens-Combretum apiculatum-Kirkia wilmsii* veld. Acocks also listed the most commonly occurring shrubs and trees as *Acacia nigrescens*, *Combretum apiculatum*, *Kirkia wilmsii*, Aloe species, *Olea europaea* subspecies. *africana*[8] . The predominant species are the succulent *Euphorbia confinalis* subspecies *confinalis* (Plate 3.1), *E. cooperi*, *E. ingens* and *E. tirucalli* which are indicative of dryness in the area.

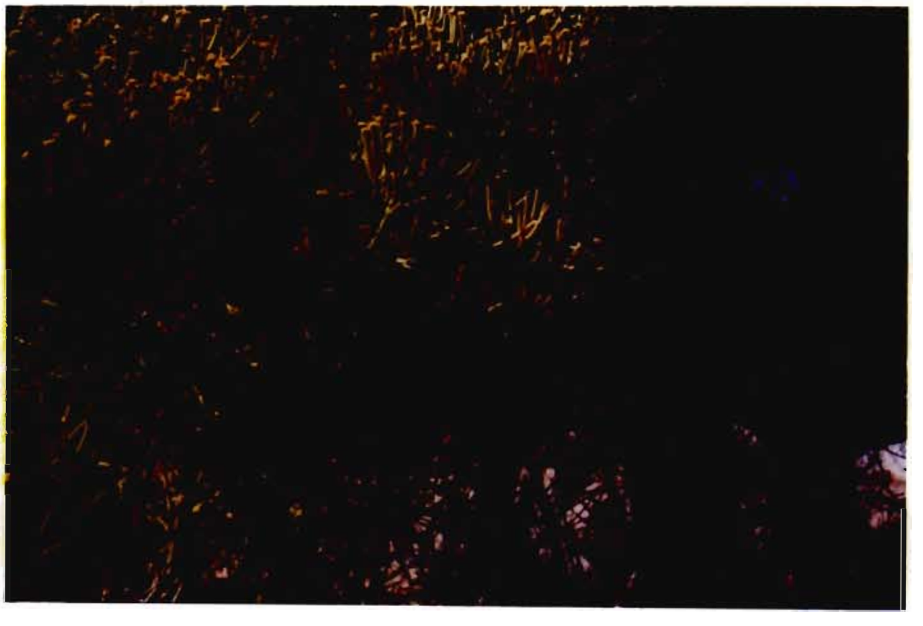

Plate 3.1 The predominant species is the succulent *Euphorbia confinalis* subspecies *confinalis*, which is an indicator of dryness and degradation in an area.

The grasses in the area are described as sweet bushveld related to Arid Lowveld rather than the Arid Sweet Bushveld[9]. These grass types are *Themeda triandra*, *Eragrotis superba*, *E. trichophora*, *Schmidtia pappophoroides*, and *Aristida congesta* subspicies *barbicollis* under grazing pressure. *Acacia tortolis* subspecies *heteracantha* is dominant on ancient fallows together with much *Themeda*.

[8] For a complete list refer to Acocks (1988).
[9] For a complete list refer to Zacharias (1990).

In a nutshell, the natural vegetation of this study area is predominantly mixed bushveld with most occurring shrubs and trees indicative of dryness in the area.

3.6 Summary of biophysical characteristics

Tributaries from the Ntswelatau Mountain have become dongas, rendering the study area dry and disfigured by erosion. The soils in the area have a low fertility potential while the drainage rate index was found to be very slow at less than 30 percent drainage of excess water per day. The study area also experiences comparatively low and erratic rainfall with rainfall variations between 350 – 650 mm. Temperature of the study area ranges from ± 8° C to ± 40° C with an annual average of ± 21° C. Vegetation in Manganeng is predominantly mixed bushveld with most occurring shrubs and trees indicative of dryness in the area.

3.7 Historical background of the study area

The history of Sekhukhuneland (the kingdom of the Pedi people) [10] will be used as a base for understanding environmental issues in Manganeng[11] as there is no recorded history about this area.

3.7.1 Recorded historical background of Sekhukhuneland

The history of Sekhukhuneland in Limpopo (former Northern Transvaal/Northern Province) is less well known compared to the Zulu (KwaZulu) and Moshoeshoe (Lesotho) kingdoms that played a major role in shaping South African history. To understand the present state of environmental issues in Manganeng, recorded historical information had to be reviewed to provide insight into causes and consequences that have led to land use changes.

3.7.2 Historical boundaries

From 1828 till present, Sekhukhuneland lay within the triangle formed by the Oliphants (Lepelle) and Steelpoort Rivers (Delius, 1996). This area is divided by three mountain

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[10] In this part of Limpopo, the dominant ethnic group is the Pedi people.
[11] Manganeng is a village that forms part of Sekhukhuneland (Figure 3.5).

ranges: the Sekhukhune Mountains which lie along the western bank of the Steelpoort River, the Strydpoort Mountains which run from east to west on the northern side of the Oliphants River and the Leolo Mountains which almost connect these two ranges and transverse the triangle formed by the river courses (Figure 3.5).

3.7.3 Land ownership

Initially, Pedi politics were centred within different chiefdoms that fought for regent power and larger land area. An imbalance occurred after the Difacane[12], and matters were aggravated when a Trekker community established themselves in a village of Ohrigstad, east of the Steelpoort River in 1845 (Figure 3.5) (Delius, 1983).

The 1879 defeat of Sekhukhune by British troops and Swazi warriors brought still further loss of land to the Pedi people. Much of the land on which they lived had been demarcated as farms by Boers and some of it had been sold to speculators long before any effective external authority had been imposed on them.

[12] Difacane is the 1820s struggles and migrations unleashed by the conflicts, which accompanied the emergence of Zulu dominance in Natal.

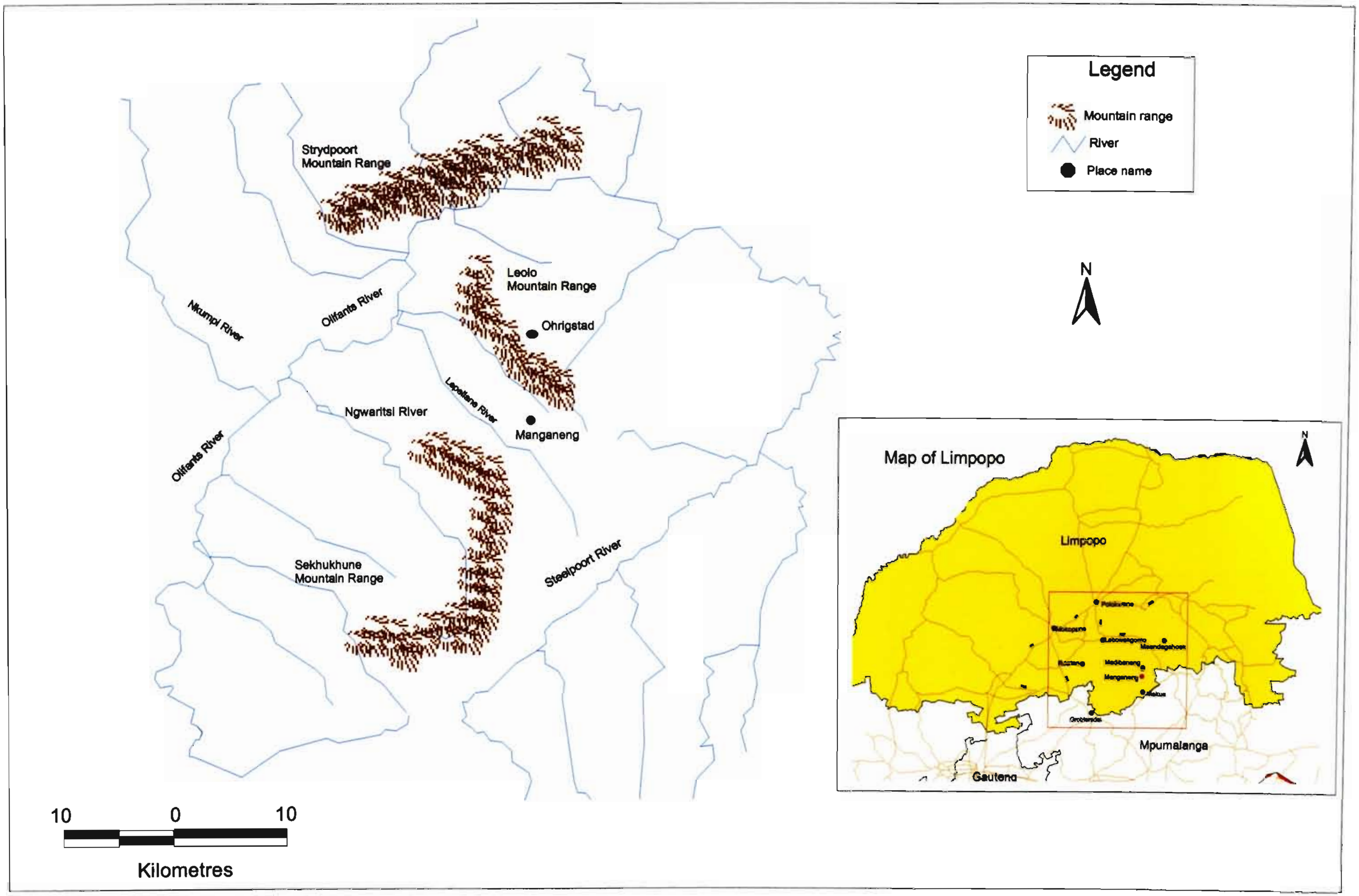

Figure 3.5 Manganeng encompassed by the Olifants and Steelpoort Rivers
Inset: Map showing the location of the study area, Manganeng, Limpopo.

When their independence was breached, they found not only new rulers demanding taxes but landlords claiming rents. This land was converted overnight into crown land (British owned), company farms, mission lands and an increased number of privately owned farms with tax demands continuing into the 1950s (Delius, 1996). It has been noted that Manganeng formed part of a band of land in this region (Geluks location-Figure 3.6) which did not have to pay taxes as the land was allocated to chiefs who had complete rights of land.

3.7.4 Land distribution and land tenure

This Pedi domain was previously divided into Nebo and Sekhukhuneland districts with three smaller locations set aside for African occupation. The narrow band of land adjacent to the Leolo Mountains demarcated in 1885 was known as Geluks location (Figure 3.6).[13] This location had a communal system of land rights which remains a widely cherished model rooted in the history of the Pedi kingdom. This model bore little relationship to the small pockets of land in which the Pedi were confined from the 1880s (Delius, 1986).

[13] Manganeng forms part of this narrow band of land.

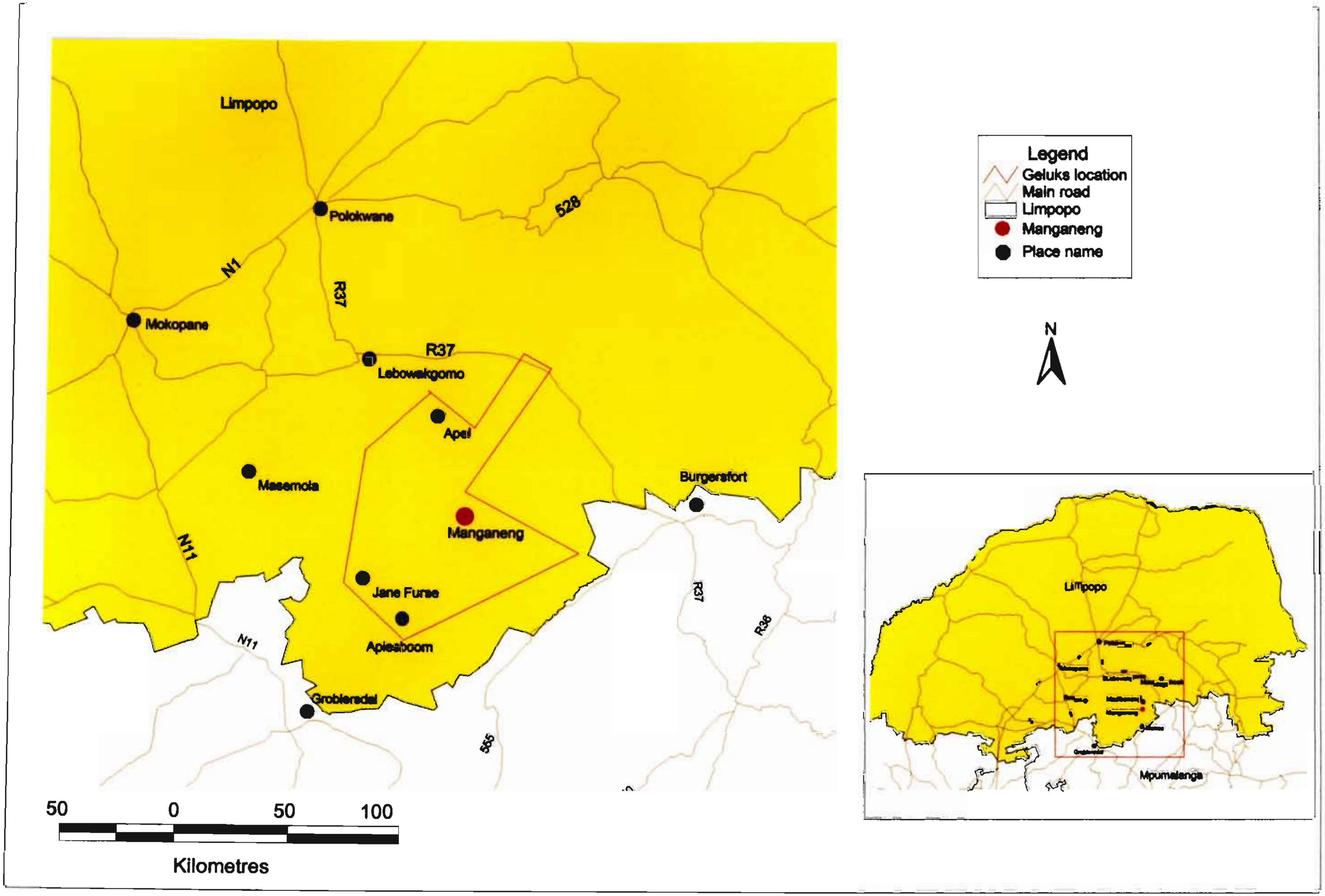

Figure 3.6 Map showing the narrow band of land known as Geluks location.
Inset: Map showing the location of the study area, Manganeng, Limpopo.

With the British in power in 1904, after the defeat of the Boers by the Pedi and the raiding of Boer cattle, the Pedi claims for additional land was revoked. From 1904 onwards, the government imposed rents on the inhabitants of crown lands while land companies and farmers intensified their demands[14] (Delius, 1996).

When Major D.R. Hunt arrived in the area in 1908, one of his goals was to establish a tribal fund to buy farms in areas released for African land purchase. This was opposed by the chiefs of Sekhukhuneland who believed that they should not buy what rightfully belonged to them.

Groups of individuals who bought farms ultimately changed the chiefs' attitude, which led to an agreement in 1922 for the establishment of a levy of one Pound (£) per taxpayer with the view of gradually repurchasing Sekhukhuneland. Over the next 30 years, 29 farms were purchased using this tribal fund. The Native Affairs Department (NAD) changed their policy in the 1920s towards retribalisation and chiefs in Sekhukhuneland were given greater recognition and material rewards (Delius, 1996).

3.7.5 Environmental changes in South Africa [15]

Since the turn of the century, concerns were expressed over the capacity of the homelands[16] to sustain a growing population, including concerns over the destruction of natural resources by both Africans and White settler farmers. By the 1920s there was mounting anxiety over the deterioration of these homelands. The terms and intensity of this discussion were increasingly shaped by a conservationist discourse focussed on the issue of soil erosion. By the 1930s this became a dominant element in characterisation of the problems facing these homelands (Delius, 1996).

[14] This excluded the Geluks location, they did not have to pay taxes as they had a communal system of rights in land.

[15] Manganeng lacks recorded historical (environmental) data. The history of environmental changes in South Africa has been used as a basis for understanding environmental changes in Manganeng (Sekhukhuneland) instead.

[16] These were subsequently called "reserves" during the apartheid regime when land allocation followed the Land Act of 1913.

In the 1930s African cultivators were singled out for special attention. White farmers railed against destructive methods of African producers. Drought, dongas, demographic data, declining yields, rivers running brown with mud and an imperfect understanding of African ecology all helped to fuel official concern (Beinart, 1984; Beinart, 1989).

A Native Economic Commission (NEC) was then appointed in 1930 to travel and take evidence of this land degradation and in 1932 it presented its report. This report indicated that -

> *"Growing human and stock populations in the homelands- the result of the irrational, uneconomic and unscientific nature of African society and agriculture had dire consequences for the soil. Overstocking on the other hand was a consequence of religious/cultural rather than economic way for the Pedi people. These factors led to donga erosion, deleterious plant succession, destruction of springs, robbing the soil of its productive properties, leading to the creation of desert conditions"*

(Delius, 1996).

This commission rejected arguments that the conditions in these homelands demanded a retreat from segregationist policies and concluded that the prime solution involved effective measures to develop these areas. This involved reduction in stocking rates, fencing of lands, concentrated settlements, improved seed and expansion of agricultural education. This commission also conceded that more land was required in order to relieve congestion in the existing areas and to allow scope for the introduction of better farming methods. Although these were sound recommendations, the NEC failed to give guidance as to how its objectives could be achieved within the restricted amounts of land available to Africans (Delius, 1996).

Between the 1930s and the 1940s there were disagreements and discussions on soil erosion, cultivation methods and land allocations. This led to resistance in the homelands and chiefs joining forces with the African National Congress (ANC) to fight for their rights. There was an outcry from the people regarding land allocations (amongst other things). Matters became worse as the National Party (NP) came into power. Hendriek

Verwoerd (the president of South Africa during that time) took control of the NAD in 1948 and clamped down on ANC activities in the homelands. In 1958 a revolt arose in Sekhukhuneland (Walshe, 1987).

This revolt, coupled with the disagreements on methods of cultivation, soil erosion and land allocations mentioned above led to defiance by the people in the homelands in practising land management strategies recommended by the NEC. They started cutting fences and trees without obtaining permits from the Natives Trust overseer, refused to register with the Trust, ploughed land that was designated for grazing and refused to move to land designated as residential sites. Those people who believed that they were contributing to the purchase of farms to expand the location were outraged and embittered when they discovered that they were paying Trust rent (Delius, 1996). These activities led to the present state of the environment where wide spread soil erosion coupled with vegetation depletion has occurred.

3.7.6 Agriculture

From the 1820s, Sekhukhuneland was a region of ecological contrast and transition. The treeless highveld plains were broken by valleys and steep slopes while the bushveld had dense scrub and rock scattered mountains. In 1896, the area experienced a prolonged drought. Locust swarms settled on and consumed crops regularly. By the end of that year, there was a major shortage of grain, which resulted in famine. The communities were also stricken by outbreaks of fever while the following year in April, oxen were infected by rinderpest. In order to contain this rinderpest disease, infected cattle were destroyed. This greatly reduced the number of cattle stock in the area (Delius, 1986).

After the war in 1901, there were very few cattle, while fire had devastating effects on vegetation in the area. In 1906, East Coast Fever attacked cattle, and officials once again destroyed the diseased cattle. Almost 20 000 cattle were destroyed, which was close to three-quarters of the entire herd (Delius, 1986). In the 1930s the communities thought there was going to be an extension of their lands, which is why they let the NAD and the

Native Trust officials divide their farms into residential, arable and grazing land. However, the extension of land did not materialise, resulting in defiant communities who disregarded the NAD and used available land and its resources according to their own social needs.

3.7.7 Summary of the historical background of Sekhukhuneland

There is no recorded history about Manganeng, hence the use of the history of Sekhukhuneland as a base for understanding environmental issues in the area. The historical boundaries of Manganeng have been delineated by three mountain ranges Sekhukhune Mountains, Strydom Mountains as well as Leolo Mountains. Manganeng formed part of a band of land called Geluks location which did not have to pay taxes as the land was allocated to chiefs who had complete rights of land in terms of land ownership. This Geluks location had a communal system of land rights which remains a widely cherished model rooted in the history of the Pedi kingdom. Manganeng also experienced environmental degradation over the years which culminated into investigations such as this study- to highlight problem areas and recommend potential solutions.

CHAPTER 4 – Materials and Methods

4.1 Data capture

The flow chart in Figure 4.1 illustrates the sequence of methods applied in producing land use maps using Geomedia Professional (Limp and Harmon, 1998) and ArcView GIS 3.2. These methods are described in more detail in the following sub-sections.

4.1.1 Aerial and orthophotographs

For this study, aerial photographs and an orthophoto with reference numbers 2429DB 15 and 2429 DB 20 were used. The aerial photographs were dated 1950, 1964, 1977, 1995 and the orthophoto was dated 1983. No post 1995 aerial photographs were available and the only available orthophoto was for 1983. The orthophoto was the only photo at 1:10 000 scale while both the 1950 and the 1977 aerial photographs were enlarged (X 3) at the Surveyor General to 1: 10 000 scale. The 1964 aerial photograph was also enlarged (X 4) to 1:10 000 scale while the 1995 aerial photograph was enlarged up to 1:20 000 scale. These aerial photographs were enlarged so as to ensure that all the maps used project at the same size so that it would be easier to identify features and to digitise the different land use types.

4.1.2 Identification of different land use types

Prior to any activity taking place, all land use types were identified. This identification relied on the different textures, tones, patterns and sizes observed on the aerial photographs and orthophoto. A classification system was then created following the Food and Agriculture Organisation classification system where all features were observed and identified (FAO, 1993, Thomspson, 2001). This classification made it possible to compare and identify changes that have occurred.

Since this classification system had too many overlapping features, it was decided to name each land use type according to the dominant feature observed. In cases where there were indistinct boundaries, it was decided to select an arbitrary line to separate these features. Field visits to the study area and ground truthing exercises using a Global Positioning System (GPS), (Trimble, 1999) were undertaken to verify these features. Table 4.1 shows the various land use types in the study area and explains why each has been identified and given that particular classification.

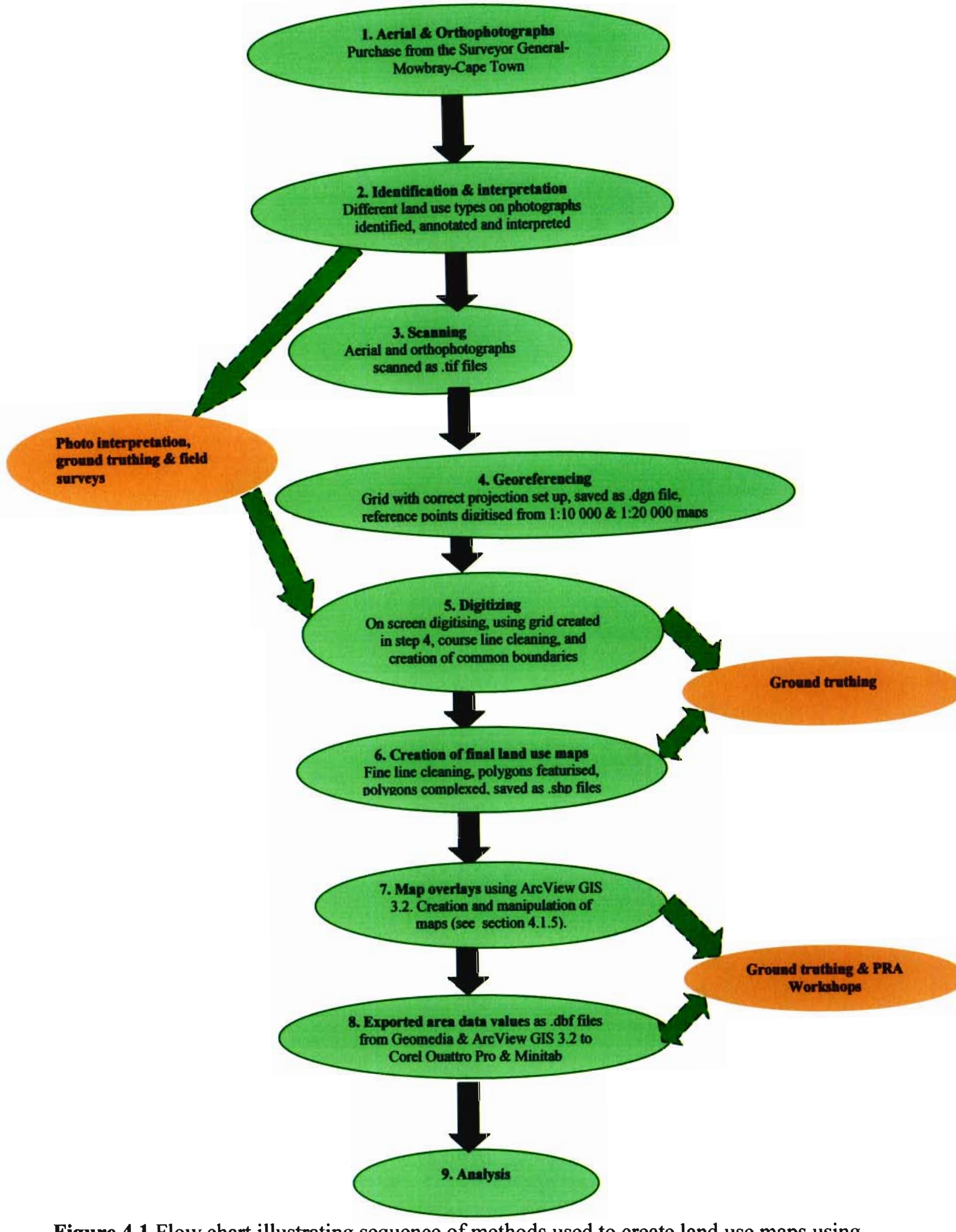

Figure 4.1 Flow chart illustrating sequence of methods used to create land use maps using Geomedia Professional and ArcView GIS 3.2.

Table 4.1 Land use classification as observed from aerial photographs

Land use & associated features	Interpretation
Bare rock	Sections of the mountain covered with rocks. Note: although a number of trees do grow on the mountain, the community is not permitted to harvest/collect fuel wood on it as it is regarded as sacred (Plate 4.1).
Clustered trees	Small trees/shrubs that are grouped together, also overlapping with other land uses such as residential, farms, abandoned land and occurring next to the river (Plate 4.3).
Deposited sand	Eroded sand/soil from the mountains, which is deposited into residential, abandoned land, farms and the river. This has been viewed as (very) light (texture-coloured) areas on the aerial and orthophotographs around residential, abandoned land, farms and the river.
Dongas	Gully erosion where extensive soil loss has occurred (Plate 4.2) -- forming river like tributaries.
Farms	Cultivated land.
Grazing land	Land that is not in use where livestock pasturing also occurs. Some parts of this land are used for recreational purposes, i.e. soccer fields, etc.
Missing data	Some aerial photographs did not cover the whole study area, resulting with some land use maps having missing data
Old road	Footpaths/access roads leading to farms and villages west of Ntswelatau Mountain (built before 1950).
Reservoir	Water catchment built around the late 1980's, but still not operational.
Residential	Where residential houses are built. Roads and footpaths have been incorporated into this land use as they form part and parcel of any residential land.
River	Sebilwane and Pshirwa rivers.
Road	Footpaths/access road crossing from the south towards the north west of Ntswelatau Mountain. Built around 1964 when the community started paying taxes and collecting pension funds.
Scattered trees	Small trees/shrubs that are scattered, also overlapping with other land uses such as residential, farms, abandoned land and occurring next to the river (Plate 4.4).

This classification system was adopted from FAO, 1993 and Thompson, 2001 and from land parcels as observed on the photographs.

Plate 4.1 Bare parts of the mountain strewn with rocks

Plate 4.2 Insufficient rainfall has left parts of the Sebilwane River dry, note the size of the river now developed into a donga.

Plate 4.3 Clustered trees observed near the foot of the mountain.

Plate 4.4 Scattered trees observed on the mountain[17].

[17] The other plates for different land uses have not been included in this document

4.1.3 Scanning

The series of aerial photographs and the orthophoto used were scanned with a Contex (FSS 6200- True at 300/500 dpi) at Image Scanning Technology, Durban and then saved on a compact disk as TIFF files at 300 dpi.

4.1.4 Georeferencing

As the only corrected scanned image was that of the orthophoto (1983), this was georeferenced first using Geomedia Professional (Limp and Harmon, 1998). The other scanned images of aerial photographs had to be georeferenced by identifying identical features on each of the scanned images which were regarded as a target, and on the image of the orthophoto which was regarded as a source. In other words, the aerial photographs were rectified for distortion first before being georeferenced using the orthophoto as a source. Five to eight points were used to rectify the aerial photographs.

This method then corrected the images, though with minor Root Mean Square (RMS) errors i.e. RMS 1950: 12.35 and 12.43m; RMS 1964: 11.29m; RMS 1977: 11.27; RMS 1983: 9.70; and RMS 1995: 7.96 and 7.87m (Limp and Harmon, 1998). Such RMS values are relatively small and do not affect the accuracy of measurements at the scale of the aerial photos (Ahmed, 1999).

4.1.5 Digitizing

Using Geomedia Professional (Limp and Harmon, 1998), the identified land use types (Table 4.1) were then digitised off the scanned and corrected images as backdrops with the help of a Smartsketch which automatically builds topology, thus snapping features into place immediately after digitizing (Limp and Harmon, 1998). As a means of minimising errors that may occur, digitizing was first made on the 1977 image which was very clear, covered the whole study area and was photographed six years before the orthophoto. The orthophoto used was not digitised first because it did not cover the whole study area and some of the features were very faded, making identification of land use parcels and digitizing difficult.

A land use map for 1977 was created by digitizing the 1977 image (**Figure 4.2**). After this initial digitizing and creation of the 1977 land use map, the 1964 and 1950 images were edited as backdrops to the 1977 land use map to reduce differences, as digitizing the same

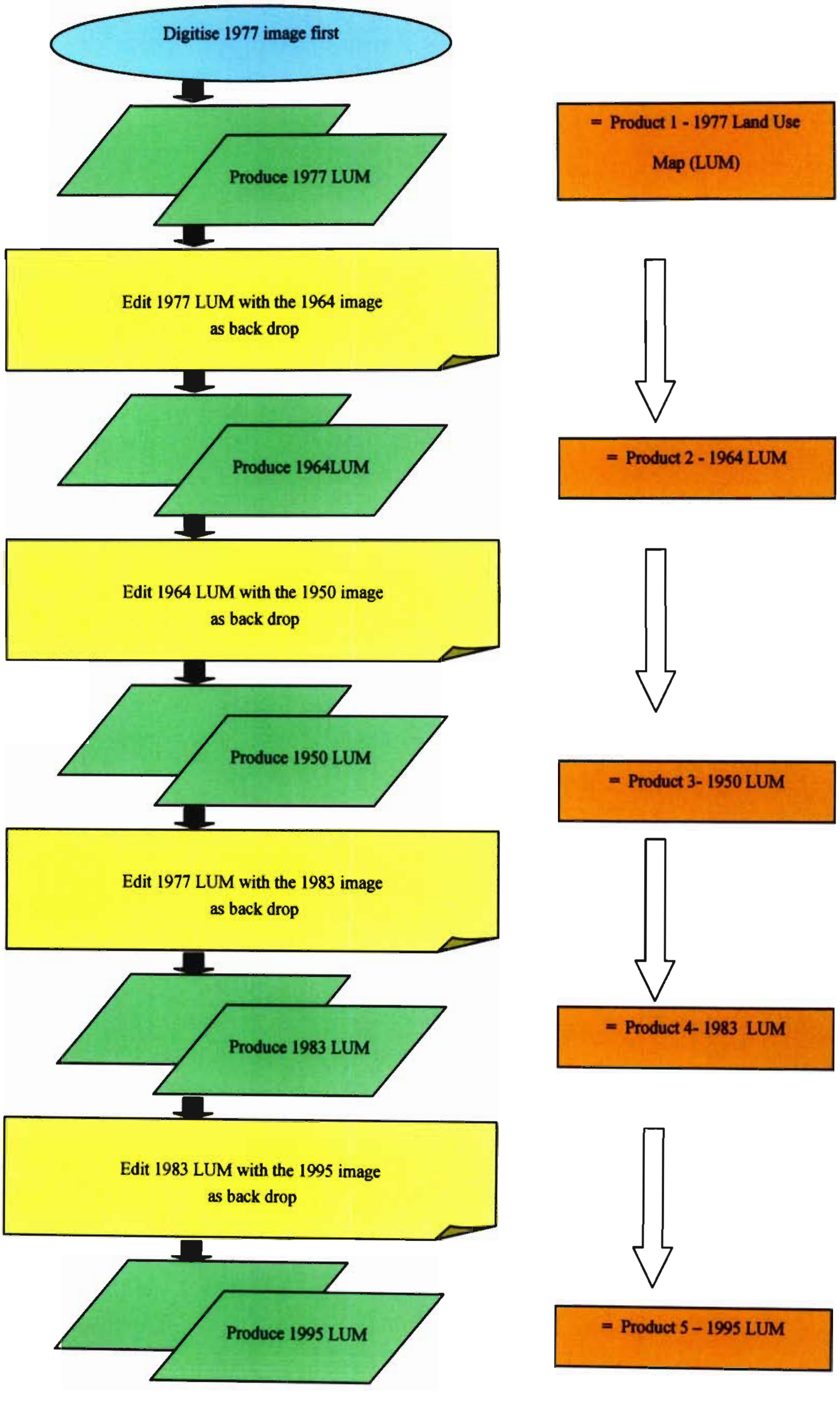

Figure 4.2 Detailed flow chart illustrating sequence of developing Land Use Maps (LUM)

line does not always produce the same results (Dunn *et al*, 1990). Thereafter, the 1977 land use map was edited using the 1983 and 1995 images as backdrops. After all this digitizing, five land use maps were produced for the years 1950, 1964, 1977, 1983 and 1995.

4.1.6 Field surveys and ground truthing

In order to ascertain the accuracy of the interpretation of aerial photographs, field surveys and ground truthing exercises using a GPS were conducted. Firstly, an extensive walk around the area was done with aerial photos at hand, pinpointing different land use types (using the 1995 aerial photo which was the most recent aerial photo of the area). Although it had been five years since the most recent aerial photograph was taken, not many changes had occurred. It was found that the best way to view most of the area was to climb Ntswelatau Mountain with the assistance of a member of the community (Plate 4.5). A drive within the area and around the outskirts provided assistance in viewing the extent of donga/soil erosion in the area (Plates 4.2 and 4.6). Walking around Sebilwane river also confirmed the extent of dryness in the area, as well as water shortage for cultivation.

Finally, a ground truthing exercise was performed using a Global Positioning System (GPS), (Trimble, 1999). This exercise was aimed at confirming that the location of features identified on the aerial photographs corresponded to their locations on the ground.

Plate 4.5 A view of the area from Ntswelatau Mountain. The main road, together with the new houses are visible from the left towards the centre of the photograph.

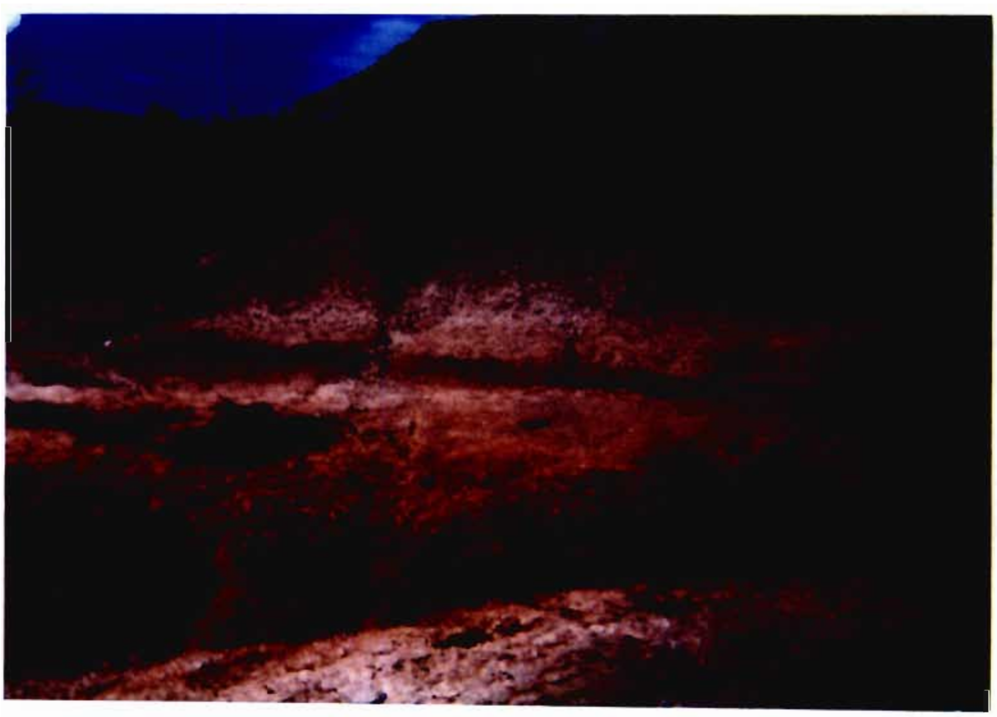

Plate 4.6 A view of a donga across the bridge when entering the area. Taken from within to view its depth (±4 metres) and width (±7 metres)

4.1.7 Ecological time line

An ecological time line is a method used to elicit explanations for environmental changes from long term residents (Reid *et al*, 2000). In this study, interviews and a Participatory Rural Appraisal (PRA) workshop were used to gather this information. The main focus was on environmental changes over a period from 1950 to 1995, thus elder members of the community were approached.

4.1.7.1 Interviews

Initially, an arrangement was made with the staff from the EDA to inform the community about interviews that would be held. The contact person only informed a selected few elders in the community, which reduced the number of interviewees. Structured and semi-structured interviews were initially conducted with seven elder members of the community (Appendix B: Questionnaire). This was in order to obtain an oral history of the area dating back to the 1950s. Five of these interviewees were females while two were males (Plate 4.7).

Four of the group (three females and one male) knew their ages which ranged from 53 to 66, two females were not sure about their ages and one male would not disclose his. Three more interviews were then conducted with women from a communal farm in the area. Their ages ranged from 49 to 63.

It should be noted that the respondents in this survey were aged roughly between 50 and 60 years. This implies that during the period 1950-1964, they were about 20 years old or even older, mature enough to understand and see changes in land use in Manganeng.

4.1.7.2 Participatory Rural Appraisal (PRA)

With the help of a contact person from the area, a PRA workshop was conducted with members from the Manganeng Traditional Council after their meeting. This group consisted of elders (males) from the high court. In order to conform to cultural rules in the area, the respondents' ages were not asked[18]. Their ages were estimated between 55 to 75 years. This PRA workshop assisted in providing an overview of events from a political, social and institutional perspective. This workshop complimented information gathered from the interviews as stated in section 4.1.7.1 above (Appendix C).

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[18] Young members of the community are not permitted to ask or question an elder's age as it is regarded as disrespectful. The ages of the Traditional Council members were not asked but estimated to uphold tradition.

It should be noted that most participants in the interviews were females, thus, undertaking a PRA workshop with these male participants who were also members of the Council provided an insight into environmental issues of Manganeng with an element that took account of political and social issues in more detail. See the group photograph of the Council members--Plate 4.8.

Plate 4.7. Some of the community members examining the aerial photographs and discussing environmental changes.

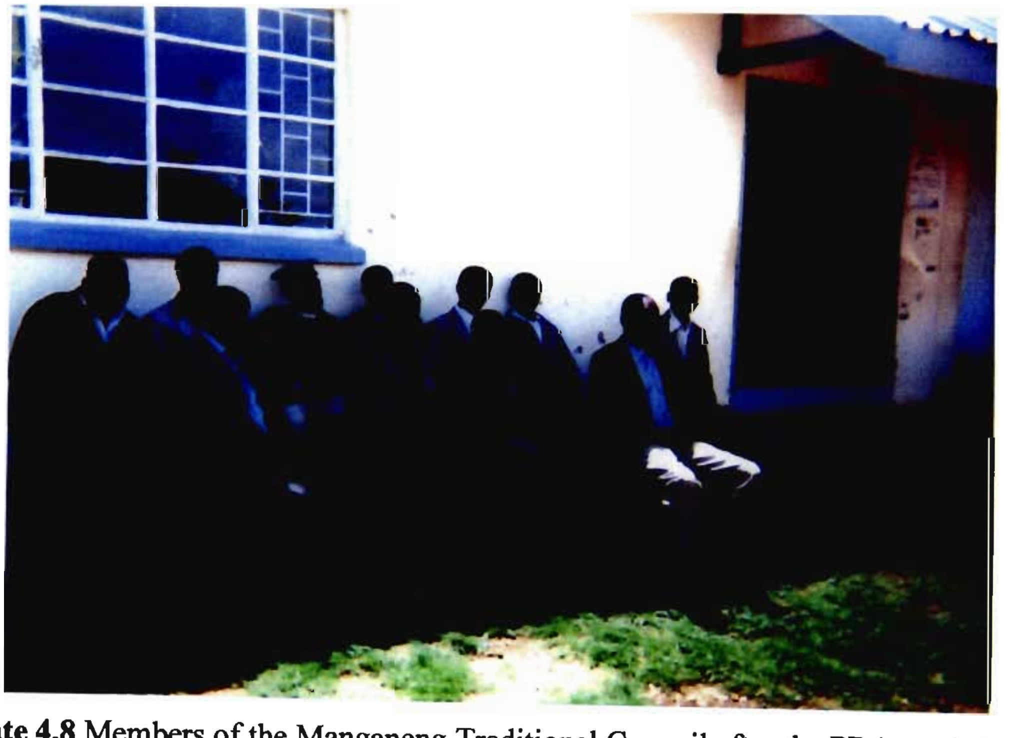

Plate 4.8 Members of the Manganeng Traditional Council after the PRA workshop.

Aerial photographs of the area from 1950, 1964, 1977, 1983 and 1995 were displayed. A tape recorder was also used to record all the descriptions and discussions. This was in order to use the information at a later stage for verification and reference.

A discussion was then held about environmental events that occurred in the area, always-using aerial photographs as a point of reference. This discussion revealed the history of the area with special focus on local erratic environmental changes and identifying different time periods. The group had an occasional disagreement about the different time periods (events) vs. the exact years, and these disagreements were recorded. Verification of these disagreements was benchmarked against data obtained from the Computing Centre for Water Research.

4.2 Analytical techniques

The following subsections provide an overview of the analytical techniques used for analysing data generated from this study. These techniques cover the evaluation of both quantitative and qualitative data.

4.2.1 Quantitative analysis

In order to obtain the land use change results from all five digitized maps, different techniques had to be applied. Firstly, surface area analysis had to be performed to evaluate the amount of area each land use occupied for each year, and then the amount of change that had occurred was calculated using Corel Quattro Pro 8 (Corel Corporation and Corel Corporation Limited, 1997), to provide percentage values. These results were then plotted on graphs using Minitab v12 (Minitab for Windows, 1998). Land use maps created were then overlaid, showing the changes in different land covers. Interviews and the PRA workshop assisted in verification of the data as well as providing a basis from which to understand the causes and effect of land use change in the study area.

4.2.1.1 Surface area analysis

With the use of Geomedia Professional and ArcView GIS 3.2, individual areas for each land use cover type were exported as tables and calculated using the spreadsheet package Quattro Pro 8. The sum of all these values was then calculated and converted to percentages. Data obtained was then used to plot graphs using Minitab v12 (Minitab for Windows, 1998) to illustrate the amount of each land use covering the area.

4.2.1.2 Land cover change analysis

Total area values for each land use for any one year were subtracted from the preceding year, giving land use change values (Equation 1) in hectares.

Year 2 (area) - Year 1 (area) = Land use change value ....(1)

The method mentioned above was also applied to obtain percentage values for each land use change (Equation 2) (Appendix E) (Westinga, 1999).

Year 2 (%) - Year 1 (%) = % Land use change ....(2)

The values obtained from the above equations were used to evaluate land use change in hectares and percentage values, thus assisting in establishing a quantitative analysis of land use change in this study.

4.2.2 Qualitative analysis

The sample group consulted for the interviews and the PRA workshop was too small to warrant a full statistical and quantitative analysis. Instead, information obtained from these interviews and workshop was used to-

(a) develop an ecological timeline of the study area,
(b) compare this information with the spatial data obtained from GIS,
(c) fill the gaps where data was not available (e.g. rainfall and temperature data used for this study was from a meteorological stations near the study area and not in Manganeng itself),
(d) obtain information that would not generally be available from using GIS (e.g. conservation methods used by the community to reclaim dongas, irrigation methods and land management systems applied by the community, etc)

The use of the interviews and PRA workshop in his case was mainly to provide verification of causes and consequences of land use changes in the area.

4.2.3 Potential land use change analysis

Percentage change values obtained as described in section 4.2.1.2 were used to project land use that will change over a 20 year period. A limitation of this method is that it only takes into account the time frame and observed land use, and disregards other external factors that may affect change in land use, such as climate, future development that may occur, land management strategies that are in place and those that may be implemented in the future, etc. Although this limitation has been noted, it is suggested that the results can provide an estimate of possible land use change in the next few years, if present conditions continue.

4.2.4 3-D Image Analysis

Contour lines in Microstation (.dgn) format for Manganeng were obtained from the Surveyor General at Mowbray, Cape Town. The .dgn files were then converted to ArcView shapefiles (ESRI, 1996) and the data was subsequently cleaned (e.g. broken lines were joined and contour lines that had elevation values of zero were corrected). ArcView's 3-D and Spatial Analysis Extensions were then used to create a Digital Elevation Model (DEM) and Triangular Irregular Network (TIN) (ESRI, 1996). This 3-D image was used to display land covers in 3-D by draping the shapefiles onto the DEM.

4.3 Accuracy and error assessment

There are several occasions where error can occur during the creation of land use maps and their analysis. These errors can occur during identification of land cover types and their boundaries, digitizing and also during manipulation of data by the user. This section will describe the various possible sources of error and measures that were taken to minimise them.

4.3.1 Errors in aerial photos

(a) The same route may have been followed during each flight when the aerial photographs were taken. However, the plane may have also been at a different altitude and/or the picture taken at a different angle from one year to the other.
(b) The maps were enlarged, thus distortion might have occurred.

Not much could be done to rectify these errors. (See next subsections on methods used to overcome problems on photo quality and parcel boundaries).

4.3.2 Errors that occur during identification of features

Errors which occur during aerial photo interpretation and digitizing are known as operational errors (Walshe *et al*, 1987). This is when the location of boundaries between land parcels are unclear or are misleading, while sometimes parcels on the ground are omitted from the map, creating a filtered version of what is on the ground (Campbell, 1983).

In order to interpret and identify features on the maps objectively, a stereoscope was used to view features that were not clear. Field visits to specific locations in the area with the aerial photos available also helped to verify and pinpoint the different land use types observed.

4.3.3 Errors that occur during georeferencing

(a) Aerial photos were georeferenced, using locations of prominent features that appeared in all aerial photos and the orthophoto.

(b) All the RMS values differed from one aerial photo to another by less than 13 metres. This resulted in features not occurring at the same place, that is, not allowing for a perfect fit.

In an attempt to minimise errors during georeferencing, five to eight reference points were used to rectify the aerial photographs and had RMS values ranging between 7 and 13 metres. These RMS values were relatively small and were not expected to impact on the accuracy of measurements at the scale of the aerial photos (Ahmed, 1999).

4.3.4 Errors that occur during digitizing

Errors may have occurred during digitizing. As a means of overcoming these shortfalls, the 1977 image boundaries were used for all land use maps created. Where the map did not cover the whole study area, polygons were made indicating missing data. After digitizing was completed, all the maps were cleaned by ensuring that all anomalies and line connectivity's were fixed, e.g. loops, kickbacks, overshoots, undershoots, overlapping of features, etc. Overlapping features were fixed manually, as they would have affected map overlays.

4.4 Qualitative techniques in land use change studies

It is not always accurate to assume that interviews and workshops can provide all the answers to queries related to land use change, hence the need to combine a qualitative technique with a quantitative technique in order to verify the accuracy of data that is generated. The use of qualitative techniques in most cases serve as a benchmark to validate whether spatial data generated from GIS is accurate. Qualitative techniques also assist in generating information that would not generally be available from using GIS. Overall, qualitative data can not be used on its own to assess land use change detection.

4.5 Summary of materials and methods

This chapter has highlighted materials that were used for conducting this study, as well as illustrated the process flows for creating land use maps and classification of land uses identified on the aerial photographs. Errors that may have occurred during the creation of the maps were also indicated, with measures used to overcome the possible shortcomings. The following chapters will provide the results of this study as well as recommendations.

CHAPTER 5 – Results and Discussions

5.1 General land use changes in Manganeng

The land use maps created for 1950, 1964, 1977, 1983 and 1995 are presented in Figures 5 A, 5 B, 5 C, 5 D and 5 E respectively. Land use classification as observed from aerial photographs has been described in Table 4.1. Total area values (in hectares) and total area change values (in hectares) of land use in Manganeng from 1950 to 1995 are presented in Tables 5.1 and 5.2 while total percentage (%) area values and total percentage (%) area change values of land use in Manganeng from 1950 to 1995 are presented in Tables 5.3 and 5.4.

The land use maps created illustrate a significant increase in percentage area of residential land and a decrease in percentage area of grazing land. Bare rock increased slightly, while dongas and scattered trees experienced no significant changes in percentage area. There were very slight changes observed in areas covered by farms and clustered trees while deposited sand had decreased. The following subsections will provide more information on the different land uses mentioned above from 1950 to 1995. Information portrayed within these subsections was gathered from the land use maps created using a GIS. These land use maps only illustrate where land use change has occurred.

5.2 Present land use in Manganeng

Most of the area around the mountain is covered with human settlement. Across the road and on the eastern-side of the mountain are farms with others abandoned and used as grazing fields for livestock. Numerous dongas could be observed in the area. Continued harvesting of wood has left most of the area bare with parts of Ntswelatau Mountain covered by rocks (Plate 4.1). Vegetation in the area is predominantly of small shrubs. Insufficient rainfall has left Sebilwane River dry, almost converting it into a donga (Plate 4.2). Although most people in Manganeng have been allocated land for farming, they continue farming within residential land. Soil eroded from Ntswelatau Mountain tends to be washed towards the river, thus rendering the soil fertility rate around the mountain (where the soil has been washed away) to be low.

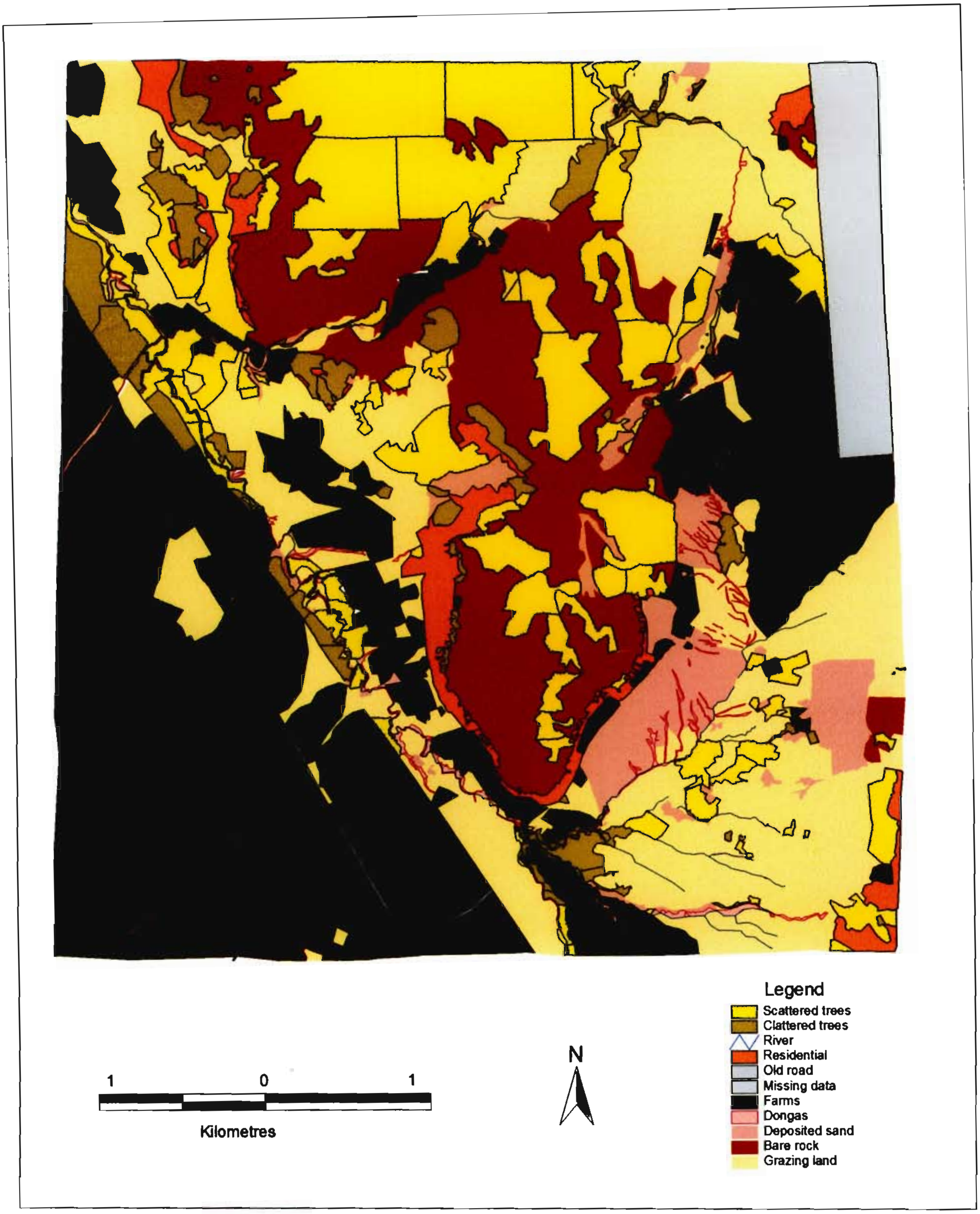

Figure 5 A. Land use map of Manganeng in 1950

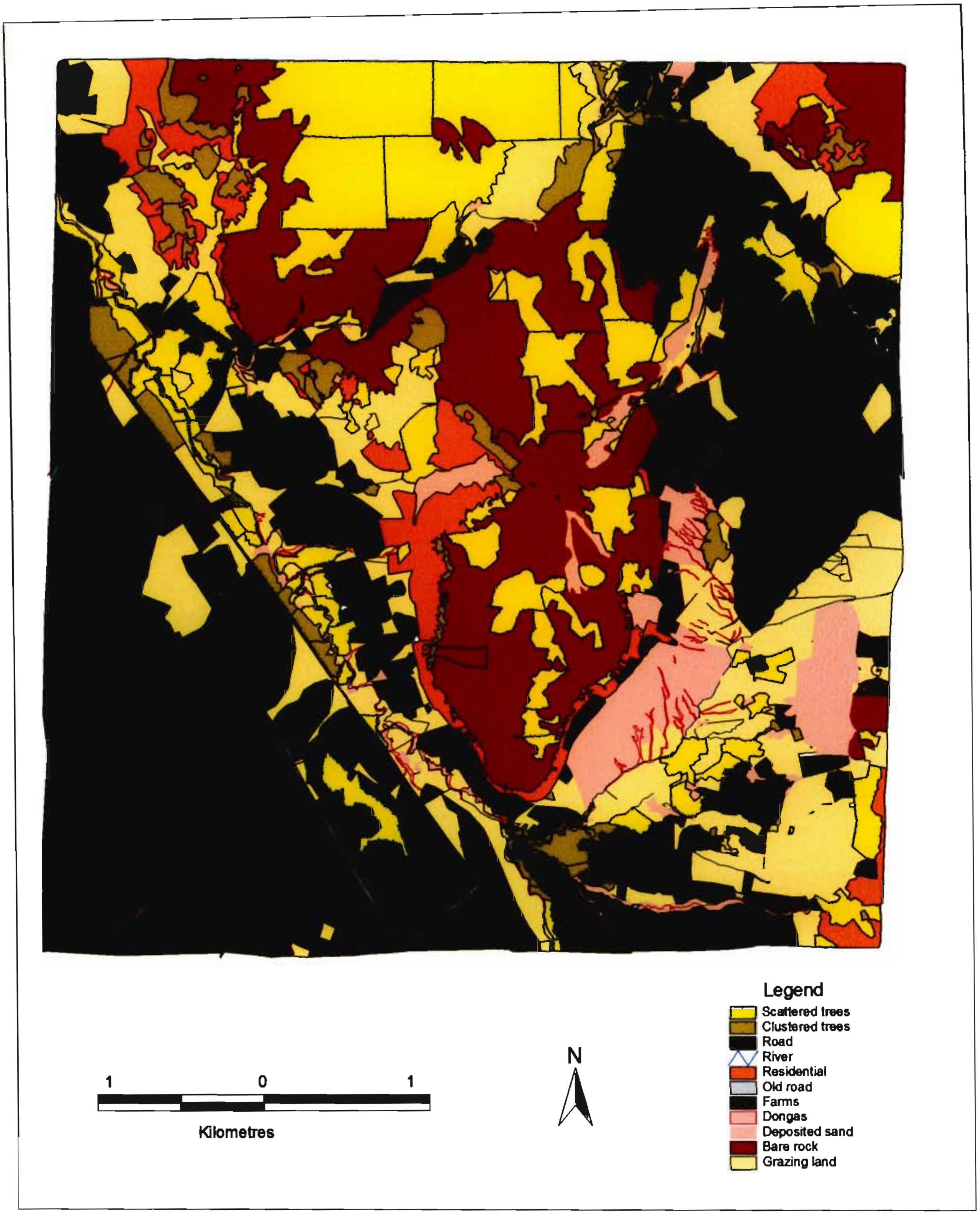

Figure 5 B. Land use map of Manganeng in 1964

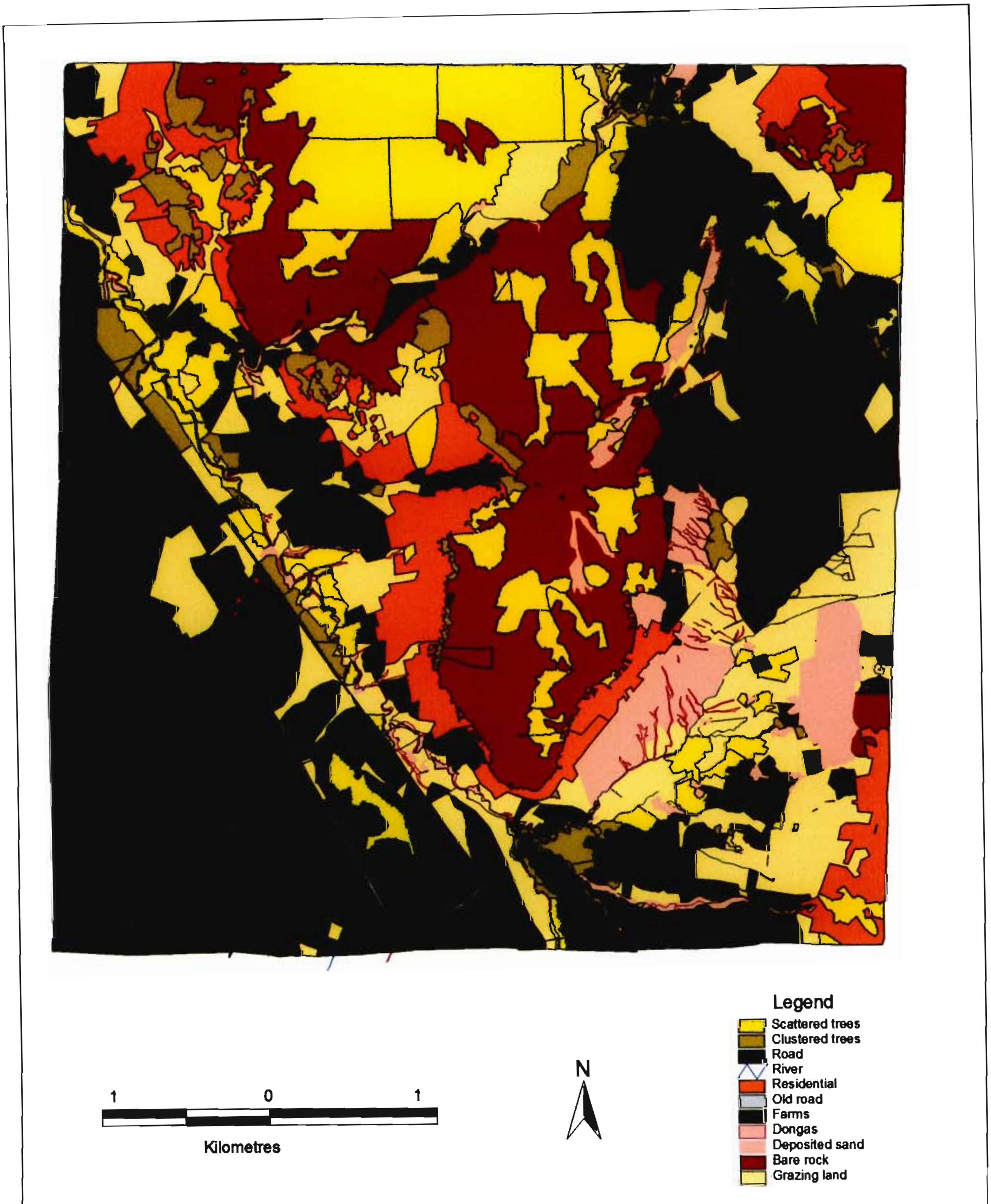

Figure 5 C. Land use map of Manganeng in 1977

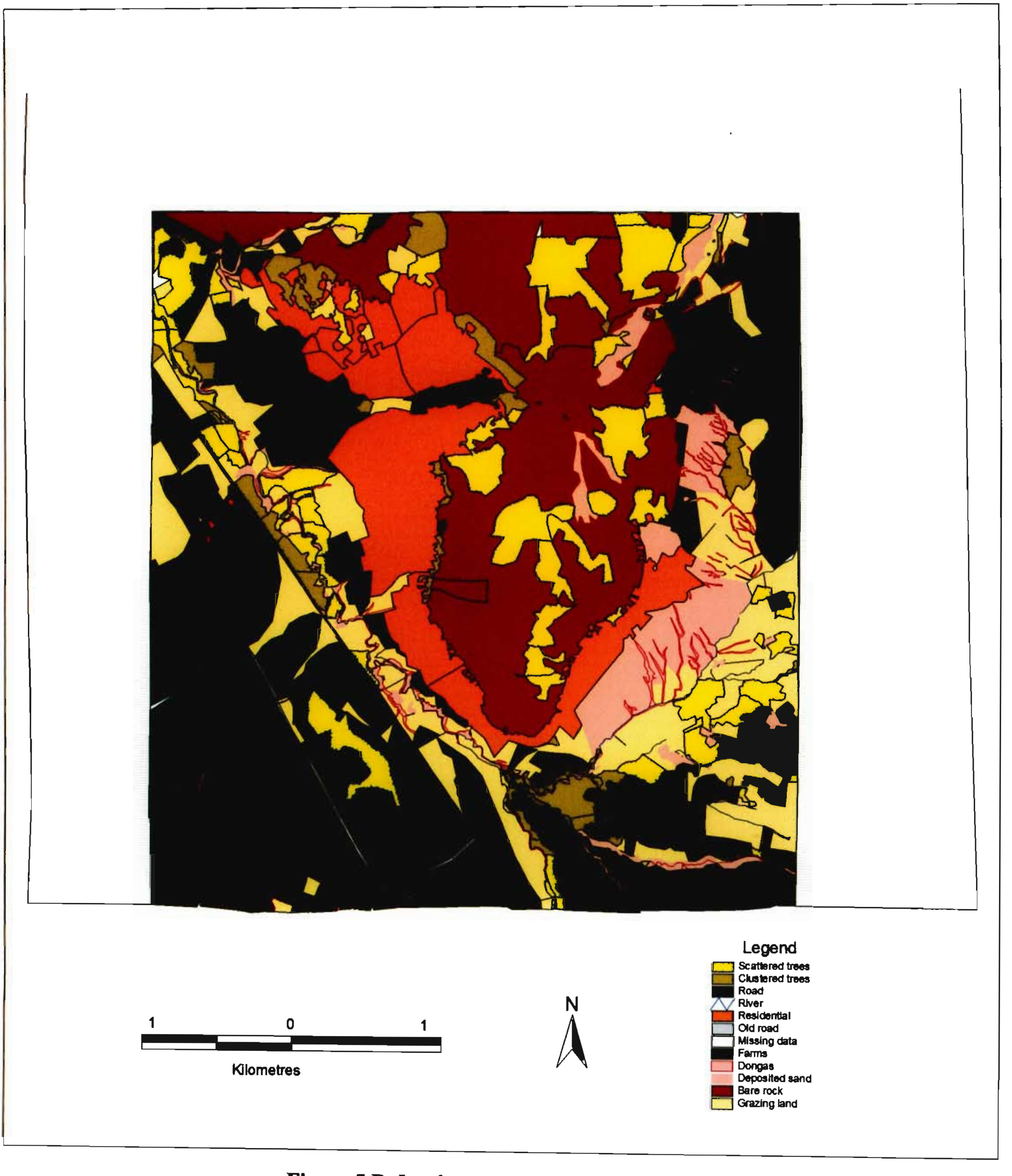

Figure 5 D. Land use map of Manganeng in 1983

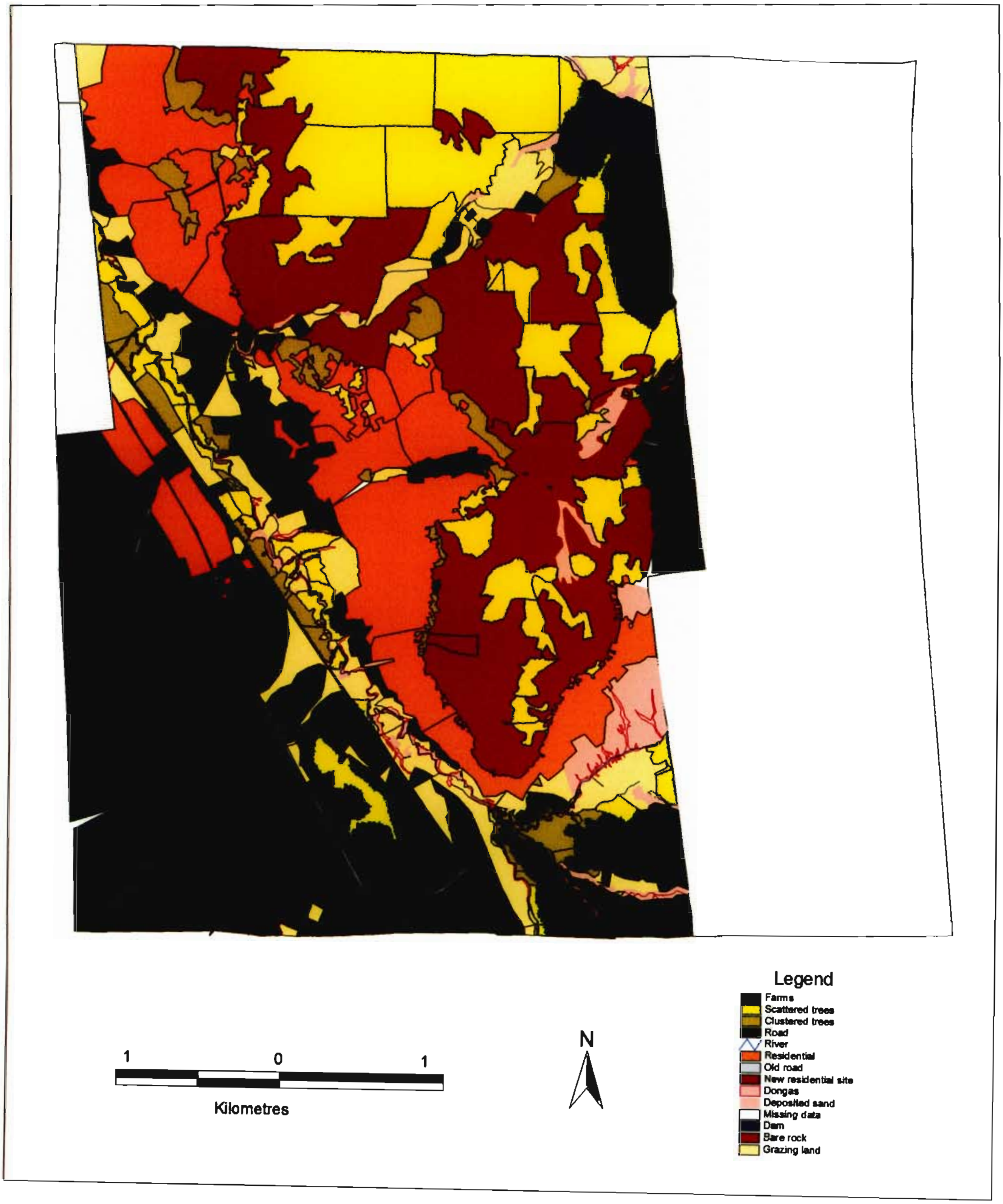

Figure 5 E. Land use map of Manganeng in 1995

Table 5.1 Total area values (in hectares) of land use in Manganeng from 1950 to 1995.

Land use	1950	1964	1977	1983	1995
Grazing land	1213.734	832.688	790.247	390.66	317.891
Bare rock	736.355	771.882	772.202	448.651	678.036
Deposited sand	224.082	234.7	210.627	136.155	86.695
Dongas	52.937	52.744	50.878	40.975	37.128
Farms	1708.856	2180.84	2112.604	1050.971	1324.601
Residential	139.072	229.995	378.547	290.13	516.086
Clustered trees	222.141	199.896	199.381	91.295	139.526
Scattered trees	846.537	833.692	811.019	285.161	616.912
Reservoir	0	0	0	0	41.7
Total area	**5143.714**	**5336.437**	**5325.505**	**2733.998**	**3758.575**

Table 5.2 Total area change values (in hectares) of land use in Manganeng from 1950 to 1995.

Land use	1950 -1964	1964 -1977	1977 -1983	1983 -1995	1950 -1995
Grazing land	-381.046	-42.418	-399.587	-72.769	-895.843
Bare rock	35.52	0.32	-323.551	229.385	-58.319
Deposited sand	10.618	-24.073	-74.472	-49.46	-137.387
Dongas	-0.193	-1.866	-9.903	-3.847	-15.809
Farms	471.984	-68.236	1061.633	273.63	-384.255
Residential	90.923	148.552	-88.417	225.956	377.014
Clustered trees	-22.245	179.485	-108.086	48.231	-82.615
Scattered trees	12.845	-22.673	-525.858	331.751	-229.625
Reservoir	0	0	0	41.7	41.7
Total area	**218.406**	**169.091**	**-2591.51**	**1024.577**	**-1385.14**

Table 5.3 Total percentage (%) area values of land use in Manganeng from 1950 to 1995.

Land use	1950	1964	1977	1983	1995
Grazing land	23.59	15.6	14.8	14.28	8.45
Bare rock	14.31	14.46	14.5	16.41	18.03
Deposited sand	4.35	4.39	3.95	4.98	2.3
Dongas	1.03	0.98	0.95	1.49	0.98
Farms	33.22	40.85	39.66	38.44	35.24
Residential	2.7	4.3	7.1	10.61	13.73
Clustered trees	4.31	3.74	3.74	3.33	3.71
Scattered trees	17.45	15.62	15.22	10.43	16.41
Reservoir	0	0	0	0	1.1
Total area	**100.96**	**99.94**	**99.92**	**99.97**	**99.95**

Table 5.4 Total percentage (%) area change values of land use in Manganeng from 1950 to 1995.

Land use	1950 -1964	1964 -1977	1977 -1983	1983 -1995	1950 -1995
Grazing land	-7.99	-0.8	-0.52	-5.83	-15.14
Bare rock	0.15	0.04	1.91	1.62	3.72
Deposited sand	0.04	-0.44	1.03	-2.68	-2.05
Dongas	-0.05	-0.03	0.54	-0.51	-0.05
Farms	7.63	-1.19	-1.22	-3.2	2.02
Residential	1.6	2.8	3.51	3.12	11.03
Clustered trees	-0.57	0	-0.41	0.38	-0.6
Scattered trees	-1.83	-0.4	-4.79	5.98	-1.04
Reservoir	0	0	0	1.1	1.1
Total area	**-1.02**	**-0.02**	**0.05**	**-0.02**	**-1.01**

The following subsections will provide quantitative and qualitative analytical results for this research. This will cover surface area and land cover change analysis, potential land use change projections, 3-D image analysis and results from the interviews and PRA workshop.

5.3 Surface area and land cover change analysis

Individual areas for each land use cover type were exported as tables from Geomedia Professional and ArcView 3.2 and calculated using the spreadsheet package Quattro Pro 8. The sum of all these values (Table 5.1- 5.2) was calculated and converted to percentages (Table 5.3-5.4). Data obtained was plotted into graphs illustrated in Figures 5.1 (a) and 5.1 (b). Regression analysis for the different land uses is displayed in Appendix D.

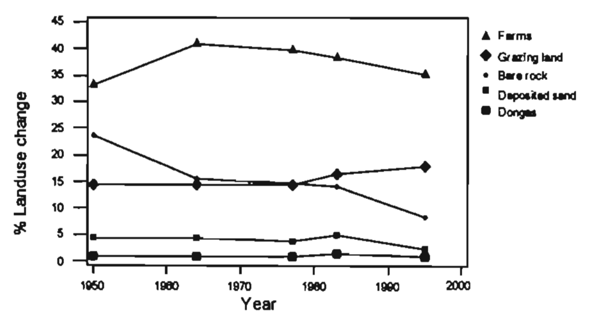

Figure 5.1 (a)

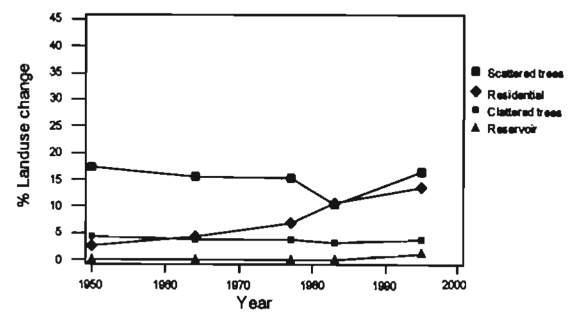

Figure 5.1 (b)

Figure 5.1 (a) and (b) Total percentage (%) area values of land use in Manganeng from 1950 to 1995.

It is noted that missing data on the 1950 and 1995 aerial photographs as well as the 1983 orthophotograph have contributed to a small discrepancy in providing a complete reflection of land use changes in the created land use maps. However, a ground truthing exercise which included a GPS and walk around the study area with a map provided a base from which land parcels were verified.

Map overlays that have been developed in this study have only provided insight as to what has changed in terms of land use area. The reasons for the causes and consequences of these changes were extracted from the interviews and PRA workshop, hence will be reported on within the qualitative sections as mentioned previously.

5.3.1 Farms

There was a change in percentage area covered by farms (regression; $p < 0.05$, d.f. =1: Appendix D). The area covered by farms increased from 1709 hectares (33.22 percent of the study area) in 1950 to 2181 hectares (40.85 percent of the study area) in 1964 which represents an increase of 127 percent. There was a decrease in this land cover from 2113 hectares in 1977 to 1050 hectares in 1983. Between 1950 and 1964, surface area covered by farms increased by 7.63 percent (Table 5.4) and a gradual decrease was observed from 40.85 percent to 35.24 percent from 1964 to 1995 (Table 5.3).

Comparing the surface area change for farms over a period of 45 years, it was observed that in 1950 the area covered by farms was 33.22 percent and in 1995, the area was 35.24 percent. This is a slight increase of 2.02 percent. As discussed already, there was missing data from the 1950, 1983 and 1995 photographs. Hence, the land use maps for 1950, 1983 and 1995 did not cover the whole study area, which resulted in some land use parcels not being captured on the maps.

Map overlays

The land use maps created for 1950, 1964, 1977, 1983 and 1995 were overlayed to observe changes in sizes of the polygons representing farm land. There was missing data on the eastern portion of the map overlays because the 1950, 1983 and 1995 land use maps did not cover all the surface area. Missing data was also observed on the top western portion of the map overlays.

An increase in patch sizes of farms on the north east and south east of the land use map overlays was observed. This increase is more evident from the 1995 farm polygons. Polygons (solid green) on the south west of Figure 5.2 illustrate that no change occurred since 1950. This is denoted by the same polygons of land having the same size and colour coding from the first year (1950). The same was observed on other polygons in the south and centre of Figure 5.2. These polygons in the south and centre represent farm patches for 1964, 1977 and 1983 which did not change over the years. The absence of change in size and colour coding of the polygons implies that the land parcels were abandoned (no farming occurred) or that the parcels were converted to other land uses.

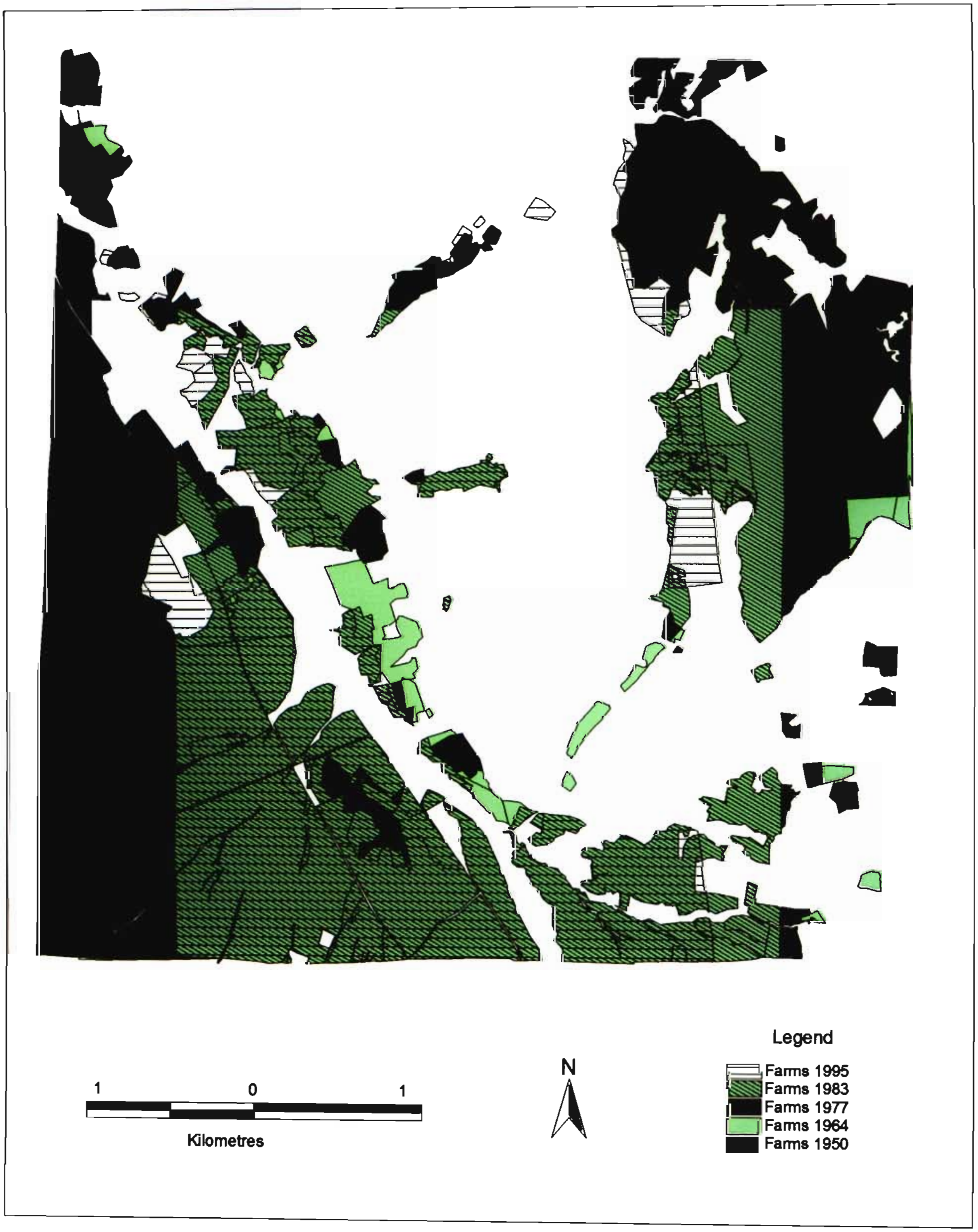

Figure 5.2 Land use change map overlay of farms in Manganeng from 1950 to 1995

5.3.2 Grazing land

There was a significant decrease (regression; $p < 0.05$, d.f. =1: Appendix D) in percentage area of grazing land from 1950 at 23.59 percent to 1995 at 8.45 percent (Table 5.3; Figure 5.1 (a)). The area covered by grazing land was 1214 hectares in 1950, but decreased to 833 hectares in 1964. Between 1964 and 1977, a decrease of grazing land area was observed at 42.4 hectares (Table 5.2). A continuous decrease in this land use was observed from 790 hectares in 1977 to 318 hectares in 1995.

Map overlays

Land use maps for 1950, 1964, 1977 1983 and 1995 were overlayed to observe changes in sizes of the polygons representing grazing land (Figure 5.3). Most of the grazing land was converted to other land uses such as farming and residential land. Data on the eastern part of the land use maps only illustrates changes for 1950, 1964, 1977 and 1983. The 1995 land use map had no data to cover the whole area.

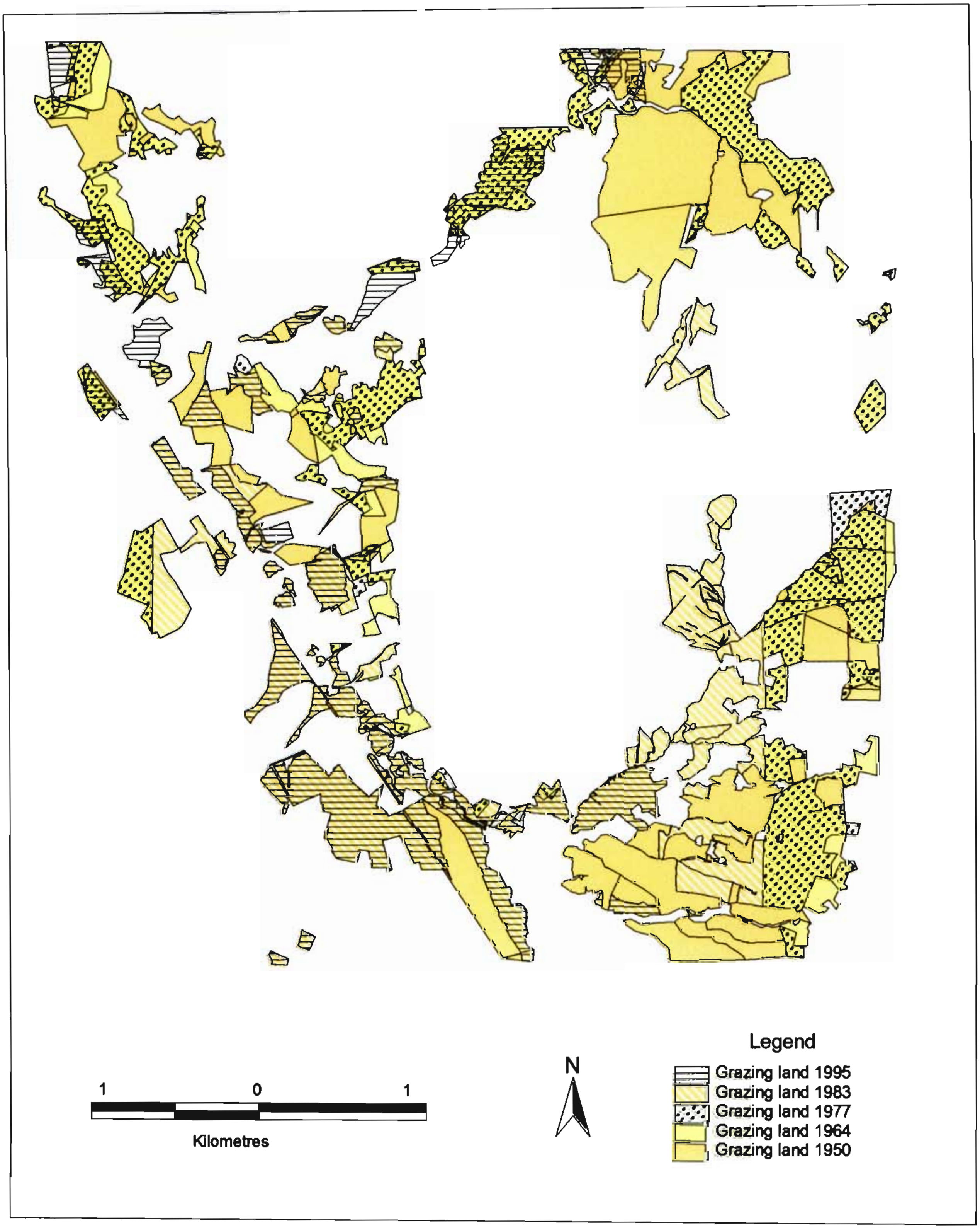

Figure 5.3 Land use change map overlay of grazing land in Manganeng from 1950 to 1995

5.3.3 Bare rock

There was an insignificant increase (regression; $p > 0.05$, d.f. =1: Appendix D) in percentage area covered by bare rock from 1950 to 1995 (Table 5.3; Figure 5.1 (a)). This land use has remained stable from 736 hectares in 1950 to 772 hectares in 1977, with a slight increase observed from 449 hectares in 1983 to 678 hectares in 1995. The increase in percentage area of bare rock observed between 1983 and 1995 has been insignificantly small at almost 3 percent.

This insignificant increase could have been caused by-

- a reduction in size of mountain vegetation caused by fuel wood harvesting and grazing by livestock, leading to more exposed rocks on the mountain;
- changes in climatic conditions, where the area received less rain, resulting in more exposed rocks on the mountain, thus demonstrating a reduced size of mountain vegetation;
- the 1983 and 1995 land use maps which did not cover the whole area, probably allowing a display of slight errors in the percentage area of this land use (as viewed on an aerial and orthophotograph, and quantified in GIS).

Map overlays

No map overlays were produced for bare rock as there is insignificant land use change over time.

5.3.4 Deposited sand

There was an insignificant decrease (regression; $p < 0.05$, d.f. =1: Appendix D) in percentage area of deposited sand from 1950 to 1995 (Table 5.3; Figure 5.1 (a)). The percentage area covered by deposited sand remained stable between 224 hectares in 1950 and 234 hectares in 1977. A slight increase of 1.03 percent (Table 5.4) occurred from 1977 to 1983, and decreased at 2.68 percent (Table 5.4) from 1983 to 1995.

Map overlays

No map overlays were produced for deposited sand as there is insignificant land use change over time.

5.3.5 Dongas

There was no significant change in percentage area of dongas (regression; $p \leq 0.05$, d.f. =1: Appendix D). They have remained stable from 1950 to 1995 at almost 1 percent (Table 5.3; Figure 5.1 (a)).

The percentage area covered by dongas ranged between 0.95 percent and 1.49 percent (Table 5.4). Changes that were observed for dongas between 1977 and 1983 (± 0.54 percent, Table 5.4) and between 1983 and 1995 (± 0.51 percent, Table 5.2) are significantly small, and could be attributed to missing data that could not be compared between the 1983 and 1995 land use maps.

Map overlays

No map overlays produced for dongas as there is no significant land use change over time.

5.3.6 Scattered trees

Scattered trees had no significant changes in percentage area (regression; $p<0.05$, d.f. =1: Appendix D) over a period of 45 years (Table 5.3; Figure 5.1 (b)). The percentage area covered by scattered trees remained stable from 1950 to 1977 at ± 15 percent (Table 5.3). This percentage area decreased slightly between 1977 and 1983 at 10.43 percent, but increased slightly from 1983 to 1995 at 16.41 percent (Table 5.3). This implies that from 1950 to 1995, the surface area changed from 17.45 percent to 16.41 percent, which is relatively negligible.

Map overlays

No map overlays produced for scattered trees as there is no significant land use change over time.

5.3.7 Residential land

There was a significant increase in percentage area (regression; $p > 0.05$, d.f. =1: Appendix D) of residential land (Table 5.3; Figure 5.1 (b)). This increase in residential land has been continuous from 2.7 percent in 1950 to 13.73 percent in 1995. In 1950, the area covered by residential land was 139 hectares, this increased to 516 hectares in 1995. This was a total increase at 13.73 percent for residential land.

Residential land increased by 1.6 percent (91 hectares) between 1950 and 1964. This increase continued at 4.3 percent (148.5 hectares) between 1964 and 1977. Between 1977and 1983, a decrease was observed at 88.4 percent. However, this decrease has been linked to the missing data on the 1983 land use map. There was an increase of up to 225.9 hectares (at 3.12 percent) in 1995.

Map overlays

Land use maps for 1950, 1964, 1977 1983 and 1995 were overlayed to observe changes in sizes of the polygons representing residential land (Figure 5.4). Residential land polygons increased gradually from 1950 to 1995. It was noted that most of the residential land polygons increased in size and were not replaced by other land use parcels.

Most of the changes can be observed in the centre of Figure 5.4. Residential land was built along the edges of Ntswelatau Mountain, forming a U-shape. Over the years, the residential polygons increased significantly away from the Mountain. The same growth in residential polygons is visible north west of Figure 5.4. Smaller polygons of residential land are also visible to the west of Figure 5.4.

There was no land use change observed east of Figure 5.4. The land use maps for 1983 and 1995 did not have data that covers portion of the area, hence the difficulty of comparing changes that may have occurred.

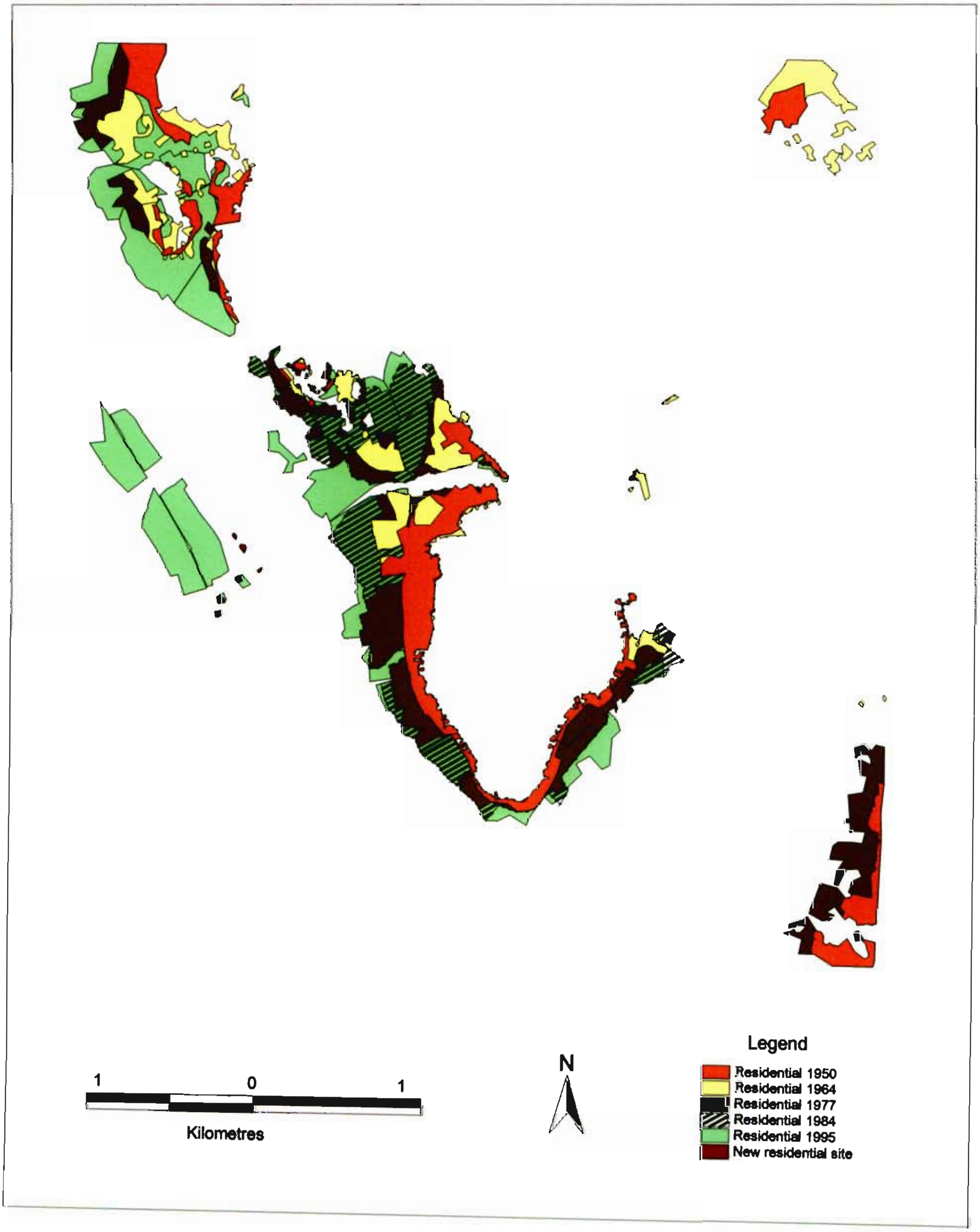

Figure 5.4 Land use change map overlay of residential land in Manganeng from 1950 to 1995

5.3.8 Clustered land

Clustered trees had no significant change in percentage area (regression; $p \leq 0.05$, d.f. =1: Appendix D) over a period of 45 years (Table 5.1; Figure 5.22). They have remained stable from 1950 to 1977 at almost 4% (Table 5.3).

5.3.9 Reservoir

The reservoir was observed only on the 1995 photograph. This implies that the reservoir was built sometime between the 1983 and 1995 when the photographs were taken.

5.4 Qualitative analysis

Information presented in this section was gathered from interviews and a PRA workshop. These interviews and a workshop were not used to elicit a statistical analysis, but were used to develop an ecological timeline which can be used to verify some of the changes that have been identified from using GIS and temperature and weather data. The other reason for adopting this approach was the fact that the sample group interviewed and workshoped was relatively small. The first part of this subsection reflects on a community perspective on land distribution and land tenure, while the second part provides background information about land use changes in Manganeng.

5.4.1 Land distribution and land tenure in Manganeng: a community perspective

In common with other former homelands in Limpopo, the land tenure system in Manganeng is still subject to tribal authority, and is governed by the chief and his headman. This system is rather inappropriately termed *communal* since the major portion of the land is allocated to individuals for private cultivation.

The right to cultivate is unchallengeable and is inherited from father to son. All members of the community who desire land for cultivation are granted their wish, and the large majority of households do cultivate crops. Those who wish to cultivate land or build a house approach the headman who will refer the matter to the chief, and a plot will then be allocated.

Most respondents interviewed in this study believed that land allocation occurred only after discussions between the chief, his headman and the Local Department of Agriculture and Land Affairs. However, it was pointed out that the chief performs a significant role of granting land within the community, while the *molimi*[19] only assisted in pointing out available and suitable land for cultivation and/or building of houses.

Governing power is not appropriately distributed between the Traditional Council (headed by traditional leaders) and the Transitional Local Council (headed by elected government officials). The community is not aware that they have rights to land. They believe that, although they have been allocated land, it still belonged to the chief. People staying in Malaeneng (an extension of Manganeng, Figure 3.1), have deeds of land and infrastructure on plots they occupy[20], while many of those who live in the old village have none[21].

5.4.2 Land use change in Manganeng: a community perspective

There is a cross-link between land use and human actions, which directly alters the physical state of the environment. These physical changes of the environment tend to have feedback effects on land uses and human driving forces (Reid *et al*, 2000).

This statement was echoed during the interviews and a PRA workshop when respondents recalled how Manganeng used to look in 1950, and changes that occurred ever since. The following subsections provide a community perspective on causes and consequences of these land use changes. Issues addressed within this subsection have been delineated according to changes in land use types as observed by the respondents.

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[19]A person who works for the Department of Agriculture and Land Affairs is called a *molimi* (in the local language –Sepedi, Northern Sotho).

[20] More information on land tenure in the area could be obtained from the CSIR-Pretoria who have been investigating the land tenure system in Manganeng and areas around Sekhukhuneland (1999-2004).

[21] The old village is where most of the community has settled - the area between the road and west of Ntswelatau Mountain (Figure 3.1).

5.4.2.1 Transformation of the human settlement

(a) Increase in service infrastructure

Road- The main road in Manganeng (Figures 3.1) was constructed around 1964 by Mr Joubert who came to payoff pension funds in Sekhukhuneland (refer to Section 2.9). In the 1970s, an additional branch to the road was constructed as an access route to farms and villages, west of Ntswelatau Mountain. This road was later tarred for road maintenance because, after heavy rains, potholes accelerated the rate of erosion and limited the amount of traffic to/and from the area.

Reservoir- The planning phase for the reservoir (Figure 3.1) construction in Manganeng took place around 1987, and the engineering phase around 1988. The actual construction of the reservoir started in 1989. During the planning and design of this reservoir, the community was not consulted. The opinion voiced by the respondents was that the reservoir did not belong to them. The construction of this reservoir has affected farming activities along Pshirwa River, which has dried out.

Ramade (1984) mentioned that continued damming and silting of rivers contributes to the drying up of streams, which serve as a major source for irrigation, thus resulting in a drought inflicted region if the area also receives very limited rainfall. This is very evident in Manganeng where vegetation has been cleared to create space for constructing infrastructure. A decrease in farming activities along Pshirwa River is also evident.

(b) Increase in human settlement

Human settlement has increased due to population growth in the area. During the interviews and PRA workshop, some respondents emphasised that population growth in Manganeng was not necessarily extended by immigrants, but by an increase in existing family sizes, resulting in large numbers of extended families creating new homesteads. A portion of the respondents mentioned that a small number of the neighbouring communities have migrated to Manganeng, enhancing the need for more housing. By and large; housing infrastructure has increased dramatically over the years.

5.4.2.2 Modifications of the natural rangeland

(a) Vegetation depletion

The whole of Manganeng was initially covered by a diversity of vegetation. This has been confirmed during interviews and the workshop. Tapson (2000) from CSIR-Pretoria translated the following vegetation names (Box 5.1) (as provided by the interviewees) from Sepedi into Latin.

Box 5.1 Translated vegetation (species) names

Morula= *Sclerocarya birrea*	**Mogohlo**= *Acasia grandicornuta*
Moseble= *Peltophorum africanum*	**Mothalo**= *Ziziphus mucronata*
Mohlwehlwe= *Rhus gueizii*	**Mokgengwana**= *Commiphora pyracanthoides*
Mohwelere=??	**Moshwana**= *Acasia tortolis*
Mogaba= *Kirkia wilmsii*	**Mogoto**= *Grewia microthyrsa*
Mabilo= *Vangueria infausta*	**Monamane**= *Cassine transvaalensis*;
Mogoto= *Grewia microthyrsa*	**Mohlophi**= *Boscia albirtrunca*
Mohlatswa= *Ximenia caffra*	**Mopudu**= *Mimusops zeyheri*

It was noted that an increase in human settlement and the creation of farmland have decreased the density and/or diversity of vegetation in the area. Climatic conditions as well as continuous harvesting have also played a major role in altering the vegetation. Ramade (1984) and Hugo *et al* (1997) confirmed that insufficient rainfall, extensive harvesting of vegetation and overgrazing could give rise to bush encroachment, with an alteration to vegetation in an area. This was the case in Manganeng where the area had no forests, except for shrubs, which were randomly scattered and have been harvested extensively. Most of this vegetation (Box 5.1) could still be found in Manganeng, though, at a small scale.

Most respondents mentioned that they harvested fuel wood on the edges of the mountain and within uncultivated land. Collection of fuel wood on Ntswelatau Mountain has been, and is currently restricted. Ntswelatau Mountain is regarded as sacred. It transpired during the interviews that only a few community members and livestock do harvest trees on this mountain at a very small scale.

(b) Wildlife migration

Competition for food and insufficient vegetation for camouflage were the main reasons cited for wildlife migration in the area. Most respondents interviewed were able to recall the wildlife species names. These names were mentioned in Sepedi, and Tapson (2000) from the CSIR-Pretoria translated them as follows:

Box 5.2 Translated wildlife (species) names

Phithi= red forest duiker	**Letlabo**= mountain reedbuck
Phuthi= grey duiker	**Kgabo**= vervet monkeys
Kome= klipspringer	**Mutlwa**= scrub hare
Khomu= scrub hare	**Dichuene**= baboons/monkeys
Phudubudu= steenbok	**Nkwe** = leopard
Tau= lion	

Lange *et al* (1998) mentioned that an alteration in vegetation in an area encourages wildlife migration. The same has occurred in Manganeng. Human settlement and the clearance of vegetation have facilitated changes in the environment, making it unsuitable for wildlife. Competition for food and poaching of wildlife also increased the prospects of migration.

5.4.2.3 Human activities impacting on agricultural practices

(a) Inappropriate farming methods

Most families have been allocated at least two hectares of land for farming. Others have inherited land from their elders or by marriage (Section 5.1.1). Fertiliser is rarely applied to the soil and there are very few irrigation schemes in place. These irrigation schemes are largely from wells/taps in the area and not from the river system. This implies that rainfall is the most dominant mode of enriching the soil for agriculture in the area.

(b) Improved pasturing methods

Livestock pasturing is allowed in farms that have not been cultivated for that particular year[22]. This appears to be an acceptable way for all community members as most residents have very few livestock. Other places used for grazing are on the mountain and across the road (west of the mountain) where there are many farms close to Malaeneng (Figure 3.1).

In the early 1970s, agriculturalists were used to de-stocking as a measure of decreasing stocking rates to minimise soil erosion. If a family had five cows, three had to be sold or killed to maintain the stocking rates (Delius, 1996). A family's wealth is indicated by the number of livestock that family owns. This method of decreasing livestock numbers fostered livestock theft and unstabilised many families both socially and economically in the past. This form of de-stocking was not implemented on a regular basis, and has not been carried out in the past 20 to 25 years.

(c) Donga reclamation

The respondents did not regard dongas in the area as a problem. It was mentioned that the elders in the community have been reclaiming what they can by using stones, dead trees and aloe plants (*dikgopa*) in sacks to block these dongas. All dongas that were located outside the homesteads and very large in size were left alone. These dongas have portrayed a slight increase in size over the years. This increase only becomes evident after heavy rains in the area. The community strongly believe that these dongas have stabilised over time.

Apparently, no outside organisation has approached the community about reclaiming some of the dongas to increase available land for cultivation, except for discussions held with some of the members from the EDA and CSIR.

[22] The community applies rotational farming methods to their land.

5.4.2.4 Natural activities impacting on the environment

(a) Insufficient river flow rate

Between 1953 and 1954, and around the early 1980s, the first half of Sebilwane River used to flow after heavy rains while the last half remained dry. None of the respondents could recall Sibilwane River filled with water to the base of the riverbank. There are no irrigation schemes (from the river) for irrigating farms in Manganeng. Sebilwane River was never full for the community to rely on it for irrigating their farms.

(b) Changes in climatic conditions

This subsection focuses on the different names given by the local community to different ecological periods, and debates held on climatic conditions in Manganeng as recorded from the interviews and a PRA workshop.

It should be noted that when participants had disagreements on the exact years and names of these time periods, the researcher later cross-checked the climatic conditions information against that received from the Computing Centre for Water Research (CCWR).

i) Ecological time-line

Most respondents recalled the exact years for different time periods, which made it easy to match the named time-periods (the years) as well as documented information from the CCWR presented in Figure 3.2. The different names for different environmental events are mentioned below:

- There was sufficient rainfall around 1996, and this period was named ***Mabele ke o bea kae.*** The community was able to produce many agricultural products and did not have enough room to store their surplus.
- Between 1978 and 1980 the area was dry, and this era was named ***Mabele a ma sehla*** (yellow wheat), when the people had to eat yellow miellie-meal.
- It rained heavily around 1967, and this period was named ***Poponono***.
- It rained heavily in 1953 and this time period was named ***Mabele a lerotse,*** when the

harvested agricultural products were very large in size.

- In 1945, drought inflicted the area. This period was named ***Tlala ya moletelo*** which means, "waiting hunger". The area received heavy rains in 1946.
- There was draught between 1920 and 1930 and this time period was named ***Tlala ya mohlophi***.
- Before 1930, it rained well and this era was named ***Tlopa mpedi***.
- Most respondents recalled their elders mention how dry the area was during the late 1880s and early 1900s.

ii) Ecological events (rainfall)

- There was sufficient rainfall in 1953 such that Sebilwane River had running water. The first half of the river, up next to Pshirwa river, north towards Madibaneng (Figure 3.1), was flowing while the last half (south of Nstwelatau Mountain) was dry, operating only as a spring.
- A huge rock fell from the mountain during a heavy storm (between 1964 and 1975), leaving a white mark along its path. This mark is still visible today.
- The area was drought inflicted in 1976. Some respondents mentioned that it only rained well in 1977 and drought followed from 1978 to 1980, and that good rains resumed from 1980 to 1981.
- It was confirmed that around the early 1980s, there were good rains to the extent that the first half of Sebilwane River was flowing, and that the area received less rain between 1983 to 1995.

Recorded information (Appendix B) from the CCWR and Figure 3.2 provide an overview of the rainfall pattern in Manganeng. This rainfall pattern information from the respondents (as mentioned above) was a perfect match when compared to data provided by the CCWR.

5.4.2.5 Visual change assessment (2003)

A visual impact assessment and informal interviews conducted with the local community in 2003 have indicated that not much change has occurred in the area since early 1900's. The only visible change observed is an increase in human settlement with a slight decrease in farm land.

This is evident across the road from Manganeng, in Malaeneng where serviced low-cost housing has replaced farm-land. A walk along the river and the dongas has indicated an insignificant increase in donga sizes.

Harvesting of fuel wood is still forbidden on the mountain, which implies that the visibility (% change) of bare rock on the mountain would not have increased significantly. Farm land has also decreased slightly (across at Malaeneng) with rotational farming still being implemented in Manganeng.

During the visual assessment, it was noted that grazing land had been farmed while land that was previous farmed was left abandoned. A general trend has emerged wherein there was a consistent interchange between grazing land and farm land. Areas where clustered and scattered trees were previously viewed did not portray significant changes.

5.5 Potential land use change analysis

Percentage change values obtained from the GIS-based analysis generated land use maps (Appendix F and Table 5.1) were added to a raw score prediction formula to predict the extent of change which certain land uses will undergo over a 20 year period if present conditions continue. This prediction formula is presented below:

Predicted Y = (SD*y*) Predicted (Z*y*) + M*y*..(3)

where SD*y* represents a raw score regression coefficient , Predicted Z*y* represents a raw score and M*y* represents a regression constant (Aron and Aron, 1997).

This evaluation and prediction method has only taken into account the time frame and the observed land uses, and has overlooked other external factors that may affect change in land use. These external factors include climate change, future development, land management strategies that are in place and those that may be implemented in the future.

The reason why most of these factors were overlooked was due to lack of information and if information was available, it was not enough to produce a trend that could be followed to predict the outcomes of future land uses in the area. Although this limitation of leaving out certain factors that could contribute to future changes in land use have been noted, it is suggested that the results obtained within this document can provide an estimate of possible land use change in the next few years, if present conditions of resource use and environmental management continue.

The following land uses, grazing land, bare rock, farms and residential land have been selected as priority land use types. If their use continues at the present rate, then the results could prove to be detrimental to the natural environment of Manganeng, unless sustainable management strategies are implemented.

5.5.1 Grazing land

The predicted percentage area of grazing land in 2005 may be 5.90% while in 2015 it may reduce further to 2.86%. Figure 5.5 illustrates a continuous decrease of percentage area covered by grazing land. This implies that if the community continues to extend their farming activities and residential land into grazing land, then there will not be as many open spaces which by and large cater for livestock grazing and sometimes as sports fields for the younger community members.

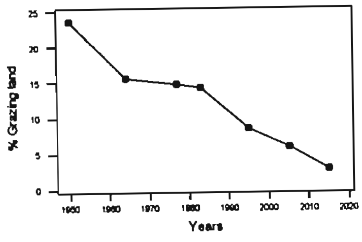


Figure 5.5 A line graph showing the decreasing percentage area of grazing land.

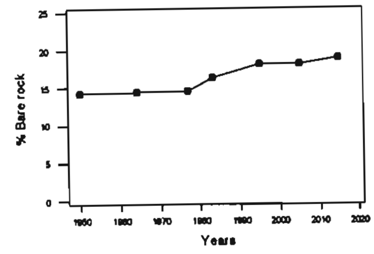


Figure **5.6** A line graph showing the increasing percentage area of bare rock.

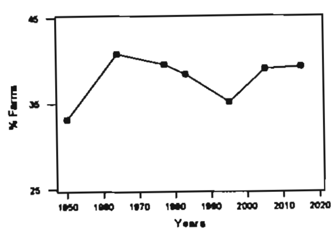


Figure 5.7 A line graph showing the predicted percentage area of farms.

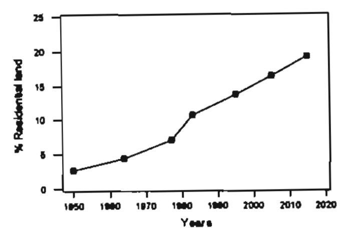


Figure 5.8 A line graph showing the predicted percentage area of residential land.

5.5.2 Bare rock

The predicted percentage area of bare rock in 2005 may be 18.01% while in 2015 it may increase to 18.86%. Figure 5.6 illustrates this continuous increase of percentage area covered by bare rock. An increase in this land use implies that most vegetation around and on top of the mountain, including within residential land will be cleared. This will result in an area that has less vegetation and more rocks visible even from aerial photographs, resulting in Manganeng looking brown and dry like a desert area.

5.5.3 Farms

The predicted percentage area of farms in 2005 may be 39.16% while in 2015 it may increase to 39.35% as illustrated in Figure 5.7. An increase instead of a decrease is observed from 2005 to 2015. An increase in this land use implies that more land may be converted from other uses to farm land. This seems fitting as population growth is bound to keep increasing. This increase in farm land may also be dependent on the amount of land available for conversion from other

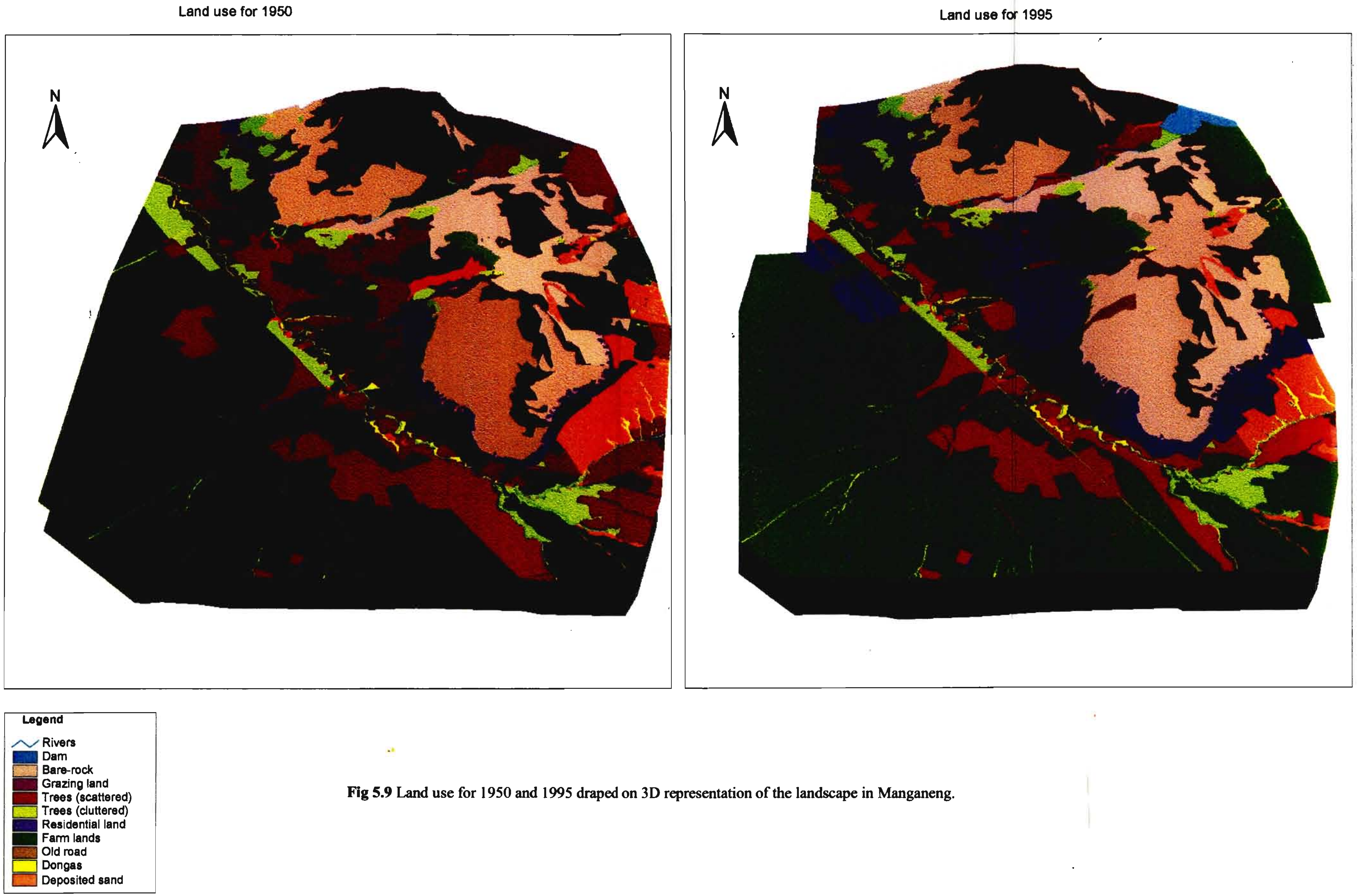


Fig 5.9 Land use for 1950 and 1995 draped on 3D representation of the landscape in Manganeng.

uses to farm land and whether that land will be suitable for cultivation purposes. The steep decrease observed in 1995 could be ascribed to the missing data from the 1995 aerial photograph.

5.5.4 Residential land

The predicted percentage area of residential land in 2005 may be 16.39% while in 2015 it may increase to 19.16% as illustrated in Figure 5.8. An increase in this land use implies that more land may be needed for residential purposes. This increase in residential land will be a consequence of population growth. It would be to the community's own benefit if a settlement plan is developed in order to monitor and improve the use of land in a sustainable manner.

5.5.5 3-D Image

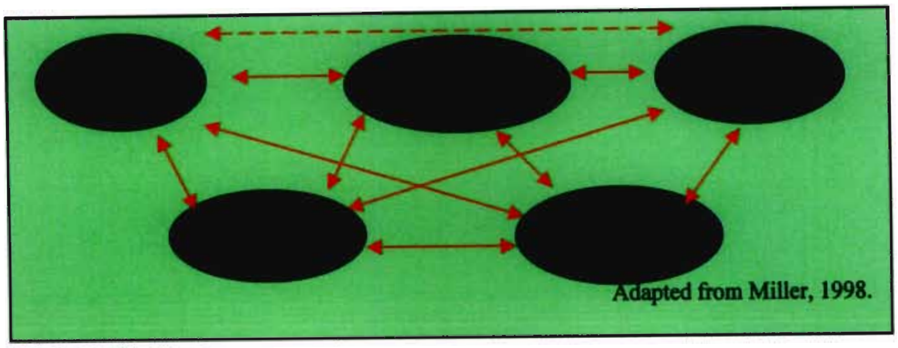
Landscape change that has occurred in Manganeng over a period of 45 years is illustrated in Figure 5.9. Most land uses have been converted to other land uses, disrupting the environmental balance that has existed in the past. Due to promising prospects of external help from different organisations such as the EDA and the CSIR, possible implementation of land use planning and community based resource management will be put in place for the conservation and protection of different resources available in the area. Thus, Figure 5.30 should be regarded as a visual guide to help decision-makers during the community based resource management planning process.

5.6 Mechanisms responsible for possible land use changes in Manganeng

The use of an ecological time line, which incorporated social investigative tools was essential in illustrating and providing insight into possible mechanisms responsible for land use changes observed in Manganeng. This method of investigation made it apparent that the driving forces towards most land use changes in the study area have been delineated by social, economic, political, cultural and/or physical attributes.

The following subsections provide insight and explanation of these five attributes as informed by the interviews, workshop and data generated by creating land use maps, using a GIS.

Box 5.3 An integrated view of attributes driving land use change in Manganeng



5.6.1 Social and economic attributes

Social and economic attributes have been combined within this study as they consistently overlap and are interrelated of each other.

5.6.1.1 Unsustainable cultivation methods which increased soil erosion over time

Women who are the dominant gender within the community cultivate land for subsistence living. Most men who could carry out manual labour within the farms have emigrated and are employed elsewhere to generate an income, which they (sometimes) send back home to support their families. Cultivation methods (such as the use of oxen for ploughing, rapid rotation of crops during seasonal cultivation and irrigation of crops) employed by these women are not always sustainable and do not generate enough surplus production which could be sold at the market. These cultivation methods tend to increase soil erosion, especially since no fertiliser is added to enrich the soil. Most families have very limited funds to cultivate the two hectares of land allocated to them. Most of these families tend to cultivate land within the homestead, which is at a small scale. Some of these cultivation methods have created irreversible land degradation to such an extent that soil erosion is regarded as one of the problematic issues in the area.

5.6.1.2 Increased population growth vs. cultivated land

An increase in population growth within Manganeng has accelerated the need for more land area for farming. This has resulted in the clearing of vegetation and the conversion of open spaces and other land uses to farm land.

Farm land was initially in direct competition with residential land. An increase in population in most cases results in an increase in human settlement, which is sometimes proportionally equivalent to the need for cultivated land, especially in rural areas. As observed in the created land use maps over the years, the need for more farm land has increased with a profound increase in residential land.

5.6.2 Political attributes

Imbalances in political power between the Transitional Local Council and the Tribal Authority have created an avenue of miscommunication and mistrust between the two councils. Lack of proper communication channels between both councils and the community has contributed to a set back in the development and management of resources in the area. Lack of access to information on legislation and funding has slowed down any form of progressive sustainable development in the area drastically.

5.6.3 Cultural attributes

Cultural attributes are ways and means in which the community celebrate and practice their heritage and cultural beliefs. Within this study, the context and focus of this cultural attributes is based on environmental conservation.

5.6.3.1 Employment of indigenous knowledge systems in natural resource management

The implementation of indigenous knowledge for resource conservation has assisted in minimising further environmental degradation in the area. Some of these methods, as mentioned in the previous sections, include the conservation of vegetation on the mountain and donga reclamation methods. Time constraints within this study made it difficult to undertake further research on other methods deployed by the community in conserving natural resources in Manganeng. Further studies that also evaluate the sustainability of these basic conservation methods, will have to be undertaken.

5.6.3.2 Migration of wildlife

Some community members still practice traditional hunting with dogs. Although most of the wildlife has migrated over time, there is still small game such as scrub hares left. Migration of wildlife has left a gap in the ecological chain as the dispersal of seeds and the regeneration and recovery of these vegetative species occurs at a minimal and slower pace.

5.6.3.3 De-stocking

Culling of livestock in the past may have played a significant role in the reduction of soil erosion. Increased livestock numbers tend to wreck havoc on soil, especially soil found on hilly mountains and next to riverbanks. The amount of livestock each family owns at present is not large, thus implying that soil erosion is not occurring at an alarming rate as was the case in the past.

5.6.3.4 Donga reclamation

The size of the dongas has not increased significantly over the years. Conservation methods such as the use of aloe plants and sand in sacks to block dongas implemented by the community has assisted in maintaining the donga sizes if not completely rehabilitating them, and therefore reducing the amount of soil erosion in the area.

5.6.4 Physical attributes

Physical attributes within this study encompass both "green" and "brown" issues. These issues include both the built environment and natural resources. The built environment constitutes man made structures while natural resources include aquatic/terrestrial resources as well as ecological attributes. The following subsections take a closer look at how impact by these green and brown issues may have impacted on land use change in Manganeng.

5.6.4.1 Transportation links with other communities

The construction of a tarred main road has provided the community with a link to the outside commercial operations where food and other products can be transported into and out of the community. This main road is well maintained, therefore making this transportation link with other communities reliable.

5.6.4.2 Damming of the Pshirwa River

The construction of the reservoir may, in the long term, assist the community in terms of supply of clean potable water. At the moment, it is still non-operational while farming activities along Pshirwa and Sebilwane Rivers have decreased. Most community members used to rely on both of these rivers for irrigating their farms. After the Pshirwa River was dammed, farming activities decreased with a number of farms (along both the Pshirwa and Sebilwane Rivers) abandoned. Standpipes that are placed strategically across Manganeng are too far from the farms for the community members to irrigate their farms.

During a visual assessment carried out in 2003, the researcher noted that dam operations were still on hold. A number of community farms had also sprung up, irrigated by either trucks that deliver water twice weekly or pipeline connections to draw water from the public standpipes.

5.6.4.3 Unfavourable climatic conditions

Manganeng has experienced drought over a number of years. The annual amount of rainfall received by the area is very marginal to sustain farming activities for larger quotas of production unless an external form of irrigation for the farms is put in place. The Sebilwane River is dry while Pshirwa River has a minimal amount of water flowing through.

5.3.4.4 Increased settlement

A continuous increase in population growth in the area has led to an increase in human settlement/residential land. This increase in residential land has been at the expense of other land use types which have been converted, thus altering once productive areas into residential land.

5.3.4.5 Conversion of open spaces to other land uses

Most open spaces, such as grazing and recreational land (sports fields) have been converted into farming and residential land. This conversion of recreational land has changed the landscape of Manganeng which was once very green, providing for regeneration of vegetation in the area. An assessment of potential changes in land use patterns in the area also suggests that this trend in reduction of open spaces may possibly continue .

CHAPTER 6 – Conclusions and Recommendation

6.1 General conclusions and recommendations

This study has confirmed that Manganeng, like most historical "homelands" is a rural area with a communal land tenure system. The community has been forced to subsist on crop farming in an area which, for reasons of rainfall, climate, topography and soil quality, may be inappropriate for agriculture. Cultivation of land, coupled with increased residential land use has increased pressure on land resources and aggravated environmental degradation over the past years.

This study established that from 1950 to 1995, residential land increased significantly, while farmland and bare rock on Ntswelatau Mountain had increased insignificantly. Other land uses such as dongas and scattered trees had remained stable over time. Grazing land had decreased significantly while deposited sand and clustered trees decreased insignificantly.

Activities such as the cultivation of grazing land initially demarcated for pasturing livestock, the implementation of unsustainable farming methods as well as an increase in human settlement have played a major role in affecting the environment, causing continuous environmental degradation. These activities have caused a decrease in vegetation cover, loss of soil fertility and soil erosion. Large dongas in Manganeng are seen as part of the landscape, with most people not perceiving them as a major problem because these dongas do not affect their daily lives.

It is important to emphasise that the main aim of this study was to investigate changes in land use patterns in Manganeng. Results that have been obtained from this study can be used by the community, agencies and government as a basis to establish where intervention for resource management and planning can be implemented.

The following subsections are conclusions and recommendations that outline what will be needed to achieve sustainable natural resource management in Manganeng.

6.1.1 Indigenous knowledge

The local community is very much aware of their natural environment. This has been evident from the way they have conserved part of their vegetation by putting restrictions on tree felling on the mountain and by implementing donga reclamation methods using stones, dead trees and aloe plants (dikgopa) in sacks to block these dongas. It is recommended that further research be undertaken to evaluate the indigenous methods of conservation implemented so far, and to evaluate if these methods are sustainable. Alternative methods should also be considered if these indigenous methods are found to be unsustainable.

6.1.2 Land use maps

In land use change studies, a GIS is used to generate land use maps. This technology aids in providing insight during measurements about the extent and rate of change that has occurred. For this research, land use maps were successfully generated, providing data that could be quantified and used as measures to evaluate land use change that has occurred. It is recommended that further research be undertaken where further data is collected and linked with other studies to assist in preparing land classification and future land use plans.

6.1.3 Quantification of land use change

A GIS was used to generate land use maps with data that was quantified to determine the extent of change that had occurred. It was observed that-

- Residential land in Manganeng had increased significantly. This was due to population growth and a demand for more land for residential land use. This has resulted in the clearance of vegetation and the use of open spaces, decreasing the size of land initially allocated for grazing livestock. It is recommended that further research be conducted to establish whether it would be feasible to develop a sustainable settlement plan. This plan should be developed jointly and by consultation with the Department of Agriculture and Land Affairs, the chief, his headman and the community in order to improve spatial development and infrastructure for the area.

- Grazing land decreased significantly due to the clearance of vegetation and conversion to other land uses. It is, therefore, recommended that during the development of a sustainable settlement plan, open spaces are taken into consideration. This would mean selecting areas where "green lungs" are established for nature to recover and regenerate species which may have declined in numbers.

- Farm land and bare rock had slightly increased. This slight increase in farm land has been fostered by the community's need for more land for cultivation. On the other hand, the clearing of vegetation on the mountain decreased vegetation cover and allowed for more rocks on top of the mountain to be visible, creating an increase in area covered by bare rock. It is recommended that the agricultural extension officers be involved to provide guidance and assistance with regard to agricultural activities in the area. The community will be able to make informed decisions which will guide their allocation of farm land and ways of minimising environmental degradation in their area.

- Deposited sand and clustered trees had slightly decreased. The building of residential houses and cultivation of land on land previously occupied by deposited sand (as observed on the land use maps) caused an insignificant decrease in percentage area covered by deposited sand. Harvesting of fuel wood slightly decreased the percentage area covered by clustered trees. It is recommended that any plans made for the construction of houses or continued tree harvesting should be monitored by the Department of Agriculture and Land Affairs, the chief, his headman and the community in order to minimise activities that will accelerate depletion of vegetation cover, loss of soil fertility and soil erosion (see Table 4.1 for land use classification of deposited sand).

- The following land uses, i.e. dongas and scattered trees remained stable over the years. Stabilisation of both these land covers was because of donga reclamation methods applied by the community while restrictions on tree felling in certain areas (e.g. mountain) ensured minimal disturbance to natural vegetation. It is recommended that these practices of donga reclamation and restrictions on tree felling be continued. Further research should also be conducted to see if other methods are also applied and how these complement each other.

6.1.4 Forces driving land use changes

Socio-economic needs of the community encouraged the use of available natural resources in the area. The need to generate an avenue for subsistence living was based on cultivation of land, irrespective of present and future condition of the environment. Unsustainable methods applied have created irreversible land degradation to the area. It is hoped that the recommendations made in the sections above could improve environmental conditions in the area.

Imbalances in political power between the Transitional Local Council and the Traditional Council have contributed to the slow development and lack of proper management of resources in the area. It is recommended that all stakeholders be involved in all decision-making processes as legislated by the National Environmental Management Act of 1998.

Physical attributes such as the tarred road and the dam are positive attributes only if all stakeholders are involved in their management and sustainable upkeep to benefit the whole community. See proposed recommendations on open spaces and residential land (refer to 6.2.3).

The use of a GIS on its own would not have been able to provide this study with an insight and understanding of the forces driving land use changes in Manganeng. The use of an ecological time line, which incorporated social investigative tools was essential in illustrating and providing insight into possible mechanisms responsible for these land use changes observed in Manganeng. This method of investigation made it apparent that the driving forces towards most land use changes in the study area have been delineated by social, economic, political, cultural and/or physical attributes.

6.2 Recommendations

It should be noted that some of the following recommendations may overlap in time, scale and activity.

6.2.1 Short term (2 years)

Immediate measures that could be taken in a period of two years:

(a) The best way to maintain dongas in the area would be to leave those dongas that are large in size and far from residential areas as they are because they have stabilised over time. Thus, it is recommended that dongas which are smaller in size, or those that are just developing should be reclaimed immediately using donga reclamation measures already used in the area.

(b) It is recommended that a perennial type of grass (V*ertiveria zinazoides*) should be planted along the riverbanks of Sebilwane and Pshirwa rivers. This type of grass assists in stabilising the soil when planted along riverbanks. It is a seasonal plant that will always regenerate its seed. This V*ertiveria* zinazoides grass can also be planted along the edges of the dongas in the area. The Department of Agriculture which is based in Schoonord District could be contacted to assist and provide guidance in this regard. EDA and CSIR could also recommend interested organisations that will be willing to assist and maybe donate some seeds.

(c) Manganeng is practically covered with annual grasses which do not assist much in preventing soil erosion. It is recommended that grasslands in the area be re-seeded and vegetation that promotes soil stability be planted to stabilise the soil in order to minimise further soil erosion. The Department of Agriculture which is based in Schoonord District could be contacted to assist in this regard (as in (b) above).

(d) Footpaths created by both humans and livestock cause the top soil to be exposed, so that when it rains, water runoff removes this soil, causing soil erosion which ultimately develops as dongas. Not much could be done to prevent the creation of footpaths. It is recommended that continued monitoring of the area be undertaken where footpaths that show signs of donga development are blocked at their earliest stages. Where possible, footpath maintenance would need to be adopted where stones and dead wood are packed in a staggered manner to create steps. This mode of intervention will assist to hold up the soil and minimise erosion when there is water runoff, especially from the rain.

(e) From the interviews and the workshop, it became apparent that governing powers are not well distributed between the Transitional Local Council (TLC) which was established after the 1994 elections and the Traditional Council. The Department of Agriculture and Land Affairs seems to have restricted powers to carry out its duties, and have to follow the hierarchy when they want to implement anything (i.e. land management strategies, construction of infrastructure, etc). Although the TLC have been abolished since the study was undertaken, traditional authorities and local government are still dealing with the same issues and governing powers still not well distributed.

This issue on its own deserves further research, which the CSIR are undertaking. It is hoped that their findings will aid in reconciling the two councils where the government and the community could be able to work together in introducing a more sustainable settlement plan in order to improve the environment, infrastructure as well as the quality of life in the area.

6.2.2 Medium term

These measures could be taken in a period of two to five years.

(a) It is recommended that agricultural education and environmental awareness should be used as mitigation measures to minimise further environmental deterioration in Manganeng. This could be done by involving the Department of Agriculture and the whole community in all decision making processes and making them aware of the value of their natural resources.

(b) It is recommended that any project that is to be implemented in the area involving sustainable management and resource conservation should be managed by both the community and the assisting outside organisation. This will, in effect, give the community a sense of ownership and in that way, they will most probably participate in large numbers (same as in the communal farm that is already operating in the area), learn to understand their natural habitat functions and improve their livelihoods.

6.2.3 Long term (5-10 years)

This measure could be taken in a period of five to ten years to manage natural resources effectively:

An integrated land use plan needs to be developed for the sustainable use of resources in the area. The Transitional Local Council, the Traditional Council and the community should be involved in developing this plan. This plan should also take cognisance of indigenous knowledge and new methods implemented to conserve the environment and its resources.

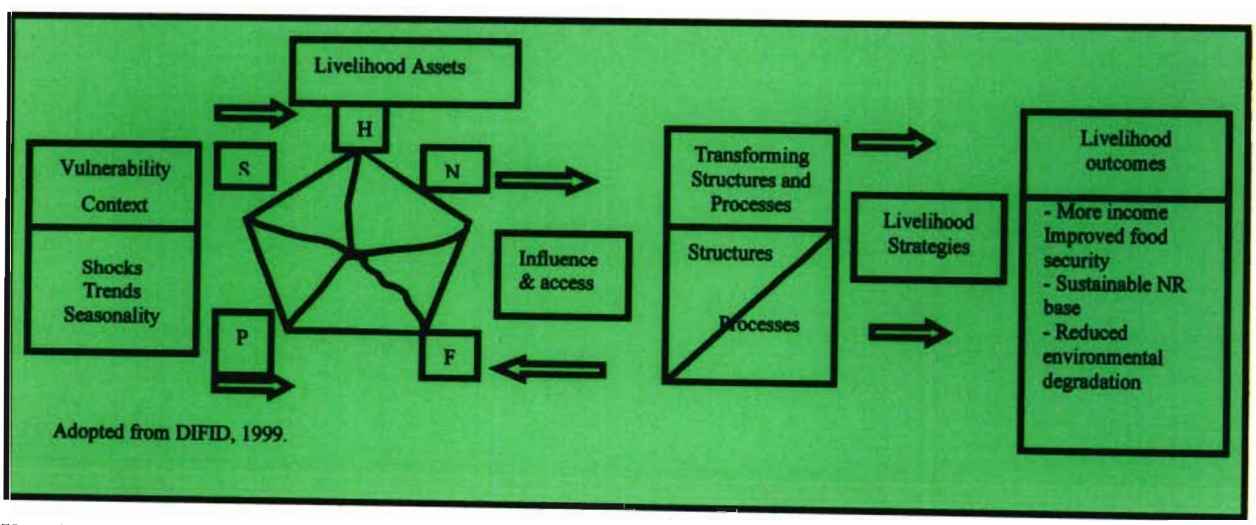
6.3 Adoption of a Sustainable Livelihood Framework

Community-based resource management strategies in most rural areas can be categorised as natural resource based or non-natural resource based. Development initiatives can empower people by broadening the range of most implementable strategy options. Most communities are vulnerable to a range of challenges and reducing these vulnerabilities may be a higher priority than increasing production or the quantity of their assets. The only critical area is that of diversifying livelihood choices, which would also reduce vulnerability to continual poverty and land degradation within these communities.

(Goldman et al, 2001).

Sustainable community-based resource management in Manganeng could also follow the Department for International Development (DFID) Sustainable Livelihood Framework which is a valuable tool used to improve the understanding of livelihoods. The five types of assets that are used as integrative models in estimating an areas' livelihood asset base include natural and social, human, physical and financial capital (Goldman *et al*, 2001).

Box 5.4 Sustainable livelihoods framework



Key: **H= Human capital, N= Natural capital, F= Financial capital, S= Social capital, P= Physical capital.**

Adoption of this framework will guide any form of sustainable community based resource management strategies which may be implemented in the future. It is highly recommended that the stakeholders in this process should include community groups in the area, various governmental departments and the private sector so that information sharing, funding and the delegation of work are integrated to ensure that these strategies are sustainable.

This study would not be able to propose any form of management strategy without evaluating those that are ongoing, and those that have been successful or have failed in the past. It is hoped that future research in Manganeng may tackle all these issues integrated within this framework in order to provide a clear understanding of natural resource use and conservation in Manganeng. This framework will provide an assessment, which will guide development options which have to be prioritised to maximise the benefits of sustainable community based resource management.

6.4 Recommendations for further research

(a) It is recommended that further research be done on soils in the area (soil mapping). This would facilitate in advising the community on suitable areas for planting different crops at different periods to increase their agricultural output.
(b) It is further recommended that research be undertaken on dongas in the area, especially with regard to their size and how to make them stable during floods and heavy rains so that soil loss will be reduced.
(c) It is recommended that traditional environmental conservation methods (indigenous knowledge) applied in the past be explored further, and if they are both environmentally sustainable and scientifically viable, then they should be reinforced.
(d) The study was able to illustrate changes in percentages areas of land use over the past 54 years. Other spatial techniques could be used for predictions of percentage cover, as well as the extent of change that has/would occur

6.5 Limitation of the study

(a) The aerial photographs used in this study were at different scales. Some photographs were enlarged so that comparisons could be made at nearly the same scale.
(b) Other parts of the study area were not flown /covered when the aerial photographs were taken. This has produced gaps in the land use maps that were created. The extent of change that has occurred where there is missing data has not been evaluated.
(c) . The study area did not have climatic data. This study used data that was acquired from the CCWR.

Conclusion

This study was a mini research to investigate possible changes in land use patterns in Manganeng. Land use maps which did not exist for the area, were developed, thus making it easy to identify and interpret how changes in land use patterns have occurred in the area (Figure 5A to 5E). This study has also quantified land use changes that have occurred between 1950 and 1995.

The study has also identified some of the mechanisms responsible for possible land use change and recommendations for follow up work have been provided, as well as a framework that can serve to package Manganengs' special needs for improved resource management. Potential future land use changes have also been projected. It is hoped that information from this study will serve as a basis for developing further databases for land use and land cover management for Manganeng since data specific to Manganeng does not exists.

This study did not undertake a statistical analysis of the interviews and PRA workshop since the sample group was too small. The study was also packaged as an easy to follow information document in order to make it easy for the community to understand its contents. The aim was to hand over and present the document and its findings to the local chief. In this way, it would be easy for the chief and his constituents to approach the local Department of Agriculture to ask for assistance for implementing their Community Based Resource Management Programme. Currently, local government approves programmes from rural communities on the basis that there is commitment and buy-in from the community and that the community understands issues that are relevant to their area and willing to take ownership for implementing those programmes. This approach seems to work since it provides some form of commitment from all stakeholders.

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APPENDIX A

RAINFALL AND TEMPERATURE DATA

Table A 1: Rainfall data- taken from 1924 to 1993

Table A 2: Minimum and maximum monthly temperature data (°C)

Table B 1. Approximate rainfall data (year and monthly average values) for Manganeng*

Collected from-

Maandagshoek: Station ID 0593126 Weather Bureau at 24° 36'S, 30° 05'E, 975m altitude,

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
1924	116.0X	71.iP1	48.6P	.OP	28.7P	.OP	i.2P	14.4P	17.7P	47	i88.9	iii.9	745.55%
1925	158.8	42	268.8	6.1	16.5	30.5	0	0	73.2	0	50.8	22.6	669.3
1926	70.7	80.9	43.2	0.5	10.4	1.3	4.6	0	12.7	3.3	88.1	72.3	388
1927	38.2P	139.5	32.1	56.6	37.1	0	75.7	14.5	18.8	108.8	97.4	66.8	685.5
1928	153.3	86.7	38.8	53.5	15.2	0	2.8	11.4	6.6	17.6	46.5	56.7	489.1
1929	87.9	47.4	98.2	15.2	3	4	0	1	21.6	188.8	96.6	95.7	659.4
1930	143.3	127.1	123.1	75.7	2	7.4	12.7	0	3.8	0	68.1	103	666.2
1931	139.2	172.1	0	22.8	0	0	36.9	0	0	20.5	137.7P	66.3	5.955
1932	101.6	93.1	38	38	13.0P	0	0	2.8	0	58.9	58.1	74.4	4.779
1933	118.8	39.6	48.4	14	0	2.5	0	0	11.7	17	167.5	145	564.5
1934	165.2	124.2	145.1	52.3	9.4	4	0	0	27.2	54.7	112.3	67.1	761.5
1935	79.1	89.9	21.9	34.5	2.5	0	0	0	21.6	19.5	0	141.7	410.7
1936	120	72.6	64.5	31.5	20.1	0	0	0	6.1	67.1	88.4	64.5	534.8
1937	165	282	54.4	31.8	0	0	0	0	6.6	19.8	29.5	115.4	704.5
1938	59.3	42.8	42.5	107.7	5.6	34.6	0.5	0	61.3	69.3	15.5	244.2	683.3
1939	235.7	227.4	80.1	8.9	11.9	8.4	34.5	0	57.5	38.3	199.4	90.2P	9.923
1940	60.9	49.6	94.8	61	41.9	24.6	0	4.3	46.7	19.6	226.7	127.7	757.8

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
1941	48.2	119.2	83.3	89.4	0	0	6.4	0	7.1	79.6	32.5	74	539.7
1942	56.4	11.7	88.2	2.3	58.9	37.1	0	3.5	53.6	63.6	171.2	86.7	633.2
1943	108.9	60.3	106.1	172.2	26	1.8	45.2	10.9	15	25	139.2	29.8	740.4
1944	163.8	172.4	49.1	16.7	4.3	14.2	0	0	1.3	62.4	63.6	62.1	609.9
1945	181.7	23.9	37.3	63.2	0	0	0	0	10.2	78.7	59	53.1	507.1
1946	217.5	169	138.9	14.7	0	0	0	0	0	26.7	62.8	112	741.6
1947	95.6	150.4	86.2	13.7	0	6.1	2.3	0	13.2	45.3	149.1	102.7	664.6
1948	100.6	67.6	147.9	18.3	5.3	0	0	0	21.9	107.8	83.8	37.5	590.7
1949	196.7	126.5	32	23.4	21.8	0	0	0	13	24.4	83.2	156.5	677.5
1950	211	9.5	62.1	54.4	9.9	0	0	0	32.6	29.7	19.5	130.1	558.8
1951	86.6	16.5	52.4	45.2	67.2	0	0	41.1	7.3	175.9	27.4	108.3	627.9
1952	18.2	89	57.6	10.2	1.5	22.4	0	0	9.7	56.4	34.1	156.8	455.9
1953	81.0P	52.5	62.6	76	19	0	0	0	19.5	18.3	125.2	122	5.761
1954	79.5	192.6	29.4	42.4	11.6	0	0	0	11.1	48.4	161.4	100.7	677.1
1955	243.5	176.3	160.5	80.3	3.2	40.5	9.5	0	0	76.1	94.5	201.6	1086
1956	68.1	192	38	13.8	46.3	15.5	0.3	0	69.2	38	31.5	84.6	597.3
1957	233.3	55.6	122.4	16.8	33.4	25.4	14	23.3	85	37.5	114.5	143.2	904.4
1958	196.3	125.9	20.7	40.7	0.8	2.3	1.9	2.5	8.8P	29.2	124.9	170	7.24
1959	81.3	91.9	12.7	29.7	8.6	0	7.2	0	36.2	60.8	133.9	179.7	642
1960	39.2	165	63.2	90.9	13.5	0	1	0	11.3	16.6	171.4	185.3	757.4
1961	39	129.1	54.7	61.8	19	54.1	4.1	14.8	18.9	33.6	75.4	75.3	579.8

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
1962	22.7	128.7	13.6	57.4	18.5	0.5	0	3	0.4	20.5	171.5	142.2	579
1963	65.3	5.5	39.5	37.3	2.7	55	10.9	0	0	39.6	62.1	83.5	401.4
1964	107	70.6	41.2	34.2	9	4.2	0	0	0	120.7	93.2	97.5	577.6
1965	85	54	1.5	9.5	0	0	0	0	57.5	22	117.5	78.8	425.8
1966	62.3	42.5	0	13	0	0	0	6	10.5	57	67.5	112.9	371.7
1967	82.5	110.5	43.5	99.5	0	3	27	5.5	0	38	145.5	97.5	652.5
1968	64.5	63.5	91.8	23	14	0	0	0	0	27.5	106.2	131.8	522.3
1969	92	73.5	144	29	7	0	0	2	36	55.7	47.5	132	618.7
1970	37	14.5	76	21.5	0	0	18	3	12.5	18	81.5	171.5	453.5
1971	110	47.2	44	20.5	21.5	5.5	0	0	23	92.5	87.5	114.5	566.2
1972	91	118	40	38	32	0	0	0	19.7	62	136.4	48.3	585.4
1973	80.7	28	81.9	42.2	12.6	0	14.4	0	99.5	52.2	75.1	114.1	600.7
1974	196.8	40	133	66.4	32.9	0	34.6	3.2	26.1	25.9	122.5	53.4	734.8
1975	169.5	29.1	47.7	32.6	16.1	0	0	0	0	8.4	87	171.2	561.6
1976	140.7	100	158.8	69	15.9	0	0	0	1	51.8	49.2	98.8	685.2
1977	65.2	49.6	50.1	50.6	37.4	0	0	0	3.3	4.2	12.4	24.1	296.9
1978	165.7$	74.1	56.7	11	0.5	0	0	0	5.4	57.4	110.1	65.9	546.8
1979	101.4	20.1	51.3	34.2	9.4	0	0	34	8.5	62	118.1	98.5	537.5
1980	215	175.5	43	17.5	0	0	0	0	31	40.5	291	84.5	898
1981	137.5	144.5	47.5	1	0	0	0	42	17	77	54.5	98.5	619.5
1982	107.5	43	40	3.5	23.5	0	0	0	0	57.5	29.5	9	313.5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
1983	148	31	165.5	0	5	0	0	41	0	51.5	175	113.5	730.5
1984	55	61	78.5	0	0	0	27.5	0	39	52.5	68.5	84	466
1985	95	227	55	0	40		0	0	21.5	53	36	48.5	577
1986	82	77	13	87	0	0	0	12.5	0	68	122.5	81.5	543.5
1987	70	14	13.5	0	0	0	0	27.0*	12	18	50	101	3.055
1988	50	23.5	64.5	12	12.5	26	0	52	2.5	51	22	74	390
1989	49	20	10	60	40	6	0	0	0	61.5	109.5	66	422
1990	79	52	71.5	11	0	0	20	0	0	27	87	26	373.5
1991	85	70	12	55	32	-99.9M	-99.9M	-99.9M	-99.9M	-99.9M	-99.9M	-99.9M	254.0+
1992	.0M	42.5	36.5	19	0	0	0	23.2	0	58	23.5	132	334.7+
1993	127.8M	66.6	27.2	26	0.3	0	0	24.5	3	52.5	105	-99.9M	432.9+

*Data compiled by Computing Centre for Water Research (CCWR), UNP.

Codes: & -Suspected error in data since there are more than 5 months of zero

Q - MAP inconsistent with other neighboring stations

M - At least one daily value missing

-99.9- All daily values for the month are missing

$- Contains daily data which was coded as accumulated data (total reliable) by the SAWB

*- Contains daily data which was coded as accumulated data (total unreliable) by the SAWB

O- Monthly total exceeds 999.9

P- Synthesized value using the Zucchini technique (model 5)

X- Mean monthly value substituted since data is missing

Table B 2. Approximate temperature data for Manganeng*

Collected from-

Roedtan : Station ID 0591124 Department of Agriculture at 24° 34'S, 29° 055'E

TEMPERATURE	MAX	MIN
JAN	30.9	17.7
FEB	30.9	17.4
MAR	30	15.9
APR	27.7	11
MAY	25.4	6.4
JUN	22	2.8
JUL	22.6	2.8
AUG	25.1	5.7
SEP	28.2	10.4
OCT	29.3	14.2
NOV	30.2	15.9
DEC	30.2	17.4

*Data compiled by Computing Centre for Water Research (CCWR), UNP.

APPENDIX B

QUESTIONNAIRE

Interviewer: Manaka RMP

Participants: 10 (8 females and 2 males)

Ages: Ranged from 48 to 66

Objective: To obtain oral history from the elders of the community in order to compare and understand landuse changes and mechanisms which facilitated these changes that are visible on aerial photographs.

A. PERSONAL DETAILS

A1.

Male	
Female	
Age	

A2. How long have you been residing here in Manganeng? ....

A3. Have you ever left your village? YES/NO

A4. If yes, for how long? ....

B. CLIMATE

B1. How is the rainfall this season?...

B2. What about the last season? ....

B3. Do you remember how it was in the past? YES/NO

B4. If yes, can you elaborate?..

....

B5. Were you able to produce enough agricultural products with that amount of rain?

YES/NO

B6. Are you able to produce enough agricultural products at present with the amount of rainfall available? YES/NO

B7. Were there floods in this area before? YES/NO

B8. If yes, elaborate ....

C. RIVERS AND DONGAS

C1. When there are good rains, does the river flow? YES/NO

C2. When last was it flowing?...

C3. To what extent was it filled?...

C4. What about in the past?..

C5. According to you, what contributed to the drying out of the river?...................................

....

C6. Were there so many dongas in the past?...

C7. When did you first notice an increase in their size and number?......................................

C8. Do you think that these dongas will increase in number and size in the future?.................

C9. Are you taking any measures to prevent this increase?...

C10. What about your neighbors? Are they taking any measures to prevent further increase? ..

....

C11. Have there been measures taken in the past to stop further increase of these dongas?.......

....

C12. Do you have problems with these dongas in your farms?...

....

C13. Do any dongas pass through your yard? YES/NO

C14. Do you regard these dongas as a problem in your village? YES/NO

C15. Elaborate ....

....

D. TREES

D1. Were there different tree species in the past? ....

D2. What kind of trees? Can you name them? ....

D3. Where do you collect your firewood?...

D4. Where did you collect it in the past?...

D5. Were there forests in the area?...

D6. Do you think that trees have decreased in number? elaborate ....

....

E. GRAZING-LAND

E1. What kind of livestock do you own?..

E2. What about your neighbors?..

E3. In the past, the Pedi people had large livestock numbers, what caused this reduction in livestock numbers? ....

....

E4. Where do you allow your livestock to graze? ....

E5. Where did it graze in the past? ....

E6. Where else do you allow it to graze?..

....

F. FARMING

F1. Do you own a farm? ....

F2. How big is it?..

F3. How about the size of your neighbors farm?..

F4. How long have you owned this farm? ....

F5. Do you use fertilizers (manure)? ....

F6. How do you irrigate it?..

F7. In times of drought,(limited rains and rivers gone dry) how do you irrigate it?...................

....

G. LAND OWNERSHIP

G1. Who owned the farms in the past?..

G2. What was on those farms before they were cultivated?..

G3. Who owns the land where you built your houses?..

G4. Who owned it in the past?..

G5. Whom do you ask for a piece of land when you want to farm or built a house?.................

....

G6. Your houses have increased in a couple years. Where do these new occupants come from?..

APPENDIX C

PARTICIPATORY RURAL APPRAISAL (PRA)

Facilitators: Manaka RMP and Manyakanyaka B

Participants: 11 males (members of the Manganeng Traditional Council)

Ages: Not requested

Objective:	To gain an understanding of how landuse has changed over time.
Time:	3 to 4 hours
Materials:	Flip chart paper, colored markers, aerial photographs and a tape recorder
Take notes of:	Any discussion around the subject area and peoples comments on what see in the aerial photographs Any disagreements that may arise about dates or events and verify with other participants Adopted from Ireland, 1999

Procedure:

1. The group was informed about the aims and objectives of the research.

2. Participants were asked to give important historical events associated with environmental changes that may have occurred in their area.

3. Participants were also asked to name activities they did traditionally in terms of land management and whether this is still applicable today.

4. Since they were able to see the amount of change that has occurred to their landscape, questions were asked concerning the cause of these changes and measures used to prevent this.

Suggested discussion areas/ questions

$ What changes have they observed in their area.

$ How was their rainfall pattern from one time period to the next; have they been able to produce enough agricultural products;

$ How much and where do they harvest their fuel wood; to what extent has the vegetation changed; can they still harvest as much as they used to in the past; where does their livestock graze; is there enough grazing land for them; where did they graze in the past;

$ How is the state of their rivers; has their pattern of flow changed from the past; what about the amount of dongas visible in the area; has there been any measures used to minimise the problem;

$ Who owns the land they now live in; who owned it in the past?

$ Have these changes been positive, negative or indifferent and why?

APPENDIX D

REGRESSION ANALYSIS OF DIFFERENT LAND USES

(a) Grazing land
(b) Bare rock
(c) Deposited sand
(d) Dongas
(e) Farms
(f) Residential land
(g) Clattered trees
(h) Scattered trees

Regression Analysis

(a) Grazing land

Weighted analysis using weights in % grazing land

The regression equation is
% grazing land = 609 - 0.301 year

Predictor	Coef	StDev	T	P
Constant	609.4	114.4	5.33	0.013
year	-0.30092	0.05810	-5.18	0.014

S = 7.873 R-Sq = 89.9% R-Sq(adj) = 86.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1662.8	1662.8	26.83	0.014
Residual Error	3	185.9	62.0		
Total	4	1848.7			

(b) Bare rock

Weighted analysis using weights in % bare rock

The regression equation is
% bare rock = - 150 + 0.0838 year

Predictor	Coef	StDev	T	P
Constant	-149.82	54.47	-2.75	0.071
year	0.08379	0.02758	3.04	0.056

S = 3.803 R-Sq = 75.5% R-Sq(adj) = 67.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	133.50	133.50	9.23	0.056
Residual Error	3	43.39	14.46		
Total	4	176.89			

(c) Deposited sand

Weighted analysis using weights in % deposited sand

The regression equation is
% deposited sand = 42.6 - 0.0195 year

Predictor	Coef	StDev	T	P
Constant	42.57	55.44	0.77	0.498
year	-0.01946	0.02812	-0.69	0.539

S = 1.844 R-Sq = 13.8% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1.630	1.630	0.48	0.539
Residual Error	3	10.207	3.402		
Total	4	11.836			

(d) Dongas

Weighted analysis using weights in % dongas

The regression equation is
% dongas = - 7.1 + 0.00414 year

Predictor	Coef	StDev	T	P
Constant	-7.05	16.32	-0.43	0.695
year	0.004141	0.008267	0.50	0.651

S = 0.2925 R-Sq = 7.7% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.02146	0.02146	0.25	0.651
Residual Error	3	0.25664	0.08555		
Total	4	0.27810			

(e) Farms

Weighted analysis using weights in % farms

The regression equation is
% farms = - 7 + 0.023 year

Predictor	Coef	StDev	T	P
Constant	-6.9	210.3	-0.03	0.976
year	0.0226	0.1065	0.21	0.846

S = 21.89   R-Sq = 1.5%   R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	21.5	21.5	0.04	0.846
Residual Error	3	1437.2	479.1		
Total	4	1458.7			

(f) Residential land

Weighted analysis using weights in % residential land

The regression equation is
% residential land= - 539 + 0.277 year

Predictor	Coef	StDev	T	P
Constant	-538.93	71.49	-7.54	0.005
year	0.27690	0.03607	7.68	0.005

S = 2.945   R-Sq = 95.2%   R-Sq(adj) = 93.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	510.94	510.94	58.92	0.005
Residual Error	3	26.02	8.67		
Total	4	536.95			

(g) Clattered trees

Weighted analysis using weights in % clattered trees

The regression equation is
% clattered trees = 33.8 - 0.0152 year

Predictor	Coef	StDev	T	P
Constant	33.75	14.86	2.27	0.108
year	-0.015187	0.007532	-2.02	0.137

S = 0.5203 R-Sq = 57.5% R-Sq(adj) = 43.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1.1003	1.1003	4.06	0.137
Residual Error	3	0.8121	0.2707		
Total	4	1.9124			

(h) Scattered trees

Weighted analysis using weights in % scattered trees

The regression equation is
% scattered trees = 117 - 0.0516 year

Predictor	Coef	StDev	T	P
Constant	117.3	139.6	0.84	0.463
year	-0.05162	0.07078	-0.73	0.519

S = 9.939 R-Sq = 15.1% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	52.56	52.56	0.53	0.519
Residual Error	3	296.37	98.79		
Total	4	348.93			