A SPATIO-TEMPORAL STUDY OF LAND DEGRADATION AND LAND USE/LAND COVER TRENDS IN THE UPPER TYUME CATCHMENT USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS.

By

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Submitted in satisfaction of the requirements for the degree of Master of Science in the Department of Geography and Environmental Sciences in the Faculty of Science and Agriculture of the University of Fort Hare.

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Abstract

The study traced land degradation trends and land use changes and their relationships over time in the Upper Tyume Catchment of the Eastern Cape Province of South Africa. An integrated approach was used to investigate the reasons behind the occurrence of physical land degradation and how land use changes could have influenced degradation. A GIS-based soil erosion potential model and interpretation of aerial photographs (1: 10 000) spanning 47 years (1949-1996) were used to identify areas of differing soil erosion susceptibility. The erosion model used soils, slope, hydrology and land use as variables. Predicting slope areas susceptible to gully initiation was based on a 20m resolution DEM from which slope classes were computed. The modelling results were compared with aerial photo interpretation results and fieldwork. Visual satellite land cover analysis showed increasing vegetation degradation below the escarpment (sparsely vegetated) and variations up the escarpment (densely vegetated). NDVI and false colour composite images of Landsat TM imagery (1995, 2000 and 2002) showed the negative change in land cover. A survey of the local communities regarding reasons for the occurrence and perceptions to land degradation was carried out by way of an interview questionnaire. Results from interviews were then compared to the empirical results of geomorphologic investigations. Gullies were found to occur where the model had predicted and were extending at different rates in different areas. A linear relationship was seen between gully development and time. Average rates of increase ranged from 77 to 295 m^2/yr in the various gully zones with some of the gullies covering over 25 000m^2. Nearly 50% of those involved in land based activities cited degradation as a problem. 10% of those interviewed were of mixed opinion regarding the degradation problem. Only 40% of the population tried to combat degradation with 26% having done nothing. Discrepancies were found between what the people perceived and the scientific findings, as most respondents could not link land degradation to land use change. In general rates of land degradation accelerated as land use changes started.

KEY WORDS

Modelling	Degradation	GIS
Catchment	Landsat	

Acknowledgements

I would like to thank Prof. P. C. Lent for the supervision of this work, financial assistance and the SWAT training course with the Council of Scientific and Industrial Research (CSIR). I thank the South African Netherlands Research Programme on Alternatives in Development (SANPAD) (project number 97/36) for the financial support towards this study. Much thanks to Mr G.K. Ayirebi for the supervision, advice and words of encouragement and continued commitment at a time when "things" went "slow". I would also want to thank the following people for their contribution to this work; Caryll Tyson for the images and erosion modelling, Vincent Kakembo for reviewing the technical aspects, Chuma Zamxaka for the administration of questionnaires, Owen. T. Mandiringana for his help in soil related issues. Special thanks to Prof C.E.P. Seethal for the final assessment of this work. Lastly but not least, I would like to thank my friends for encouraging me all through, and my family support.

To my mother for all the biblical verses she sent me through ordinary mail.

Lastly but not least, my special thanks go to the people of the communities of Guquka, Sompondo, Magxagxeni and Hala for their friendliness and support.

Declaration

I declare that this thesis has never been submitted for a degree to any other University and it is based on my own original work, and that every effort has been made to identify the original sources, but if there have been any accidental errors or omissions, I apologise to those concerned.

Mr. G. MUPAKATI

15 | 04 | 2005

DATE

ALICE - FORT HARE

PLACE

2004

Dedication

To Takunda, to my family, to friends and to the memory of my father.

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CHAPTER 1 (Introduction)

PREAMBLE

Catchment and sub-catchment degradation is a phenomenon by which the potentiality of a catchment is reduced over time. Degradation may be caused by forest loss and or an increase in soil erosion (Kelly, 1976). As degradation continues, decision-makers find it their responsibility to rectify the situation while scientists find themselves under pressure to set out the simplest rules for proper catchment management (Mitchell, 1979). Deterioration of the land's productivity (land degradation) is most severe in rural areas especially of the developing world. Cases of historic land changes and degradation can be studied by the use of new technologies in conjunction with other conventional methods. Remote Sensing (RS) and Geographical Information Systems (GIS) in conjunction with interviews and field surveys can be used to trace such spatial changes. An approach that brings together natural and social sciences research techniques within a delineated catchment is broadly referred to as Integrated Catchment Management (ICM). ICM is the coordinated management of land and water resources within a watershed with the aim of controlling and/or conserving natural resources, ensuring biodiversity, minimising land and water degradation and achieving specified land and water management and social objectives (Hooper, 2000).

ICM is an approach that takes as its basic unit, a river catchment or sub-catchment. It recognises the catchment as the appropriate organising unit for research on ecosystem processes for the purpose of managing natural resources in a context that includes social, scientific, economic and political considerations. Integrated approaches in general retain most of the core ideas of being holistic, but are more focussed and therefore more practical. An integrated approach seeks to analyse components and linkages and concentrates on what are judged to be key or major components and linkages (Mitchell, 1997). Fig 1.1 shows the key components of the integrated approach to the study of the Upper Tyume.

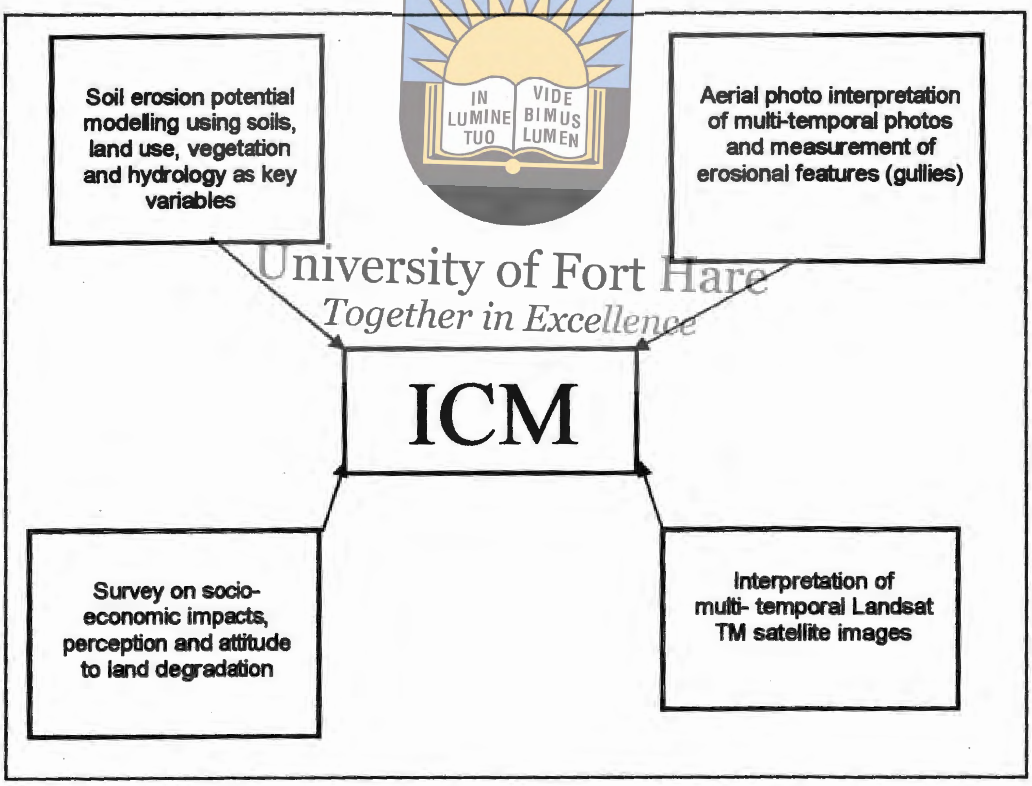


Fig 1.1 Integrated approach in the Upper Tyume.

This study, which investigates spatial patterns of land use change and land degradation using the integrated approach, is organised around three themes namely; land use change, land degradation and hydrology. These scientific themes will be discussed in some detail in chapter 3.

RESEARCH FRAMEWORK

Objectives of the Study

There are three main objectives of this study as described below.

- To trace the rates and spatial patterns of land-use/land cover and land degradation trends in the Upper Tyume Catchment. Land use practices and land cover changes are assessed over two time periods (1938-1996) and (1995-2002) respectively.
- To establish where and why physical land degradation (especially the development of gullies) has occurred and to estimate the amount of land that is being lost through land degradation. This was done through erosion modelling based on slope, land use, soil type and overland flow routes as key factors.
- To establish the influence of land use changes on the socio-economic welfare of the people. A clear understanding of the past and current land use practices is thus crucial to facilitate comparison. A better understanding of the complex interaction of factors which caused these changes over time and how this has affected villagers should enable decision makers to formulate regionally adapted and sound policy interventions, which can stimulate a better resource exploitation system and minimize continuous environmental degradation.

Statement of the Research Problem

The study aims to trace land degradation trends in the Upper Tyume Catchment and the effect of land use change on degradation. The study thus attempts to address the following research questions:

- What were the historical land use practices and what was the environmental situation in terms of degradation rates?
- When, how and why did these landuse/land cover practices change?
- The proportionate effect of land uses to degradation (cause and effect question), is it land use change that caused land degradation or were some such changes in response to degradation?
- How, why and where did the land degrade, at what rate and to what extent?
- What are the perceptions, levels of awareness and priorities of the local land users in terms of the land as a resource?

Aim

The aim of this study is to understand the spatial patterns of indigenous land use practices, how they were modified, reasons behind these changes and to see the impact of the modifications on the communities of the upper Tyume catchment in order to seek effective solutions to such environmental issues. Physical aspects which include soil types, hydrology relief and land use/land cover are used in the investigation.

Rationale of the Research

To understand the impacts of land use and land cover change in the Upper Tyume, research on the reasons of change must be supported by accurate data on how land use has actually changed. The study seeks to provide an understanding of the trends of environmental degradation with the view of improving patterns of resource use.

To understand how land use/land cover has changed over time and how degradation has developed requires the development and use of efficient tools and reliable methodologies to document land-use changes. Remote sensing technologies are suitable for land use studies. Information on actual land-uses at a particular moment, however, requires surveys at a farm or village level. The integration of RS and GIS has been very vital and suitable for modern scientific research. Integrating RS and GIS technologies and combining them with knowledge of the economic situation, social settings and institutional settings, the complex interaction of causes and reasons for the rates of land degradation can be understood.

Hypothesis

Changes in land use practices, resultant hydrological changes of the upper Tyume and community attitude to erosion over the past years led to land degradation.

Delimitations of the Study

- The study being in line with the Agricultural and Rural Development Research Institute's (ARDRI) activities was limited to communities in the upper Tyume. ARDRI was formed in the Faculty of Agriculture at the University of Fort Hare in 1977 and was given the mandate to promote, administer and support research relevant to the developing areas of South Africa. Among its activities is a project on land use systems in the communal areas of the Eastern Cape of South Africa. Along the way ARDRI linked with institutions in Belgium, received funding from National Research Foundation (NRF) and SANPAD to investigate land use systems in the villages of Guquka/KwaGuquka and Koloni in 1996. This study forms part of this project.

ENVIRONMENTAL DEGRADATION

The current patterns of land cover around the world reflect past and current land use and management practices. Changes in land cover and land use have been accelerating, driven by a number of factors including population growth, technology development and economic growth. Land-use changes together with natural processes tend to drive land-cover change. The fundamental processes that control the type, rate, and spatial characteristics of land-use change are not fully understood. A better understanding of the processes, rates, causes, and consequences of land use change and land management practices is vital for many areas in land use and land cover change research. Modern land use and land cover change research has direct societal relevance and is interdisciplinary, involving the combination of social and physical sciences.

Land degradation is known to be a serious threat to the environment and to sustainable agriculture throughout the world. There are four major land degradation processes. They are vegetation degradation, water erosion, wind erosion, and salinisation, in order of their severity and difficulty to control (Dregne and Skidmore, 2000). Water erosion commonly has the greatest adverse effect on soils and crop production. In arid regions, land degradation frequently is referred to as desertification. Global data on the extent and severity of land degradation are scarce and inadequate, which prevents an accurate assessment of the problem and its costs. Field experiments are essential to provide the basic data needed for predicting the productivity of degraded land. Well designed predictive models, when used appropriately, can give reasonably good estimates. Informed opinion is a subjective determination of the impact of land degradation (Dregne and Skidmore, 2000). It is a "last resort" methodology that is valuable only when the opinion comes from knowledgeable people (Dregne and Skidmore, 2000).

OVERVIEW OF METHODS USED IN THE STUDY (AN INTEGRATED APPROACH)

Erosion Modelling

One of the objectives discussed earlier is to establish where and why physical land degradation (especially the development of gullies) has occurred. In this study it was done through erosion modelling based on slope, land use, soils and overland flow routes as key factors. The erosion modelling was done on part of the study area and acted as a model for the catchment. The area chosen (a significant part of the catchment in terms of size) was representative for the study area as it included almost all types of land uses available, the variations in relief (the catchment is characterized by undulating terrain as is the modelling area) and covered several major soil types within the area. Land use practices in the chosen area are also the same as those practiced in the other parts of the study area. To this effect the model can thus be satisfactorily applied to other areas in the study area or elsewhere. The modelling was done in a geospatial analysis software package called MIPS produced by Micro-Images Inc. Chapter 4 discusses in further detail the modelling process.

Land use/Land cover Analysis

Land use change was done in MIPS by digitizing the various themes for the different years from aerial photographs and Landsat TM images. Land use maps from this analysis were also used for the erosion modelling. To monitor the changes in land cover, temporal Landsat Thematic Mapper (TM) images were analysed from 1995 to 2002. Areas covering the study area were extracted and several image rectification, enhancement and processing techniques were done before analysis. Various images were then produced for visual interpretation to assess land cover change.

Questionnaire Survey

The other objective aims at tracing the rates and spatial patterns of land-use and land degradation trends to understand how land use changes affected both the economic and social welfare of the people. Two approaches were used. The first involved the use of remote sensing data to interpret land use activities at stipulated periods, which was then combined, with the land use activities derived from verbal data evidence. Secondly, sampling was done and questionnaires designed to suit the research question.

The GIS Approach

Approaches that utilise remotely acquired data and Geographical Information Systems (GIS) have been accepted internationally and are currently used in projects of various disciplines. A GIS can capture, store, retrieve, analyse and present spatial data and non-spatial data as attribute data. A GIS is not a solution by itself but a means to the solution. An ideal GIS is built to serve diverse users and should be capable of being continuously updated as new data becomes available. Because of such nature, GIS thus heavily relies on high-speed computers. The development of GIS has had a profound impact in both the natural and social sciences.

The United Nations General Assembly Resolution 42/186 of 11 December 1987 on the Environmental perspective to the year 2000 and beyond recommended the use of satellite imagery, aerial photography and GIS for assessing and monitoring the environment and creation of natural resource databases. Such data would be made available freely or for a nominal fee to countries in need. Such data collection and their socio-economic analysis should facilitate the design, implementation of land use and natural resource development plans and improve international cooperation in the environmental management of transboundary natural resources. This resolution shows that environmental issues have of late been the major concern to decision-makers, policy-makers and governments all over the world. The management of natural resources, the planning and management of land use, sustainable agricultural development, nature conservation and environmental control have become problems of the millennium that need immediate attention. All these problems require intensive use of information on ecology, agriculture, demography, properties, land use and socio-economics.

CHAPTER 2 (THE STUDY AREA)

Location of the study area

The study area is part of the Upper Tyume Catchment, which lies up, on and below the escarpment of the Amatola Mountains in the Eastern Cape Province. It lies between latitudes S 32^{0} 35' and S 32^{0} 40' and Longitudes E 26^{0} 55' and E 27^{0} 00', about 30km east of Alice town towards Hogsback on the R345 road (Fig 2.1).

Rainfall

Rain is primarily of cyclonic origin from fronts sweeping over the country or from high-pressure systems situated on the coast introducing moist air from the sea. Since the rainfall is primarily cyclonic and orographic in nature, due to relief, the amount of rain received at a particular location depends mostly on the height above sea level, distance from the sea and aspect of that location (Austin, 1989). In the study area, altitude is the major determinant of the spatial distribution of rainfall. At lower altitudes rainfall can be as low as 500mm per annum rising to about 1400 mm in the Amatola Mountains where the altitude is in the range 1200 to 1500m above sea level (Austin, 1989).

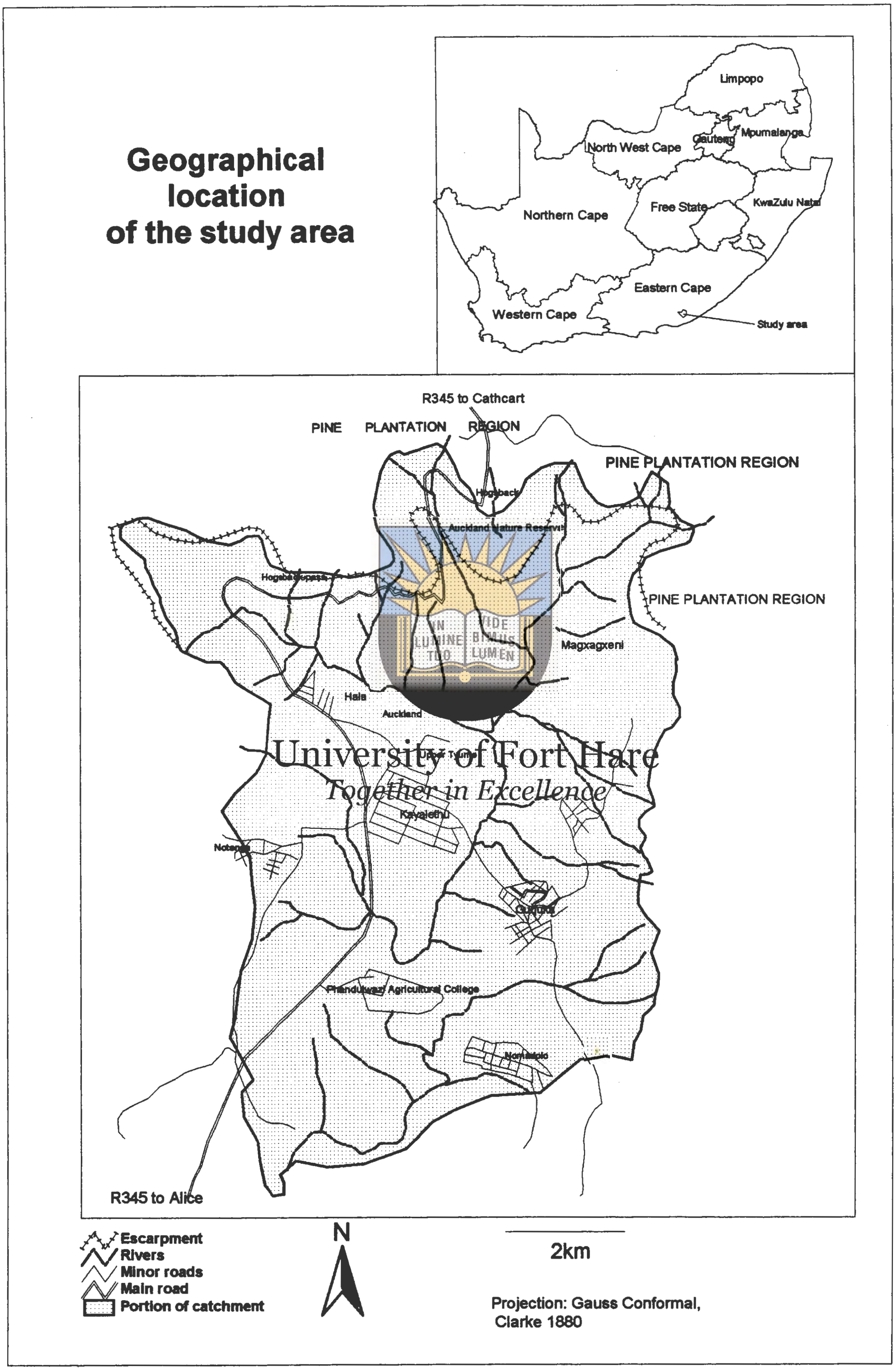


Fig 2.1 Location of the study area

In general, the catchment has a sub-humid summer rainfall with an annual rainfall ranging from 700mm to 800mm with frequent frost during winter (Austin, 1989). The two main rainfall stations in the study are Hogsback and Wolfridge. Hogsback rainfall station is located at S 32^0 35^1 E 26^0 56^1 while Wolfridge is at S 32^0 29^1 and E 27^0 00^1. Austin (1989) plotted the mean monthly rainfall for Wolfridge (Fig. 2.2 a). Rainfall figures for Guquka adapted from Bennett (2002) (Appendix 2.2) were used to plot the monthly rainfall for Guquka as shown in Fig 2.2 b. The average annual rainfall for Wolfridge is approximately 440mm that recorded at Guquka (1998-99) is 910mm. Rainfall data for Pleasant View Dam and Hogsback which lie south and north of the study area respectively is found in the Appendices.

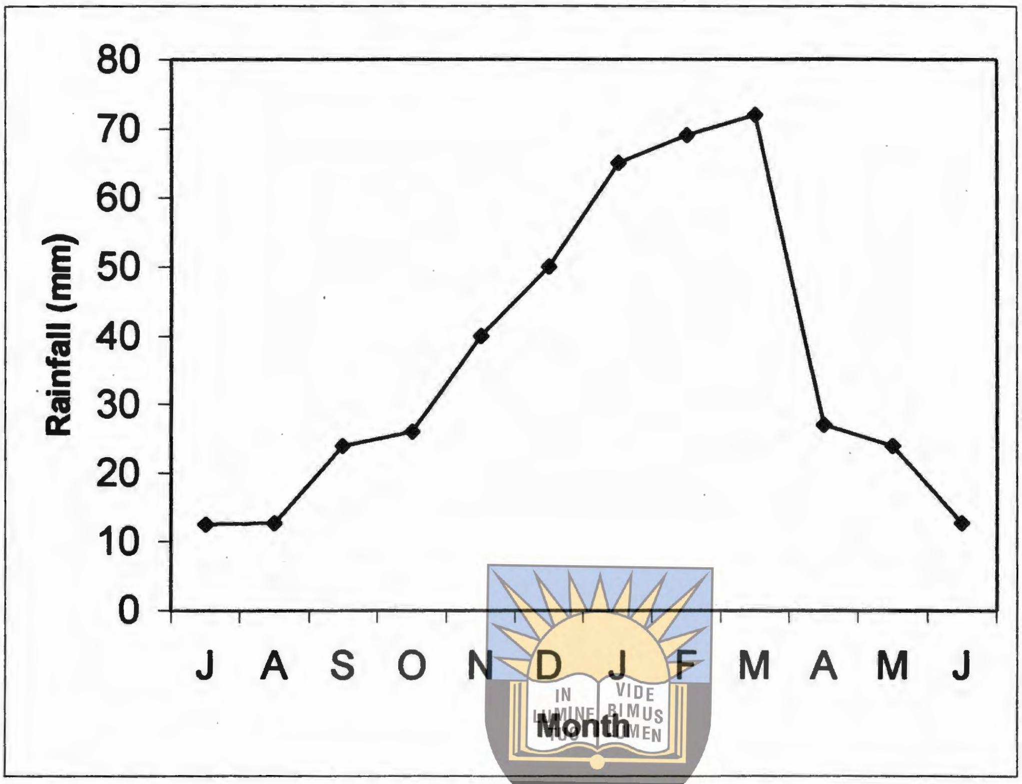


Fig 2.2 (a) Average monthly rainfall for Wolfridge (Adapted from Austin, 1989)

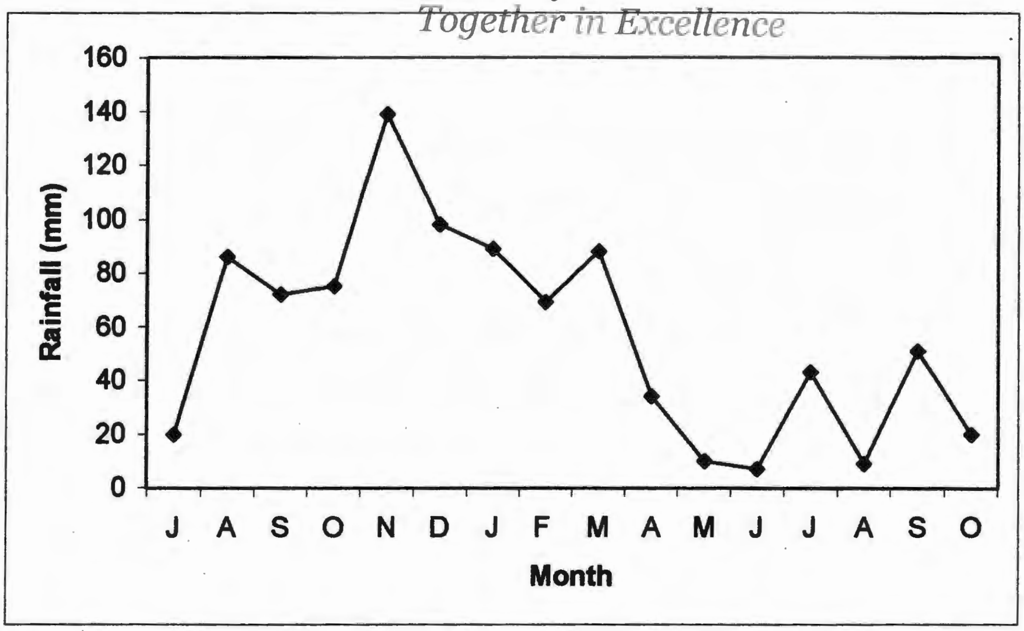


Fig 2.2 (b) Monthly recorded rainfall at Guquka (1998-1999)

Geology and Soils

The study area is predominantly underlain by sandstone, shale and mudstones of the Beaufort and Ecca groups of the Karoo Supergroup deposited in the Triassic and Permian periods. The greater part of the catchment is underlain by sandstone and mudstone of the lower Beaufort Series (Magagula, 1999). Sandstone of the Middle Beaufort Series is found in the north and northeastern part of the Tyume catchment. Most of the high lying ground are dolerites (Hill *et al.*, 1977).

The area has a rather complex topography with very steep slopes and undulating terrain. The topography is characterised by slopes of varying steepness. Slopes with gradients between 15% and 30% (Hill, Kaplan, Scott and Partners, 1977) are the most dominant, constituting 42% of all the slopes in the basin, while 16% of the area is between 30% and 55%. Slopes above 55% constitute only 4% of the study area and those below 15% constitute 38%.

Soils in the area are a derivation of the sedimentary deposits named earlier. According to the South African Soil Classification System the study area has the following soil classes; ***A2, C1*** and ***E1***. These soil classes are all products of the Beaufort sediments. Class *A1* soils are alluvial and colluvial material derived from the Beaufort sediments, which form level terraces and lower pediment slopes with a rather uneven micro-relief. The resulting soil is a dark brown fine sandy clay loam with a clear transition of 50–80 cm, which overlies a weakly structured, strongly mottled pale brown sandy clay. Narrow strips of uniform, apedal, deep brown sandy clay loams occur along the streams.

Class *C1* soils are Beaufort sediments, gently undulating African surface remnants. These consist of dark greyish brown, apedal, fine sandy loam layers that overlie mottled weathering ferricrete and ferruginised loamy gravel at depth of 60 cm and 90 cm. Matrix material of a gravely layer is distinctly red in some cases. The deeper subsoil is frequently a gleyed yellowish brown clay or sandy clay of relatively slow permeability. These soils have moderately high rainfall efficiency, and the nature of the subsoil suggests that these soils have a wetter than normal moisture regime. This is favourable for dry land crop production. Certain lower lying soils may be somewhat too wet for short periods after heavy rains because slowly permeable subsoil layers occur at shallow depth.

Class *E1* soils are Beaufort sediments, undulating to rolling African surface remnants. This is dominantly a brown fine sandy clay loam or clay loam overlying weakly ferruginised gravel which also overlies weathering rock within 60cm from the surface. Very shallow lithosoils onto rock and ferricrete occur scattered throughout the area. Weakly hydromorphic soils occur in the lower slopes and bottom lands. Soil depth is distinctly too shallow over the greater part of the area and rainfall is low rendering these soils droughty in periods of low rainfall. Lower and mid-slope soils stay too wet for a considerable time after heavy rains. The majority of these soil types have limited potential for cultivation (Bennett, 2004) Fig 2.3 shows the distribution of these soils in the study area. Note that there are other soils that are found in the study area that are also shown on the map but not discussed in detail, as they are not used in the modelling processes.

Soils of the Upper Tyume Catchment

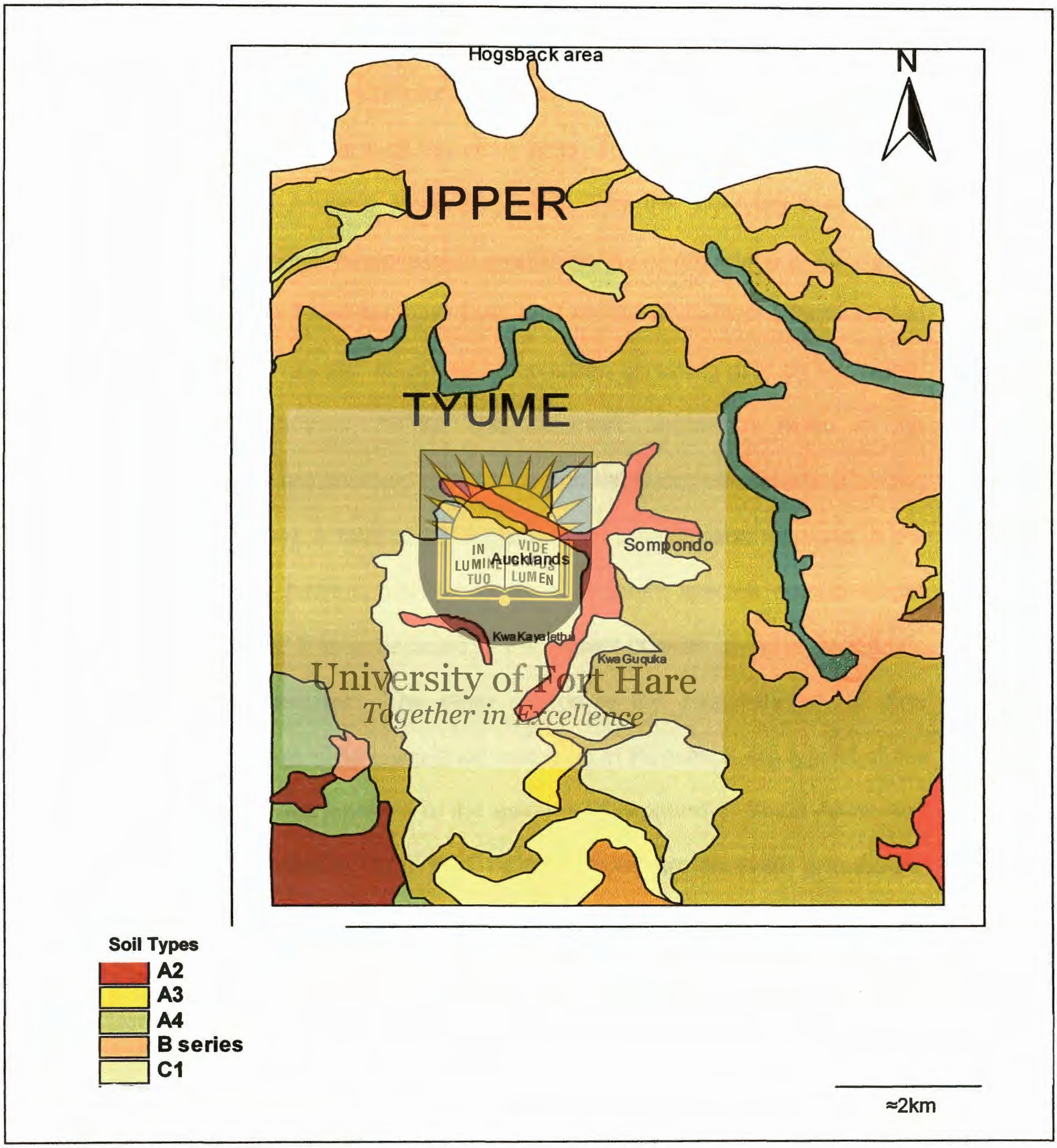


Fig 2.3 Soils of the study area (Digitised from Soils Map by Hill Kaplan Scott and Partners, 1977: Keiskamma River Basin Natural Resources Survey, Ciskei Government Services).

Vegetation

The study area is covered by different vegetation types. Specific vegetation types are dominant in certain parts of the study area. The vegetation is going to be described from the Amatola Mountains down into the low-lying areas. The vegetation of the Amatola Mountains is predominantly Afromontane in affinity but it has elements of the Cape flora and southeast African endemics. It forms part of a series of "isolated islands" of related composition occurring only on the higher mountain ranges (Marais, 1978). The dominant vegetation types in the Afromontane region are sourveld grasslands and tall evergreen forests (Cowling & Hilton-Taylor, 1994). A total of 1215 plant species have been recorded in the Amatola Mountains (Marais, 1978) but some of these species are no longer common in the area. This is because of the impact of alien invasive vegetation species on the grasslands. The other reason is the establishment of pine plantations in the area. The grasslands occurring in Hogsback are typical of the high altitude slopes and plateaus of the eastern escarpment of South Africa and occur at altitudes between 600m and 1400m. These are sourveld grasslands, also known as Dohne Sourveld and are characterised by *Trachypogon, Aristida* and *Harpechloa* species of grass.

The plateau is a mosaic of sponge wetlands, grasslands, macchia and rock outcrop vegetation types, where it is not under pine plantation or invaded by wattle. The main species found in the wetland areas are *Restio* spp. and sedges, *Carex* and *Pycreus*, with ground orchids commonly occurring (Kirkman & Wilson, 1999; Marais, 1994). Rock Outcrop vegetation is found scattered along the cliffs and rocky outcrops on the mountain sides and here *Rhus dentata* and *Leucosidea sericea* are conspicuous diagnostic species.

Sclerophyllous Shrublands, more commonly known as macchia or fynbos, occur on the plateau and mountain slopes (Hill Kaplan Scott, 1989). Overgrazing and protection from fire promote the spread of Macchia (Cowling et al, 1997; Trollope, 1973). The mountain summits are islands of Afromontane vegetation (Cowling et al, 1997; Trollope, 1973).

There are nine invasive alien species that occur in Hogsback such as *Acacia mearnsii* (black wattle), *Acacia melanoxylon* (blackwood), *Pinus pinaster* (cluster pine), *Pinus radiata* (radiata pine), *Pinus patula* (patula pine), *Eucalyptus sp.* (gum) amongst others. (Kirkman & Wilson, 1999 and Marais, 1994).

Below the escarpment stretching into the villages there are several dominant vegetation types. These include the D5, L and V types from the South African vegetation classification system. (Kirkman & Wilson, 1999 and Marais, 1994).

D5 is the *Eragrotis–Sporobolus Grassland.* This grassland was derived partly because of severe overgrazing, particularly by sheep. Grass cover is very poor. Sheet, rill and gully erosion is typical. Forbs form a significant portion of the vegetative cover. (Kirkman & Wilson, 1999 and Marais, 1994). Other species found include *Sporobolus capensis, Eragrostis sp, Microchloa caffra* and *Eragrostis plana* which is common in the vicinity of kraals. *Richardia humistrata* is an abundant forb, its rosette habit helping to protect the soil from erosion. L is a cultivation variant. This type consists of cultivated areas, associated with fallow lands that are still characterised by pioneer and seral species. Abandoned and other fallow lands in the mixed veld areas are generally dominated by *Hyparrhenia hirta* or, where grazed, by *Cynodon dactylon*. (Kirkman & Wilson, 1999 and Marais, 1994).

V represents *the* village sites. These are heavily grazed grasslands where *Cynodon dactylon* is the dorminant species with varying proportions of associates including *Eragrostis curvula*, *E plana and Sporobolus capensis*. For modelling purposes the land cover type was used rather than the different types of vegetation as described above because of the land cover data had a better temporal resolution.

A brief history of the study area

The Upper Tyume catchment is located about 30km east of Alice towards Hogsback. The catchment comprises a number of villages and amongst these are Guquka, Sompondo, Hala and Magxagxeni.

In the early 19th century, part of the Makhuzeni/Mfengu tribe (originally a group of four settlements) migrated from the Peddie and Grahamstown area to occupy the Upper Tyume river basin. The main reason for the movement was due to mounting pressure and tension caused by an increasing population density that resulted in land conflicts (Van Averbeke, Harris, Mbuti, & Bennet, 1998 a). The other important reason for the movement was the loss of land by blacks to European settler expansion. This expansion saw the passing of acts that segregated blacks.

In 1913 the Native Land Act was passed. In 1936 the Native Trust Land and the Group Areas Act were passed. This led to the creation of black areas and white areas. Areas like Hogsback and Cathcart were declared as white (Fig. 2.1). This then led to the migration of blacks that once resided in these areas into villages like Guquka, Sompondo and Magxagxeni. Headmen allocated the incomers residential plots. No arable land was given to these incomers since all of it had already been allocated. This implies that the newcomers could not derive their livelihoods from the local resources. This also subsequently led to higher population densities at the time as more people had to settle in these communities. Eventually most of these people left for urban areas.

Once established in the upper Tyume valley, the Mfengu people set up wards. Guquka, Sompondo, Hala and Magxagxeni were some of these. People in these wards had access to extensive rangelands and arable allotments, which surrounded them (Van Averbeke, et al., 1998 a). These shared rangelands and arable allotments were adequate for cattle grazing and cultivation for the communities, respectively. It is however argued that originally the layout of these wards was such that each homestead had a piece of farming land next to it and a cattle kraal (enclosure) just next to the homestead for security purposes. With time, this set up was changed and various reasons have been put forward to explain why. Some of the reasons are explained in the following paragraph.

The Betterment Planning, which was implemented in the 1960s was responsible for changes in the structure of settlements. It was an intervention intended to bring soil erosion under control (Van Averbeke, et al., 1998 a). It consisted of mechanical and engineering solutions to conservation problems. It then subsequently was geared towards establishing a completely new settlement pattern in the rural areas. People were moved against their will and concentrated at residential sites mainly to allow full time farmers access to economic farming units. It also separated the grazing lands and arable lands from the settlements. This plan effected a fundamental transformation of the people's physical economic and social environment generally leaving people worse-off that they were before (De Wet, 1990). Its success in combating erosion is also very highly questionable (Whisken, 1991; Kakembo, 1997).

During the 1960s, there was the development of the Dimbaza Industrial Zone, which created employment. Job opportunities at the University of Fort Hare were also on the rise. So the young and able bodied villagers started moving to these places for a week and/or a month and then came back home over the weekends and month ends with some money to help in improving land-based economic activities in the area.

In the 1960s and 1970s, the Homeland System was introduced and it was the same time when the Betterment Planning was instituted. The Betterment Planning involved mainly stock culling, the physical reorganization of agricultural land, reallocation and fencing of residential plots. It was during this period that the hut tax and pass controls was implemented, which essentially increased the general social insecurity of the villagers (Van Averbeke, et al., 1998).

A very important event in the history of the study area occurred in the mid 70s. The grazing area located at higher altitudes along the Amatola Escarpment was taken for pine plantations. The area now under pine plantation was covered in grassland with few trees. It served as good grazing area for all the animals and during winter the animals would be put in paddocks and they would get down to the river for water and go back to the mountain top for grazing. The mountains were also used for hunting, collecting fruits and medicinal plants (Van Averbeke *et al.*, 1998 a). Forest tree species and other plants were used as building materials, inputs to agriculture and livestock production, for traditional feasts and as clan or family totems (Che and Lent, 2004 in Lawes, et al., 2004). Women and children collected fuelwood and they were only expected to collect the dead trees and branches, but only men were allowed to cut live trees of many species (Che and Lent, 2004 in Lawes, et al., 2004). Women and fuelwood collectors where encouraged to cut green invasive alien species for fuelwood which had largely been cleared by Working for Water (WfW) teams making it difficult to obtain fuelwood. This and a diminishing supply of deadwood near villages forced some women to carry axes and take indigenous trees, contrary to both the Department of Water Affairs and Forestry (DWAF) policy and traditional practice (Che and Lent, 2004 in Lawes, et al., 2004). Gender-differentiated access to resources access to resources may have had positive implications for forest conservation because women, who by custom and tradition are restricted to firewood species, are less likely to take the rarer species incidentally when out foraging for fuelwood (Che and Lent, 2004 in Lawes, et al., 2004). The mountain range was divided into four camps and separated by fences, which were rotationally grazed. The chief and his advisors were seemingly convinced to change the land use of the area into pine plantation. This was however not discussed with the rest of the villagers. A ceremony was actually conducted to make official the change but not enough information was given to the villagers. A few years later the first pine trees were planted until the whole area was covered (Van Averbeke *et al.*, 1998 a). Frustrated with the loss of their key resource, the residents of Guquka and Sompondo decided to fight the pine tree encroachment by burning the young seedlings during winter, when there was sufficient dry grass to generate the necessary heat (Van Averbeke *et al.*, 1998 a). The pine trees and the erection of a dam on one of the main tributaries is said to have led to a reduction in the flow of water in the Tyume river leaving the Tyume almost dry in the 1983/4 drought (Van Averbeke *et al.*, 1998 a)

There were several implications of this change in land use:

- This meant a significant reduction in size of the grazing land for the communities below the escarpment which was now occupied by pines.
- Loss of suitable winter grazing land
- This weakened the stock negatively and influenced crop production.

- This was generally a heavy blow to one of the land based activities (grazing).

This all implied that only those with sufficient external incomes would somewhat sustain their stock numbers and continue with crop production.

Worse still in 1980 there was a severe drought which resulted in large livestock losses which further diminished agricultural productivity. In 1990, there was an economic decline in South Africa. This led to massive retrenchments thus reducing job opportunities for the job seekers. Large-scale retrenchments were especially felt at the University of Fort Hare.

Reasons for the choice of the study area

This study follows the objectives of ARDRI, which seek to develop a better understanding of the land use systems in communal areas of the central Eastern Cape. This is all aimed at identifying and documenting processes that could lead to sustainable improvements of the land use systems. In the initial phases, it was decided to limit work to specific settlements, and Guquka was one of the settlements selected after an initial reconnaissance of 20 villages. ARDRI staff has been collecting information regarding land use patterns in the area. In 1997 a socio-economic survey of households in this community was done.

Detailed studies on soils, vegetation, rainfall and pastoral potential (Hill Kaplan Scott, 1989) have been conducted in the area. A number of land use policies have also been implemented in this area in the past, which could have contributed to land degradation.

Van Averbeke *et al.*, (1998) (b) traced the rural livelihoods in the Central Eastern Cape. The study looked at the role of agriculture in the livelihoods of black people stretching back from the pre-colonial era. The study describes how farming has changed from being full subsistence to that of a secondary subsystem of rural livelihood that relies heavily on external sources of income. Magagula (1999) looked at the physical and chemical properties of soils in the Upper Tyume catchment in relation to environmental degradation. Hoffman et al., (1999) did a comprehensive study on land and water degradation in South Africa as a whole with a number of case studies in the Eastern Cape, which provided relevant literature for this study. Verdoodt et al. (2000) did an in-depth study of the soil physical and chemical properties in one of the villages in the study area.

Huge gullies have developed and are still developing in these areas at specific locations (Mupakati, 2001). A number of land use practices have been identified from both aerial photographs and fieldwork. These include grazing, settlement, cultivation and plantation. These land use categories have been affected by degradation differently, which gives the impression that certain land use practices are more prone to degradation (Mupakati, 2001).

A study involving sustainability of rural livelihoods by (Bennett, 2002) has been conducted in the area and it has now become vital to trace how the changing land use practices and land policies could be linked with degradation of the land and to try and make scientifically derived decisions as to how the environment could be protected.

The availability of relevant data both digital and analogue of the area, information about the area on rural livelihoods, the severity of erosion in the area and the proximity of the area to the University of Fort Hare are the reasons why the Upper Tyume Catchment was chosen as the study area.

Each of the objectives of the study mentioned was treated more or less separately using an appropriate method. These methods are described in detail in chapter 4 and results pertaining to each of these objectives are presented in chapter 5. Chapter 6 brings together the findings and chapter 7 contains the conclusions and discussion.

Summary

Environmental degradation needs to be traced from history to understand its drivers and effects. The Eastern Cape, among other provinces of South Africa, faces land degradation problems. The approach and methodology adopted in achieving the objectives of the study has not been only to understand the trends of land and degradation but also to investigate their causes through a modelling approach.

CHAPTER 3 (Literature Review)

Introduction

This chapter provides a review of the related literature of the research area and attempts to justify the chosen methodologies. Literature relating to land use, land degradation and the use of satellite imagery (LandSat TM) in land cover analysis will be reviewed at.

Land use and land degradation

Landscapes throughout the world undergo transformation processes, which may be a result of natural processes, human activities or both. Such changes could be in the way in which, and the purposes for which, human beings employ the land and its resources. Farming, for example is termed land use. Rural and non-commercial agricultural land use activities neither consider the state of the environment nor the effect of such activities. Rural land use practices usually comprise settlement, cultivation, grazing and in some cases recreation.

Land use is very significant to landscape changes. Certain land use practices are more likely to lead to degradation of land than others. Uncontrolled grazing and poor farming practices are examples of land uses that lead especially to the physical degradation of the land in rural areas.

Land use should not be confused with land cover. Land cover is a term used to describe the physical state of the land surface as for instance in cropland, vegetation, mountains or forests. The term land cover originally referred to the kind and state of vegetation for example as forest or grass, but it has been broadened in subsequent usage to include human structures such as buildings, pavements and other aspects of the natural environment such as soil type, surface and groundwater (Meyer, 1995)

Different factors and mechanisms drive land use and land cover transformation. In many cases, climate, technology, politics and economics appear to be major driving factors of land use change, which of course will affect its spatial and temporal scale. Land use changes are often associated with changes in land cover or vice versa. Land tenure system (whether commercial or communal) appears most strongly related to land degradation in South Africa (Hoffman *et al.*, 1999). The Eastern Cape, KwaZulu Natal and the Northern Province possess districts with the highest levels of degradation (Hoffman et al., 1999). Land use is certainly important and can dominate over other factors (Hanvey *et al.*, 1991). Studies in KwaZulu Natal (KZN) have indicated that gullied lands are more common in subsistence farming areas than in commercial farming areas. Talbot (1947) argued that gullying in Swartland is largely attributed to agricultural mismanagement. Garland (1987) discussed the role of paths and animal tracks in creating gullies. Agricultural practices have affected South African soil losses for hundreds of years (Hoffman *et al.*, 1999). Barker (1985) found out that much sediment input into the Swartvlei River was attributed to intense land use in the lower catchment. Land use was also a critical determinant of suspended load in two adjacent, physically similar catchment in Zululand (Kelbe *et al.*, 1992). This study investigates how land use changes and rural land use practices could have contributed to land degradation in a rural catchment of the Eastern Cape.

Land use certainly influences soil losses and there is abundant research which makes this point clear. Soils from undisturbed sites are thought as the "best case" or benchmark. Measured values for undisturbed soils range from 0.02 t ha^{-1}yr^{-1} (Garland, 1998 in Hoffmann *et al.*, 1999) to 0.75 t ha^{-1}yr^{-1} (Haylett, 1950 in Hoffmann *et al.*, 1999). Variation will be accounted for by slope, rainfall and soil conditions). Values for grazed land range from 0.6 t ha^{-1}yr^{-1} (Scott, 1951) to 1.7t ha^{-1}yr^{-1} (Haylett, 1960 in Hoffmann *et al.*, 1999). The worst case is represented by bare land. Haylett (1960) in Hoffmann *et al.*, 1999 recorded a figure of 28.1 t [illegible] for undisturbed bare ground and between 9.8 and 25 t ha^{-1}yr^{-1} for bare cultivated land. Smithen (1981) in Hoffmann *et al.*, (1999) quotes a value of 72 t ha^{-1} yr^{-1} for bare fallow ground. Some non agricultural land uses which accelerate erosion include rural and informal settlements (Watson, 1991; and Makhanya, 1993 in Hoffmann *et al.*, 1999). Literature also shows that erosion may be reduced in these areas by conservation measures.

Independent of their long-term cumulative effects, changes in land use and land cover have environmental implications, such as a shift in surface runoff dynamics which usually lead to the development of gullies, the lowering of groundwater tables, impacts on rates and types of land degradation and reduced biodiversity. It is therefore very vital that an understanding of changes in land use and land degradation trends be clearly understood for sustainable exploitation of resources.

Land degradation is a composite term, it has no single readily identifiable feature, instead it describes the way in which one or more of land resources, which could be soil, water, vegetation, relief and many others have changed for the worse (Stocking *et al.,* 2000). The United Nations, Food and Agricultural Organisation (UN/FAO) define land degradation as the temporary or permanent decline in the productive capacity of the land. Another definition describes land degradation as, "the aggregate diminution of the productive potential of the land, including its major uses (rain-fed, arable, irrigated, rangeland, forest), its farming systems (e.g. smallholder subsistence) and its value as an economic resource" (Stocking *et al.*, 2000). This feed-back loop between degradation (which is often caused by land use practices) and its effects on land use is central to most published definitions of land degradation.

The cause and effects of land degradation could be on-site or off-site. On-site effects of land degradation lead to a lowering of the land's productive capacity, resulting in reduced farm yields or a need for more farming inputs (Stocking *et al.*, 2000). Costs incurred from purchasing farming inputs are borne directly by the land user, reducing interest in reducing or reversing degradation. This implies that the ability to remedy degradation by the land user depends on whether the effect is on site or not. Off-site effects are problems that are exported and borne by the recepient site. Common off-site effects include sedimentation and deposition of eroded materials on farmland.

However, the generally and most frequently recognised causes of land degradation are as follows;

- Overgrazing of rangelands
- Overcultivation of croplands
- Water logging and salinisation of irrigated land
- Deforestation

Other factors that can promote land degradation are; soil type, slope angle, rainfall intensity, vegetation and land cover. Baver *et al.*, (1972) classify the effect of soil properties in two ways. The first is that certain properties determine the rate at which rainfall enters the soil. Secondly, some properties affect the resistance of the soil against dispersion and erosion during rainfall and runoff. An important soil property with regards to soil erodibility is the particle size distribution. In general erodible soils have a low clay content. Soils with more than 30-35% clay are often regarded as being cohesive and having stable aggregates which are resistant to dispersion by raindrops (Evans, 1982). Evans (1982) also stated that sands and coarse loamy sands are, as a result of high infiltration rates, not easily eroded by flowing water. In contrast, soils with a high silt and or fine sand fractions are easily erodible.

The proportion of water-stable aggregates with a diameter less than 0,5mm is a good index of erodibility. The erodibility of the soil increases with the proportion of aggregate less than 0,5mm (Bryan, 1974).

Other factors that contribute to aggregate stability are organic matter content and roots. The soil profile also determines the depth of the erosion features (Evans, 1982). Soil horizons below the A layer or Plough layer (Ap horizon) are often more compact and less erodible. The texture and chemical composition of the subsurface horizons can also have a negative impact on erosion, for example; soils with a structured prismatic B horizon are not only badly drained but once they are exposed, they are very susceptible to erosion since the presence of high Na+ concentration on the exchange sites of the clay particles leads to dispersion.

Soils with a dense massive structure or a well developed platey structure have impeded drainage, which can cause severe erosion. Normally deep gullies can be cut if the parent material is unconsolidated. If resistant bedrock is near the surface, only rills will be developed. Soils which are rich in rock fragments are less susceptible to erosion (Lamb, 1950; Evans, 1982). Rock fragments protect the soil against erosion and also increases the infiltration capacity of flowing water into the soil. Also the ability of a soil to accept water from rain depends on the moisture content of the soil at the time of rain.

Soil sensitivity and resilience determine how and to what extent a piece of land is prone to degradation. Soil sensitivity is the degree to which a land system undergoes change due to natural forces, human intervention or a combination of both (Stocking *et al.*, 2000). Soil resilience is the property that allows a land system to absorb and utilise change. It refers to the ability of a system to return to its pre-altered state following change. By combining the two, we can then get the different extents to which a soil system is prone to degradation. Table 3.1 below illustrates how different combinations of sensitivity and resilience lead to different chances of degradation and restoration capability of a land parcel.

Table 3.1 Interplay of sensitivity and resilience to degradation

		Sensitivity	
		High	**Low**
Resilience	**High**	Easy to degrade Easy to restore capability	Hard to degrade Easy to restore capability
	Low	Easy to degrade Difficult to restore capability	Hard to degrade Hard to restore capability

(Adapted from Stocking *et al., 2000*)

Table 3.1 shows that highly sensitive and highly resilient soils are easily degraded and can be easily restored. Low sensitivity and resilience soils are difficult to degrade and not capable of restoring their original state. For example, an iron rich but highly weathered and acid ferralsol of the humid tropics has a low sensitivity to degradation as well as a low resilience (Stocking et al., 2000).

Slopes can be characterised in three ways namely; slope steepness, slope length and slope shape. Because of the increased downslope component of gravity, erosion potential is greater on steep slopes and also on long slopes because of downslope increase in surface flow (Baver *et al.*, 1971).

Gerrard (1981) showed that plane and convex slopes did not differ significantly in the amount of soil lost by surface runoff, but concave slopes were less eroded. There is a general agreement in literature that convex slopes are most susceptible to erosion and concave slopes are least susceptible to erosion (Weaver, 1988). King (1951) focussed precisely on the initiation of gullies with respect to slope and observed that gullies tend to form on the lowermost gentler slopes or pediments of hillsides, a fact that was elaborated by Cobban and Weaver (1993) in the Eastern cape where gullies were well established below a break of slope where gradient reduced from 25 to 2 degrees.

Another important factor determining the amount of soil loss is vegetation. Regardless of slope, soil loss can be reduced by the amount of vegetation. Vegetation canopies and density are very important influencing factors. Vegetation canopies intercept water and then the water is evaporated from the leaves without reaching the surface and thus reducing runoff. High vegetation density will reduce the rate of overland water flow thus also reduce the erosive action of the running water. Roots and biological activity form stable soil aggregates leads to a good soil structure increasing infiltration thus reducing runoff.

Soil loss and the factors that cause it have been studied using different methods. The following section gives a brief review of the methods used in erosion mapping, quantification and modelling studies.

Review of methods used in erosion studies.

Techniques of soil erosion survey differ according to the eventual aims of the survey (Weaver, 1988). Gully erosion modelling has focussed more on development of qualitative and empirical-statistical models than in formulation of physically based models which focus on quantifying and or modelling gully erosion (Bocco, 1991; Stocking, 1980 in Casanovas 2003). Different approaches have been used to study the typology of gullies and the effects of gullies (sediment production and l[illegible]dation) and to predict the risk of gully erosion and its environmental, social and economic effects (Casanovas, 2003). In mapping changes in gully morphology, over a short space of time, Welch, Jordan and Thomas (1984) in Weaver (1988) found repetitive low altitude stereo-photographic techniques to be useful. Keech (1968) in Weaver (1988) used 1: 25 000 aerial photographs to measure the density of rills and gullies in Zimbabwe. Another approach by Keech (1969) in Weaver (1988) was to use aerial photographs to outline gullies on transparencies. Outlines from sets of sequential photographs then provided the basis for the determination of soil erosion trends in the Mhondoro tribal trust lands of Zimbabwe. Makhanya (1978) in Weaver (1988) used sequential aerial photographs to map changes in erosion and to identify areas of high erosion risk in Lesotho. Stocking and Elwell (1973) in Weaver (1988) in Zimbabwe used a method that adopts a single factorial scoring technique whereby 5 erosion factors are allocated values between 1 and 5. The erosion factors used were erosivity, erodibility, land cover, slope and human occupation. Factorial values were summed for each area and an erosion risk value between 1 and 25 was obtained for each region. Casasnovas (2003) used multitemporal (1957 to 1993) aerial photos and a DEM to map and quantify gully erosion in Catalonia (Spain).

Advances in remote sensing technology have opened up new prospects for soil erosion mapping. Satellite imagery clearly shows severe and very severe classes of erosion where highly reflective subsoil or windblown sand are easily recorded. However, aerial photographs provide a far higher resolution but of a smaller area than satellite imagery. The level of resolution of most aerial photographs makes it possib[illegible] all erosion processes whereas satellite imagery is limited to processes occurring over extensive areas only. Sheet, rill and gully erosion can be identified, mapped and measured quantitatively by aerial photographs (Bode, 1986 In Weaver, 1988).

A number of studies employing different methods including remote sensing have been carried out on erosion in South Africa. Remote sensing (aerial photography and satellite images) and GIS have been used in many studies.

Kakembo (1997) did an air photo and field study of areas affected by erosion in the Peddie District of the Eastern Cape. He found very little difference in erosion trends between Betterment and Non-betterment villages, and that land was gradually shifting into worse erosion categories. Rowntree (1988) reviewed erosion in the Karoo and found out that erosion itself may not represent degradation, as the cycle of erosion and deposition are part of the dynamic equilibrium of the landscape. Pile (1996) interviewed people in poor rural communities of the maize fields in KwaZuluNatal and discovered that some communities rank soil erosion quite low in importance compared with other community problems. Phillips, Howard and Oche (1996) did a study in the Eastern Cape using interviews to review local soil conservation in subsistence areas and found that several widely established indigenous or adapted soil conservation techniques are in use, allowing crop production whilst conserving soil.

Theoretical background of erosion modelling

Numerous ways of modelling land degradation have been employed in many parts of the world. The extent of land degradation can be assessed by modelling erosion and then comparing the model with the actual degradation on the ground. A number of approaches have been used to model erosion. Most of these have now become computer-based but they all focus on the Universal Soil Loss Equation (USLE) (Wischmer and Smith, 1965). The USLE was designed as a method to predict the average annual soil loss caused by sheet and rill erosion. The USLE is often criticised for its limitations in some applications but it can estimate long-term annual soil loss and guide conservationists on proper cropping, management, and conservation practices. There have been many proposed modifications to the USLE but all are woven around the same concept where rainfall erosivity, slope class, slope length, land cover, soil type and land management factors are taken as directly proportional to the rate of annual erosion (Morgan, 1986). The

Revised Universal Soil Loss Equation (RUSLE) estimates potential soil erosion using the following formula.

$$A = R * K * L * S * C * P$$

Where;

A is the potential erosion

R is the rainfall and runoff factor;

K is the soil erodibility factor;

L is the slope-length factor;

S is the slope-steepness factor;

C is the cover and management factor; and P is the erosion control practice factor

The USLE/RUSLE has been integrated with GIS to permit erosion studies in many parts of the world. Remote sensing and GIS has recently been applied in erosion studies where Soil Erosion Susceptibility (SEP) scales have been produced using some key factors derived from the USLE. Modelling which involves spatial data brought together in a computer system to generalise a set of conditions can be regarded as GIS modelling. A GIS model is a simplification of the real world, which does not necessarily include everything on the landscape, but uses only those items of importance to the research in question. Thus, such models reduce complexity and confusion by giving a simple representation of reality. It attempts to predict and/or provide new information about physical or social features and processes. This is accomplished by employing inventory and basic analysis operations which include processes like;

- *Database and coverage recoding,*
- *Overlay analysis (using or not using weights),*
- *Map algebra (add, subtract, multiply and divide) and*
- *Buffering* amongst others.

A number of GIS models have evolved to date. These can be categorised as Environmental Models, Sensitivity Models, Prediction Models, Statistical Models and Time Series Models to mention some. Most of these models overlap and one or more can be used in a particular study. The modelling of erosion in this study will be done using a Sensitivity Model, which shows what will be expected to happen under a given set of data or circumstances. Before GIS operations (inventory and basic analysis) are applied to a set of coverages or environmental conditions, the researcher must first understand the potential results and their interpretations. In such modelling processes, remotely sensed data like aerial photography in digital format is incorporated. Slopes and slope classes are computed from Digital Elevation Models (DEM), which are in turn created from digital contours fed into the GIS. An example of such modelling techniques was used by Raghunath (2002) in an erosion potential map for the Bagmati basin in Nepal using GRASS GIS. The next section discusses the other theme, which is land use and land cover analysis.

Land use/land cover analysis

Land use affects land cover and changes in land cover affect land use. A change in either, however, is not necessarily the product of the other. Changes in land cover by land use do not necessarily imply a degradation of the land. However, many shifting land use patterns, driven by a variety of social causes, result in land cover changes that affect biodiversity, water and other process (Meyer, 1995). Land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and forest management. (Meyer, 1995).

Changes in land cover driven by land use can be categorized into two types: modification and conversion. Modification is a change of condition within a cover type; for example, unmanaged forest modified to a forest managed by selective cutting. Significant modifications of land cover can occur within these patterns of land cover change. Conversion is a change from one cover type to another, such as deforestation to create cropland or pasture. Conversion land cover changes such as deforestation have been the focus of many global change research agendas (Riebsame, Meyer and Turner, 1994 in Bottomley, 1998).

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental change. The rapid development of the concept of vegetation mapping has lead to increased studies of land use and land cover change worldwide. Providing an accurate assessment of the extent and vigour of the world's forest, grassland, and agricultural resources has become an important priority (Bottomley, 1998).

Viewing the earth from space has become essential to comprehend the cumulative influence of human activities on its natural resource base. In a time of rapid, and often unrecorded, land use change, observations from space provide objective information of human utilization of the landscape. Over the past two decades, data from earth sensing satellites has become important in mapping the earth's features and infrastructure, managing natural resources, and studying environmental change (Bottomley, 1998).

A number of satellite sensor systems are in space obtaining a wide variety of images of different formats and resolutions. Landsat TM images which is used in this study is one such sensor.

Land cover change in South African catchments

Afforestation schemes in the world including South Africa's exotic plantations supply a key industry, but it was accepted that plantations of alien species in headwater areas competed for water with downstream water supply schemes. Afforestation and land use modifications affect stream flow regimes, thus making them important issues in South African hydrology (Hughes, 2002).

The current invading alien species in South Africa, especially in the Eastern Cape Province, pose a serious threat to water security and biodiversity in affected areas. WfW teams supported by DWAF teams are clearing invasive alien plants in unguaged and guaged catchments of South Africa. Many natural forests of Eastern Cape Province have been replaced by exotic forests of wattle and pine. Most of the alien species were introduced with the intention to curb the ever-increasing land degradation, mainly in remote areas.

The introduction of such exotic trees may lead to some recovery of hydrological functions of degraded lands but there will be a cost associated with water used by the growing tress. Alien invasive species use 3300 million cubic meters of water over the entire of South Africa in a single year (Versfeld *et al.*, 1998). Exotic plantations will also have a similar impact if they are planted in areas where rivers originate. It is thus very important to investigate the impact of these exotic forests on catchment hydrology. Such marked land cover changes in many parts of South Africa have contributed significantly to fluctuations in water resources and changes in land use practices (Versfeld *et al.*, 1998). The need to understand these water fluctuations has seen the application of GIS in such and related studies where large rainfall, temperature, soil and land cover databases are required as inputs.

Landsat Thematic Mapper sensor and multispectral Imagery

The evolution of the Landsat program has been a fundamental impetus to an international endeavor to better measure and monitor the earth and its precious resources. Despite early military/intelligence programs in space during the 1950's and 60's, the scientific and industrial communities in the U.S. became aware of the potential of earth observing vehicles in space. The National Aeronautics and Space Administration, NASA, in cooperation with other federal agencies, successfully launched on July 23, 1972, the first Earth Resources Technology Satellite (ERTS-1), which was later renamed Landsat 1. Landsat 1 was a Nimbus-type platform which carried a sensor package and data-relay equipment. ERTS-2 was launched on January 22, 1975, and was later renamed Landsat 2. Additional Landsats were launched in 1978, 1982, and 1984 (Landsats 3, 4, and 5 respectively). Each successive satellite system has had improved sensor and communication capabilities. (Bottomley, 1998).

Landsat Thematic Mapper is a passive, multispectral sensor that measures the strength of emitted or reflected electromagnetic radiation. The spectral capabilities of a satellite sensor are determined by the ranges of wavelengths (wavebands) recorded and the precision with which the amount of reflected energy that is measured. A sensor recording the energy of a single waveband produces a greyscale (panchromatic) image whilst multispectral images are produced from sensors simultaneously recording multiple wavebands. The Landsat Thematic Mapper sensor, for example, records in 7 spectral bands. Table 3.2 shows the wavelength regions of each of the seven Landsat bands and the characteristic features they detect.

Because we can only display and view images using the three visible primary colours (red, green and blue) any three of the wavebands available need to be chosen to highlight the particular features of interest. When any combination other than the visible bands are used, the resulting image created is a false colour composite.

Table 3.2 Landsat TM bands and wavelength regions

Landsat Band	Wavelength Region	Characteristic features
1.	*0.45 - 0.52 μm* (Blue)	Increased penetration of water bodies, analysis of soil, vegetation and landuse.
2.	*0.52 - 0.60 μm* (Green)	This band corresponds to green reflectance thus shows health of vegetation.
3.	*0.63 - 0.69* μm (Red)	Similar to band 1 and 2 but exhibits more contrast because of the reduced effect of atmospheric attenuation.
4.	*0.76 - 0.90 μm* (Near Infrared)	Responsive to the amount of vegetation biomass, useful in crop identification and emphasises crop and land water contrasts.
5.	*1.55 - 1.75 μm* [Near (Short Wave Infrared)	Sensitive to the amount of water in plants, also used to discriminate between clouds, snow and ice
6.	*10.4 - 12.4 μm* (Thermal Infrared)	Used for locating geothermal activity
7.	*2.08 - 2.35 μm* (Mid Infrared)	Discriminates rock formations especially identifying rocks of hydrothermal alterations

(Adapted from Jensen, 2000)

Materials covering the surface of the earth reflect or absorb the sun's radiation in a characteristic manner (spectral signature). From the visible wavelengths (blue-green-red) this gives a material a specific colour which we see. For a multispectral sensor, recording many wavebands spread over a far greater range of wavelengths, discrimination between materials is made much more apparent.

Different combinations of the TM bands can be displayed to create different composite effects. The following combinations were used to display images:

- Bands 3, 2, and 1 create a true colour composite. True colour means that objects look as they would to the naked eye, similar to a photograph.
- Bands 4, 3, and 2 create a false colour composite. False colour composites appear similar to an infrared photograph where objects do not have the same colours or contrasts as they would naturally. For instance, in an infrared image, vegetation appears red, water appears navy or black.

With the adequate knowledge of band properties and the appropriate combination of Landsat TM bands, the extraction of numerous themes, land use and land cover classes can be achieved for various mapping applications.

Vegetation indices

To analyse vegetation characteristics, a number of vegetation indices are in use but the most widely used and also used in this study is the Normalized Difference Vegetation Index (NDVI), which is (NIR - RED) / (NIR + RED). Raw index values range from -1 to +1, and the data range is symmetrical around 0 (NIR = RED), making interpretation and scaling easy. But vegetation values typically range between 0.1 and 0.7. Higher index values are associated with higher levels of healthy vegetation cover, whereas clouds and snow will cause index values near zero, making it appear that the vegetation is less green.

Different ratio or normalized difference images can be combined to form colour composite images for visual interpretation. The colour image incorporates three ratio images with R = TM3 / TM1, G = TM4 / TM3, and B =

TM7 / TM5. Vegetated areas appear bright blue-green, iron-stained areas appear in shades of pink to orange, and other rock and soil materials are shown in a variety of hues that portray subtle variations in their spectral characteristics.

NDVI can be used as an indicator of relative biomass and greenness (Boone et al. 2000, Chen 1998 in Bottomley, 1998). If sufficient ground data is available, the NDVI can be used to calculate and predict primary production, dominant species, and grazing impact and stocking rates (Ricotta et al. 1999, Oesterheld et al. 1998, Paruelo et al. 1997, Peters et al. 1997, Diallo et al. 1991 in Bottomley, 1998).

Image classification

Image classification is defined as the extraction of differentiated classes or themes, land use and land cover categories, from raw remotely sensed digital satellite data (Gorham, 1999 in Bottomley, 1998). For the purposes of this project, the terms land use and land cover have been combined as one entity for the description of the landscape within the area of study. It should however be noted that while land use and land cover are recognized as separate entities (Meyer, 1995), they have been combined in this study in order to conform to the level of detail employed. In this study, 5 level 1 categories comprise the land use and land cover classification employed in this project.

Table 3.3 Land Use & Land Cover Classification Categories

Category	Level 1	Explanation
1	Built-up land/Water	Settlement/Buildings
2	Grass and Pasture Lands	Grass and Pasture Lands
3	Forest Land	Deciduous/Coniferous Forest
4	Sparse shrub	Little sparse shrub
5	Barren Land	Soil/rock exposures

Spectral classification is very popular in computer image analysis. Spectral classification seeks to categorize the image cells on the basis of spectral patterns, without regards to spatial relationships or associations. There are two main types of spectral classification which are supervised classification and unsupervised classification. In supervised classification the analyst designates a set of training areas in the image, each of which is a known surface material that represents a desired spectral class. The classification algorithm computes the average spectral pattern for each training class, and then assigns the remaining image cells to the most similar class. In unsupervised classification, the algorithm derives its own set of spectral classes from an arbitrary sample of the image cells before making class assignments. Unsupervised classification was used in this study. Unsupervised methods assume no prior knowledge and therefore do not require delineation and extraction of any training data. It is based on the assumption that pixels of similar cover types exhibit similar spectral response patterns and that they are distinguishable from the spectral response patterns of other cover types. The advantages of unsupervised approaches are as follows:

- No prior knowledge of the area is required

- It avoids the training stage step where samples taken from each class must be homogeneous and evenly distributed on the image which is prone to operator errors
- Unique and important classes may be derived on the basis of spectral response which may not be initially apparent to the interpreter

One disadvantage of unsupervised approaches is that the derived spectral classes may not match the informational classes the user wants to derive. The other is little control over the algorithms used.

Land user's perception on land degradation and land use change.

Once occurring, land degradation is a very serious problem because it reduces the productivity of parcels of land especially in this millennium when populations are increasing and thus the demand for land is going up to produce more food. Efforts to control degradation have had limited success especially in developing countries.

Land degradation is understood and seen differently by different people. Thus for land degradation, the land user's concern is mainly biased towards productivity. The existence of land degradation is unlikely to be a cause of much concern until it has finally affected productivity. What may be seen by a scientist as a potentially degrading situation or a marked land use change pattern may be interpreted differently by farmers. An accurate measurement of soil loss through erosion is of interest to the scientist while the land user is generally more concerned about the effects of erosion than the absolute amount of soil loss (Stocking *et al.*, 2000). It is thus important to understand how land users perceive processes of land use change and land degradation if discussions regarding these issues are to have any relevance to them. Also, when trying to develop some form of natural resource management in a community, understanding their perception of erosion, especially whether it is perceived as a problem or not is crucial (Brinkcate and Hanvey, 1996; Pile, 1996a and 1996b; Ward *et al.*, 1999 in Vetter, 2003).

Scientific interpretation of degradation does not coincide with those of the land user (Stocking, 2000). What may be seen by a scientist as a potentially degrading situation may have different significance to a farmer. This is why this study utilized both the scientific [illegible] methods and the conventional interviews together to understand the catchment dynamics fully. Some such differences are summarised in the Table 3.4. These are however, extremes of differences since in some cases you may find overlapping ideas.

To get the perceptions and reasons for degradation from communities, interviews have been widely used by researchers. Binkcate and Hanvey (1996) administered questionnaires using the purposive sampling method in the Madebe Community of the North West Province, South Africa, seeking the attitudes and perceptions towards soil erosion.

Table 3.4 Extremes in the interpretation of outcomes of land degradation evidence

Process	Scientific Interpretation	Land User Interpretation
Heavy rainfall	High erosivity and potential soil erosion	Damage to crops, but also benefit to soil and planting opportunity
Deep gullies	Severe erosion and abuse of catchment	Livestock fatalities and loss of roads and bridges
Rills	Severe short term erosion indicating need for better land cover	Useful local drainage channels to prevent water logging
Stones on the soil surface	Loss of finer soil particles through water or wind erosion	Soil formation (Burungee people, Dodoma region, Tanzania)

(Adapted from Stocking *et al.*, 2000)

This chapter looked at the relevant literature and concepts related to this study. The next chapter will describe in detail the methods employed in this study.

CHAPTER 4 (Methodology)

Introduction

This chapter describes the methods used in this study. The methods will be discussed separately in three sections namely; erosion modelling, land use and land cover change analysis and land use change history (survey)

(A) Erosion modelling

Data used in the erosion modelling process.

- Soil data: The Ciskei Government Service's Natural Resources Survey 1: 50 000 soil map of 1977 for the Keiskamma river basin which covers the whole of the study area provided information on soils.
- Digital Contours for 3226DB SEYMOUR (SA) (1:50 000.) was used for the creation of the Digital Elevation Model (DEM)
- Topographical Map (1:50 000.) 3226DB SEYMOUR (SA) was used as a base map.
- Aerial photographs from 1949, (no specific date), 1963 (3 December), 1985 (3 May) to 1996 (3 June) and colour infrared aerial photographs (2000) were used for the creation of land use maps for use in the modelling process and assessment of vegetation conditions (infrared photos)

Before the erosion modelling process was executed, aerial photo interpretation was done and land use maps were produced from aerial photos. In this study, sequential aerial photos were analysed and interpreted to trace land use changes and compare the findings with the survey results. The aerial photos were scanned and imported into MIPS. The aerial photos were then orthorectified and georeferenced so that they could occupy their correct positions in space. After the aerial photos were georeferenced, land use maps were digitised for each of the years and they reflected the georeferencing of the aerial photos. Gully sites were chosen randomly to do specific gully development monitoring through measurement of length, widths and depths. Gullies as seen on the aerial photos for each year were also digitised so that they could also be overlain. The above processes were done in MIPS. Gully areas were measured by tracing them as seen on the georeferenced aerial photographs and their areas were automatically calculated in MIPS.

A flow chart was created to show the data analysis processes involved and how they were executed from the beginning to the end of the modelling process. The flow chart served as a reference framework describing processes being executed and used in the different stages of the project. Details and descriptions of the processes shown in the flow charts are discussed in the following pages. Figures 4.1, 4.2 and 4.3 show the flow charts that were used to guide the modelling process. The soil erosion potential is abbreviated SEP in the figures and text.

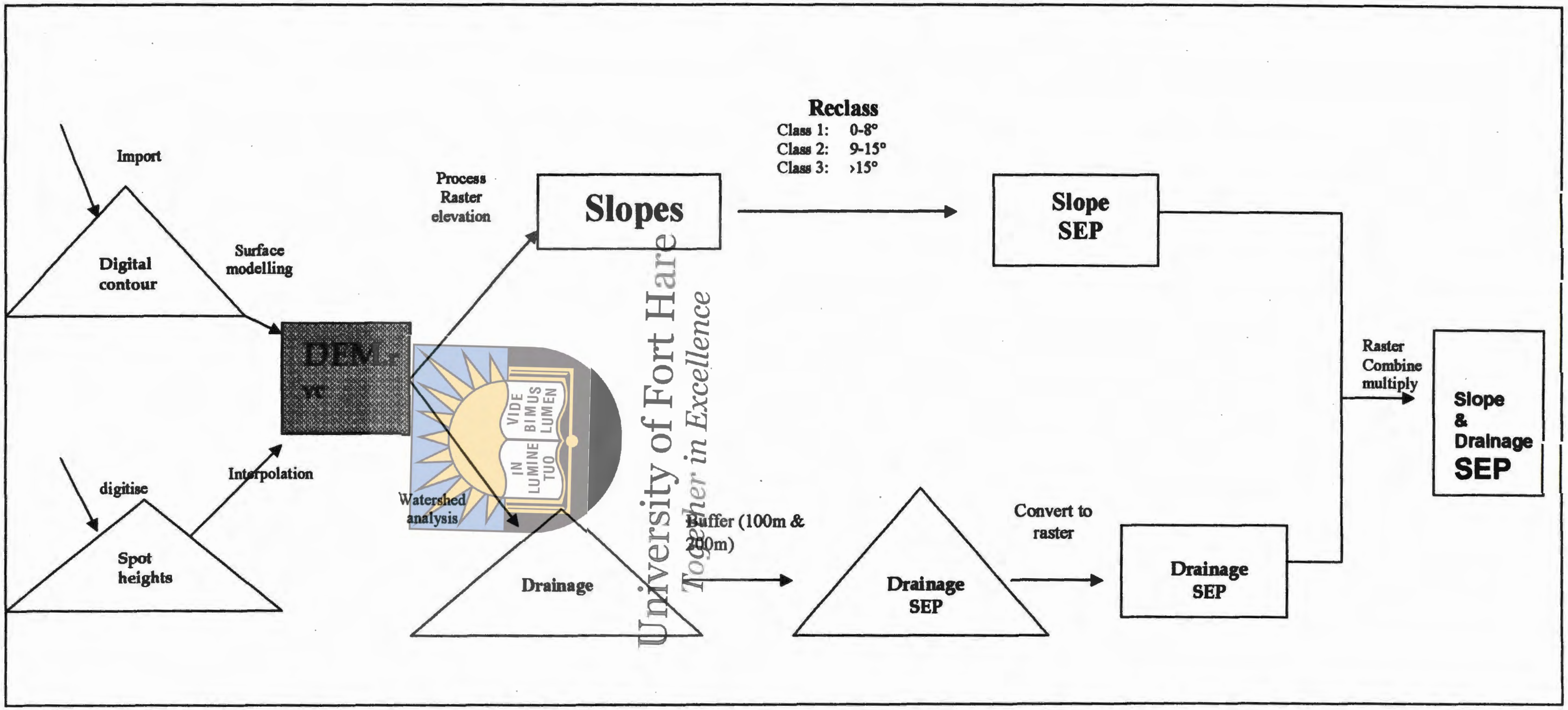
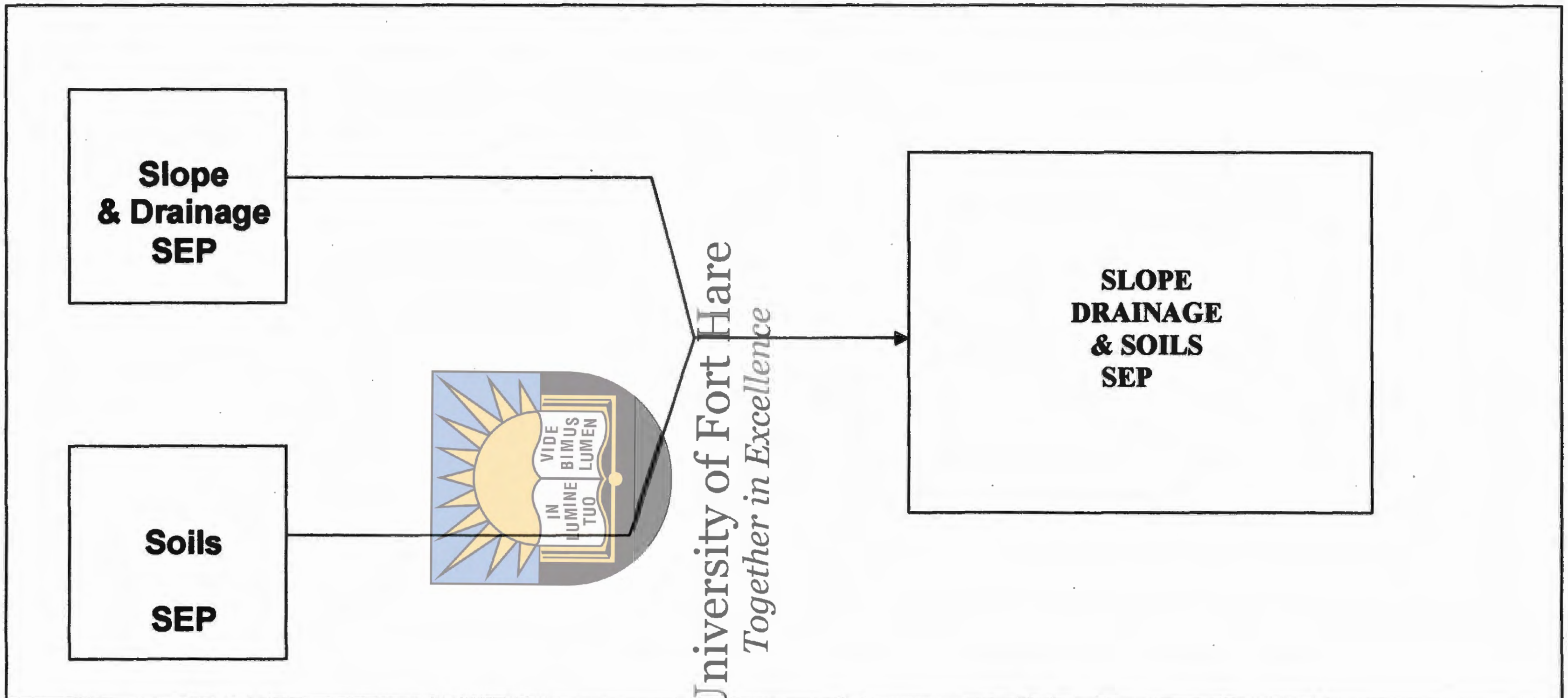


Fig 4.1 Data abstraction from contour lines and digital spot heights.



Assumption: There is no significant variation in the total amount of rainfall received at each point on the surface in the community where the modelling was done. NB. Erosion modelling was done in and around the village of Guquka.

Fig 4.2 Integration of Soil Erosion Potentials.

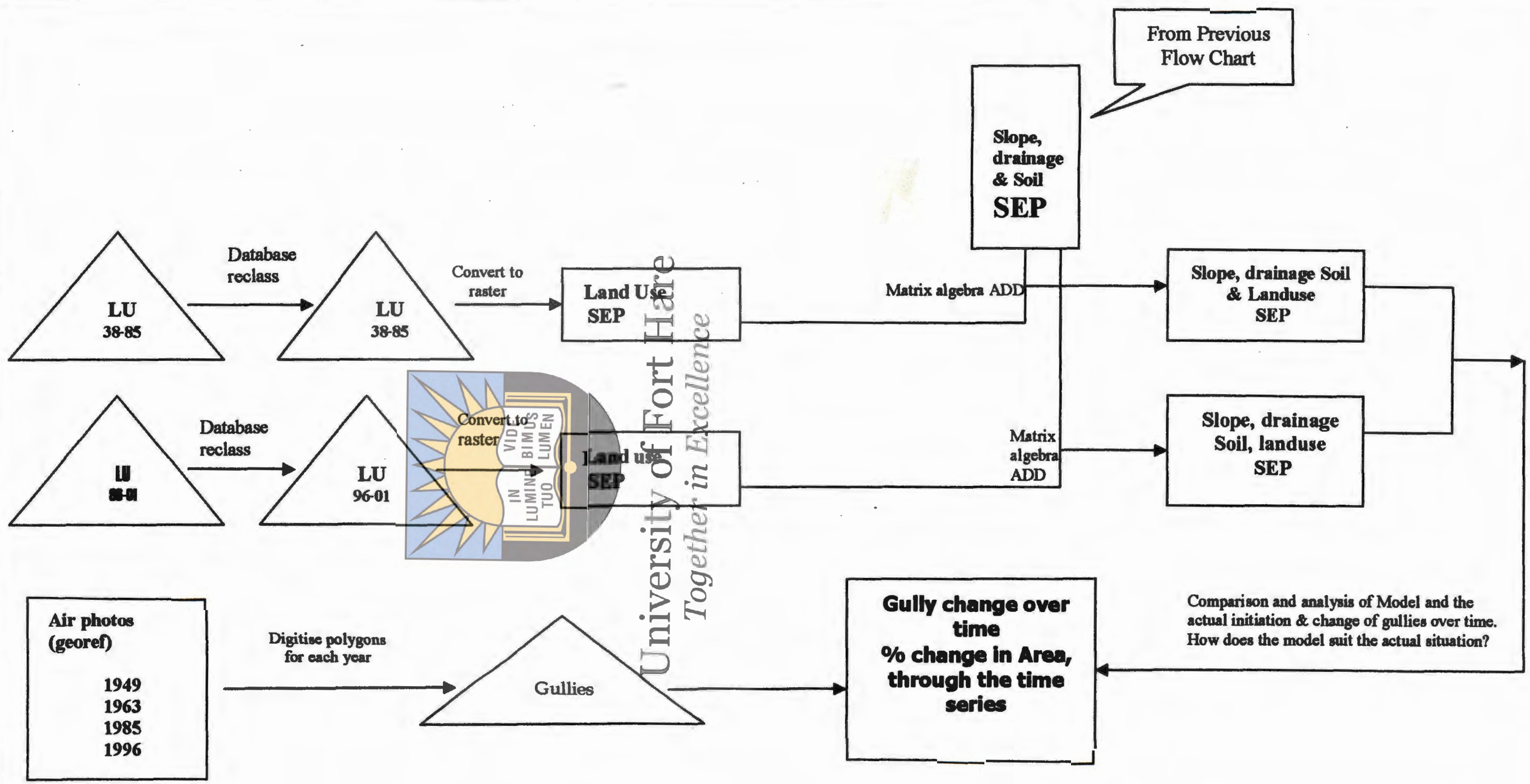


Fig 4.3 GIS operations leading to land use and gully interpretation

The erosion modelling process

GIS processes

The erosion model was done by taking key factors, which were slope, soil, land use and overland flow routes. A digital elevation model (DEM) was created through surface modelling. Surface modelling creates approximations of surfaces by means of interpolation from spatially referenced attributes. Digital contours and spot heights were used as primary inputs to the DEM for the model.

For slope and overland flow routes, a Digital Elevation Model was the primary data source. The Digital Elevation Model contained the elevation of the study area at a fixed grid interval. The D[illegible] created for the whole Seymour 1:50 000 toposheet to estimate slope and possible over-land flow routes. Input data for the creation of the 20m resolution DEM were spot heights and digital contours. Digital contours were cleaned first to correct for missing values and cross cutting contours. To get a more accurate digital elevation model, spot heights were digitised from the 3226DB SEYMOUR (SA) (1:50 000.) topographical sheet in the region between Eastings 26° 55′ & 27° and Northings 32° 40′ & 32° 33′, which is a small region around in the village where the erosion modelling was conducted. The DEM was created in TNTMips. The TNTMips process for creating the DEM was as below:

Process ——→ surface modelling

The flow chart (Fig 4.4) shows the levels of data abstraction to get to the SEP.

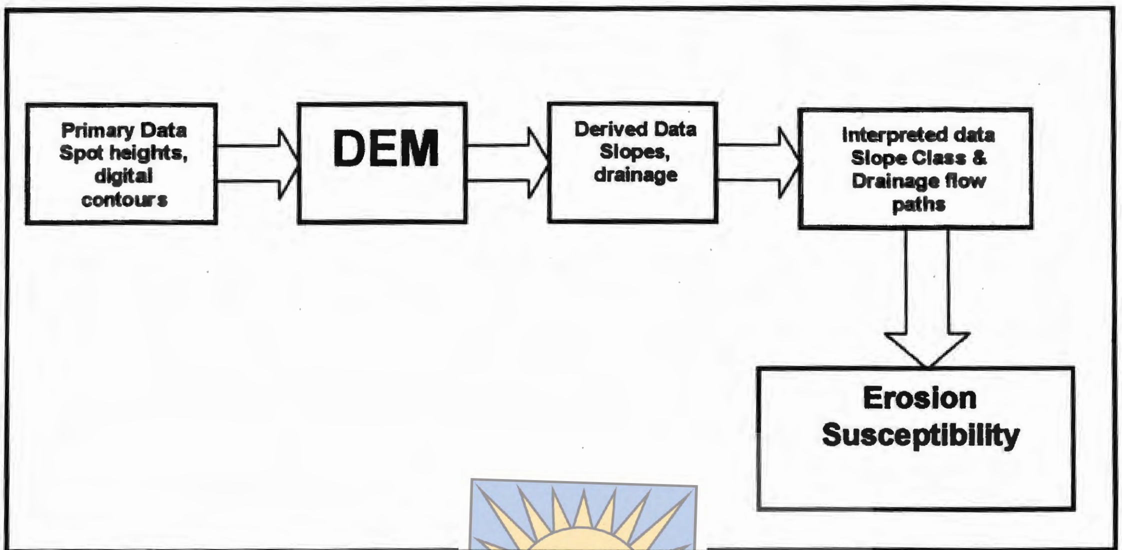


Fig. 4.4: GIS data abstraction chart

The DEM was used to compute slopes. Slopes classes computed were reclassed into three classes only, which were assigned high, medium and low soil erosion susceptibility. On the MIPS task bar, the "process" icon was clicked, then raster, elevation and slope as illustrated below:

process ⟶ **raster** ⟶ **elevation** ⟶ **slope**

Watershed analysis was performed to get drainage flow paths. The drainage flow paths were buffered to classify areas into zones of high and low potential for gully development. Results of this are significantly influenced by the flow-tracing algorithm and the resolution of the DEM. Watershed analysis was done in MIPS through the process shown below:

process ⟶ **raster** ⟶ **elevation** ⟶ **watershed**

The soil erosion potential from slopes and drainage were combined to get a slope and drainage SEP. This was then combined with the soils SEP to produce the SEP for the three variables (slope, drainage and soils).

Soils

The three main soil categories are depicted in Fig 2.3 and Table 4.2. These three soil types that occur within the area where the modelling was performed were given SEP's according to their physical properties.

The SEP's of soils in the area was determined through classification of forms of soil erosion. This was in line with a simplified South African Regional Committee for Conservation and Utilisation of Soil (SARCCUS) classification of erosion as observed in the Tyume catchment presented and by Magagula (1999). Table 4.1 shows the erosion forms that are observed in areas covered by the respective soils.

Table 4.1 Erosion forms for areas covered by respective soils in the Tyume

Soil Series	Erosion class	Description
Mispah	5	Intricate gullies
Mispah Williamson	5	Very severe rill and intricate gullies
Williamson	5	Truncated and dissected by gullies
Rietvlei (-)	5	Very severe rill and intricate gullies
Leeufontein	3	Slight sheet and rill erosion
Jozini (+)	2	Slight sheet erosion

(Adapted from Magagula, 1999)

Table 4.2 Soil classes in the study area

Soil series and phase				
Soil Type	**Dominant**	**Sub-dominant**	**Rare**	**Texture/comments**
A2	Rietvlei (+ moderately deep	Jozini (+)	Jozini (+, dense subsoil) Leeufontein Rietvlei (-)	Fine sandy clay loam commonly under grass
C1	Rietvlei (-)	Leeufontein (-, moderately deep)	Klipfontein Williamson	Apedal fine sandy loam Relatively slow permeability
E1	Williamson	Rietvlei (-) Mispah Klipfontein	Leeufontein Mayo	Fine sandy clay loam erosion risk under irrigation

Land use

From the available digital maps, four land use categories were identified. Table 4.3 summarises the four land use categories. Definitions of the land use types (LUT) employed generally correspond to those done by Liniger and Van Lynden (1998). The land use types were classified into erosion susceptibility classes. For modelling purposes, three classes were used and categorised as High, Medium and Low risk SEP.

Table 4.3: Land use classification

Land use type	Definition
Cultivation	Land used for crop cultivation, could be fallow (< 10 years) or land used for annual field cropping
Veld /grazing/sparse vegetation	Land used for animal production on natural veld (grasslands, woodlands)
Settlement	Rural settlement, roads, schools
Bush/thick vegetation	Area covered with thick bush and shrub

To clearly ascertain the magnitude of degradation, a field study was done. The main objective was to assess the size, confirm the place of occurrence and stage of development of the gullies. Stability of the gullies was also considered during the field survey. Several photos were taken for selected gullies to show the recent status of gully development.

The model

In terms of slope and watershed analysis, the model predicts SEP as below. The high SEP for slope class 9–15 degrees is based on the argument that gullies tend to develop at the break of slopes (Lal, 1990, King, 1951 and Cobban and Weaver, 1993).

Table 4.4: SEP based on slope classes

Slope range	Class	SEP
<8°	1	Medium
9° - 15°	3	High
>15°	2	Low

The Watershed Analysis process predicted from the DEM where rivers were likely to develop. These were obtained after executing the watershed analysis process in MIPS. The assumption here was that areas suited for the development of rivers would also be suitable areas for the initiation of gullies. The assumption is also supported by the fact that gullies can also develop as a manifestation of the upslope extension of drainage areas/lines. This prediction followed depressions in the relief, which the DEM precisely defines. Buffers were created for the delineated regions.

Table 4.5: SEP based on buffer widths.

Buffer zone	Class	SEP
100m Buffer	3	High
200m buffer	2	Medium
Outside the 200m buffer	1	Low

For the three soils in Table 4.2 soil type E1 was assigned to areas of high erosion potential. These soils are located on steep slopes. This is because Glenrosa is much less resistant to erosion. It is easily damaged from sheet flow and linear erosion such as rills and dongas, which are frequently created especially on steep slopes (Hendrick, 1985).

Soil type A2 was found to be deep and mostly found along rivers. It was assigned low erosion susceptibility because of the presence of the Jozini soil series, which is not easily erodible (erosion class 2), and the subclass Rietvlei, which is also moderately eroded. C1 soil types, a combination of Rietvlei and Leeufontein are located on gently sloping areas and these were assigned a medium soil erosion potential.

Table 4.6: SEP based on soil classes.

Soil Type	Class	SEP
A2	3	Low
C1	2	Medium
E1	1	High

Matrix algebra multiplication was used to derive the SEP for slope and watershed variables.

Table 4.7: Multiplication of slope and drainage class values

	Slope class		
Drainage	**3**	**2**	**1**
3	**9**	**6**	**3**
2	**6**	**4**	**2**
1	**3**	**2**	**1**

Thus values of 9 and 6 become High SEP and are reclassed to a value of 3

Values of 3 and 4 become Med SEP and are reclassed to 2

Values of 1 and 2 become Low SEP and are reclassed to 1

Table 4.8: Multiplication of the slope and drainage and soils class values

	Slope & drainage class		
Soils	**3**	**2**	**1**
3	**9**	**6**	**3**
2	**6**	**4**	**2**
1	**3**	**2**	**1**

Land use and SEP

The land use SEP for the study area had a high SEP for veld grazing because of overgrazing that occurs in the area where animal trails contribute a lot to the initial development of gullies. A medium SEP was assigned to cultivated areas affected by poor farming (like steep slope cultivation) methods. The fact that crops were growing there mitigated against rapid soil deterioration hence a medium SEP. These SEP classes were also based on the arguments by (Garland, (1988) Haylett, (1960) Watson, (1991) Makhanya, (1993) Scott, (1951) and Smitten (1981) in Hoffmann *et al.*, 1999 as explained in Chapter 3.

Table 4.9: Land use SEP classification

Land use type	Soil erosion potential	class
Cultivation	Med	2
Veld /Grazing	High	3
Settlement	Med	2
Bush	Low	1

Matrix algebra addition was performed to add the land use, slope and drainage tables to derive a composite as presented in Table 4.10.

Table 4.10: Matrix algebra addition for land use, slope, soil and drainage tables

	Slope, Soil and Drainage Class		
Land use Class	**3**	**2**	**1**
3	**6**	**5**	**4**
2	**5**	**4**	**3**
1	**4**	**3**	**2**

6 becomes Very High SEP, **5** becomes High SEP, **4** becomes Med SEP, **3** and **2** become Low SEP.

The analysis of gully development over time in the study area was performed by taking five main gully sites desc[illegible]nes in this study. Growth of the gullies in each zone was monitored and analysed by measuring the area covered by gullies in each zone in each year and then monitoring the changes over time. Fig 5.7 shows the main gully sites chosen on the basis of gully density.

(B) LAND USE AND LAND COVER CHANGE ANALYSIS

Land use and land cover change analysis was done to give a visual impression of how such changes occur. Three Landsat TM images were used in this analysis. The images were for the years, 1995, 2000 and 2002. Preprocessing of satellite images was done. This involved resampling the images, atmospheric correction or normalization, image registration and geometric correction. The images were georeferenced and were projected to the Universal Transverse Mercator (UTM) Projection. The 1995 and 2000 images were georeferenced to the 2002 image (raster to raster) using the Edit-Georeference process. All the preprocessing was done in MIPS. The 1995 image could not be extracted and resampled to match the other two images as the area of overlap was too small. Its analysis was done separately and the trends were compared. Single band visual analysis was done.

For vegetation assessment, band ratios were used. Before computing band ratios or normalized difference images, the brightness values in the bands were adjusted to remove the effects of atmospheric path radiance (haze). Atmospheric scattering or a hazy atmosphere adds a component of brightness to each cell in an image band. The adjustment of band values for path radiance effects was performed in MIPS in the Predefined Raster Combinations process, using the arithmetic operation Scale/Offset. NDVI was computed in MIPS by the following Band Ratios (NIR - RED) / (NIR + RED). NDVI images were produced and analysed. The NDVI band that was produced was then combined with other bands of the multispectral image to form colour composite images which help to discriminate different types of vegetation. In these images, the display colour assignment was,

R = (Near IR band)

G = (NDVI band)

and B = (Green band).

The images were then classified in MIPS using the ISODATA method. This method incorporates procedures for splitting, combining and discarding classes to obtain an optimal set of output classes. Five classes were assigned after ten iterations.

(C) LANDUSE CHANGE HISTORY (SURVEY)

This section describes the way in which the land use survey was conducted. The bigger part of the survey was conducted in April (2003), a time when most pupils were in school. Respondents interviewed were non-school going group who were mainly involved in land based activities.

Most of the interviews were carried out at the respondents' homes while others were conducted in the field in areas where degradation was clearly evident. The questionnaires were completed with the help of an interpreter (Xhosa speaking), to avoid the possibility of distortion of meaning both in asking questions and in answering them. The interpreter translated questions into Xhosa and the responses into English. Each interview session took between half an hour and an hour.

Apart from administering the questionnaires, observations of local conditions were also recorded. This involved visual impression and capturing data by the use of a camera. Topographic maps and aerial photos were also used to locate features and trace routes used by both people and animals in the area.

Sampling Procedure

Respondents were selected from four villages, Guquka, Sompondo, Magxagxeni and Hala. Probability sampling was employed which occurs when the probability of including each element of the population can be determined (Bless *et al.*, 2000). The population was put into the following age groups: (21-35), (36-50), (51-70) and (+ 70). Respondents from each household were picked only from the age strata defined. Guquka recorded 120 residential allotments (Bennett, 2002), which is almost the same size as Sompondo, which are the two major villages. Magxagxeni and Hala combined are almost the size of Guquka bringing the total number of households to 360. The age grouping was done to compare the differences in responses and knowledge. All the age groups were however [illegible] capable of giving relevant and accurate information. The selected individual was chosen regardless of gender. The eldest person in any selected household was however chosen as he/she was expected to have more information about historic land use practices.

The first dwelling was randomly chosen and the second dwelling would be the third house from it. The third house would also be the third house from the second house chosen. If people were not present at any selected dwelling the next house would be selected. This procedure was found to be quick and simple and to be very convenient for household sampling in the communities in question. A total of 38 households were successfully visited and a respondent interviewed.

Questionnaire design, construction and administration

Survey research is the most commonly used method of data collection in the social sciences. Its advantage is the ability to elicit information directly from the feelings and perception of the target group but its disadvantage is the personal bias that may encroach in its design and administration.

Factors that could influence response quality during questionnaire design and administration were considered. These include the community perceptions to research in the area. A number of studies had been conducted in the area and the villagers have long waited to see the fruits of such research in their area. As a result, a few straight-to-the-point questions were prepared. There was need to avoid the respondent [illegible] interview as this would lead to village developmental discussions. Leading questions were also avoided as they beg for obvious answers, which, then compromise the results of the research.

Interviews were conducted face to face. Scheduled structured interviews were employed. There are two main types of interviews: Structured and unstructured Interviews. "In a structured interview there is a definite set of questions prepared in advance. The interviewer cannot deviate from the prepared questions" (Mann, 1985). In comparison, in unstructured interviews, the questions are left open. When open-ended questions are asked, the respondent is allowed to discuss his/her answer without restrictions (Mann, 1985). The method chosen for this study was a combination of structured and unstructured interview. These were based on an established set of questions with fixed wording and in a specific sequence of presentation. The questionnaires were presented to each respondent in exactly the same way to minimise the role and influence of the interviewer and to enable a more objective comparison of results.

The questionnaire had a total of 25 questions. The first questions involved age group categories and villages in which the respondents resided. These were then followed by the land use activities and any difficulties villagers had with such activities. The last section of the questionnaire then focussed on the land degradation issue and the feelings of the communities about the phenomenon.

The questionnaires were filled out by the interviewer for the following reasons:

- To administer the questionnaires to respondents who can neither read nor write.
- To help avoid misunderstandings and misinterpretations of particular questions
- To ensure that the whole questionnaire was covered as some respondents would tend to ignore and avoid what they would regard as difficult questions.

One interviewer administered all the questionnaires to avoid biases in the results.

The questionnaire was constructed in the following format. There were structured questions with a range of possible answers, which also featured the "I do not know" option, and in some instances left room for the respondent to state other feelings about the issue in question.

There were also contingency questions, which were special types of questions, which applied to subgroups of respondents who will have given a particular response to a previous question. For example, when respondents were asked where they were living for the last ten years. If the answer was any village or area different from where they were staying at that moment, then a contingency question was asked as to why they had changed their place of residence. The questionnaire also had open-ended questions to leave the respondent free to express their answers as they wish. No restrictions or suggestions for responses were given in such cases.

To complement the interviews a focussed group discussion was carried out. Three respondents were carefully chosen from those interviewed that had shown knowledge and interest in the subject matter. These were then interviewed together. This was conducted in a structured and semi-structured manner. Respondents were free to discuss questions and argue constructively to come up with an agreed response. Debates amongst respondents gave the researcher better insight into the issues related to the problem statement. This was also found to be very fruitful as many African cultures rely on small group discussions for decision-making (Bless *et al.*, 2000)

Summary

The erosion modelling gave rates of gully degradation and erosion maps. The land use land cover change analysis highlighted the land degradation trend. The interviews gave an indication of the perceptions of the locals to degradation. Put together, the Upper Tyume served as the basic unit for ICM for this study.

CHAPTER 5 (RESULTS and ANALYSIS)

Introduction

There are three sections in this chapter. Section (A) presents the erosion modelling results, section (B) presents the landuse/landcover analysis results and section (C) the social survey results.

(A) Erosion modelling

The DEM (20 m resolution) shown in Fig 5.1 shows the relief of the 3226DB SEYMOUR (SA) (1:50 000.) map. As reflected on the legend in Fig 5.1, different colours represent different elevations. The height increases from purple-blue through yellow–green to red. The maximum height recorded was 1910m above sea level and the minimum was 540m. (NB: the DEM covers the whole of the Seymour toposheet). The DEM was used to analyse the implications of micro-scale slope changes or differences. This was done through the computation of slopes and their reclassification to specific critical slope classes.

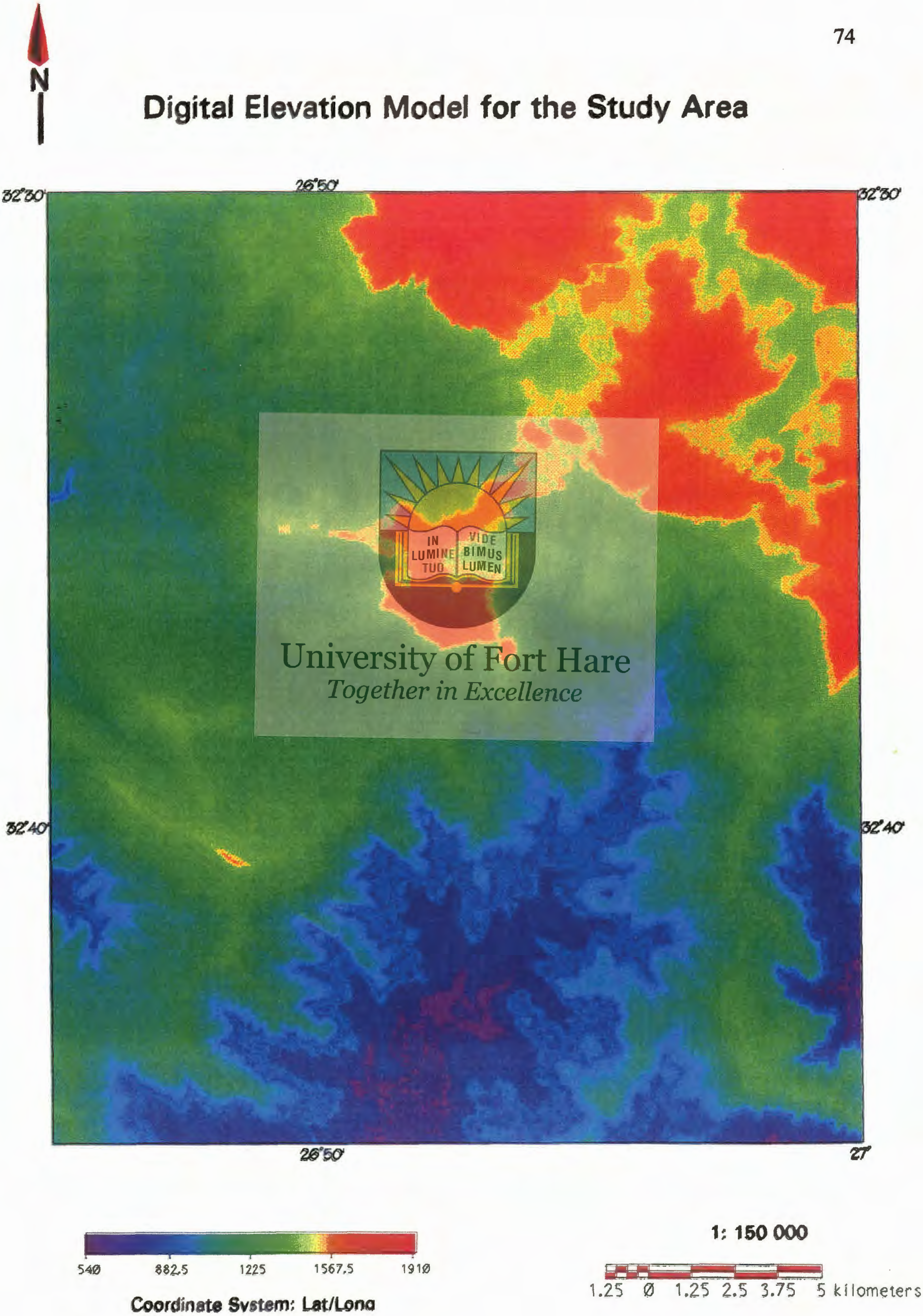


Fig 5.1 Digital Elevation Model

Slope, watershed analysis and the occurrence of gullies

The computed slopes were classified into three classes as described in Chapter 4. Class 1 slopes occupy 60% of the total area while classes 2 and 3 occupy 32% and 8% respectively. About 70 percent of the gullies were seen to occur in places with slope class 3 (9°-15°) with a high SEP. The critical angle range of class 3 as explained in the model was found to host most gullies or larger portions of linear and elongated gullies as seen in Fig 5.2. However, gullies also developed on Class 1 slopes. Fig 5.2 shows the relationship between slopes and gullies. It can be clearly seen that most gullies initiated in slope class 3 (9°-15°) which is the lighter black shading. Class 2 (> 15°) is the darker black [illegible] a whitish outline and has very few gullies. These gullies then developed and encroached into other slope classes especially slope class 1 (0°-8°) which is the white shading as in Fig 5.2. Class 2 slopes (> 15°) also host few gullies. In terms of gully lengths measured digitally in each slope class, class 1 has approximately 5.5km of gully length which is 55% of the total gully lengths of about 10km. Class 2 has about 4km of gully length which is 40% of the total and class 3 has 0.5 km which is 5%. Though class 2 has 40% of gully length, it is in this class that 80% of the whole gully network initiates as it is the critical slope class for gully initiation.

Gullies were found to be occurring very close to the drainage flow paths, which was one of the erosion model's assumption that gullies would initiate in areas suitable for the development of rivers. This fact is proven because most gullies were found within the 100m buffer created around areas where rivers would develop and few outside the 200m buffer. This shows the relationship between river development and gully initiation. Fig 5.3 shows the 200m buffer line with about 80% of all the gullies (in terms of gully lengths) and about 95% (in terms of gully area) that are found in the study area within it. This demonstrates agreement of the model's assumption and the results. Some of the gullies are however extruding out of the 200m buffer zone, which could be a result of continuous development of the gullies through headcutting.

To see the relationship between the two variables of the model (slope and drainage flowpath) and the occurrence of gullies, an overlay of the Fig 5.2 and Fig 5.3 was done as seen in Fig 5.4. The position of gullies with respect to slope and the drainage buffer are clearly observed. From the figure it can be seen that the gullies occur within the drainage buffer and in slope class 3.

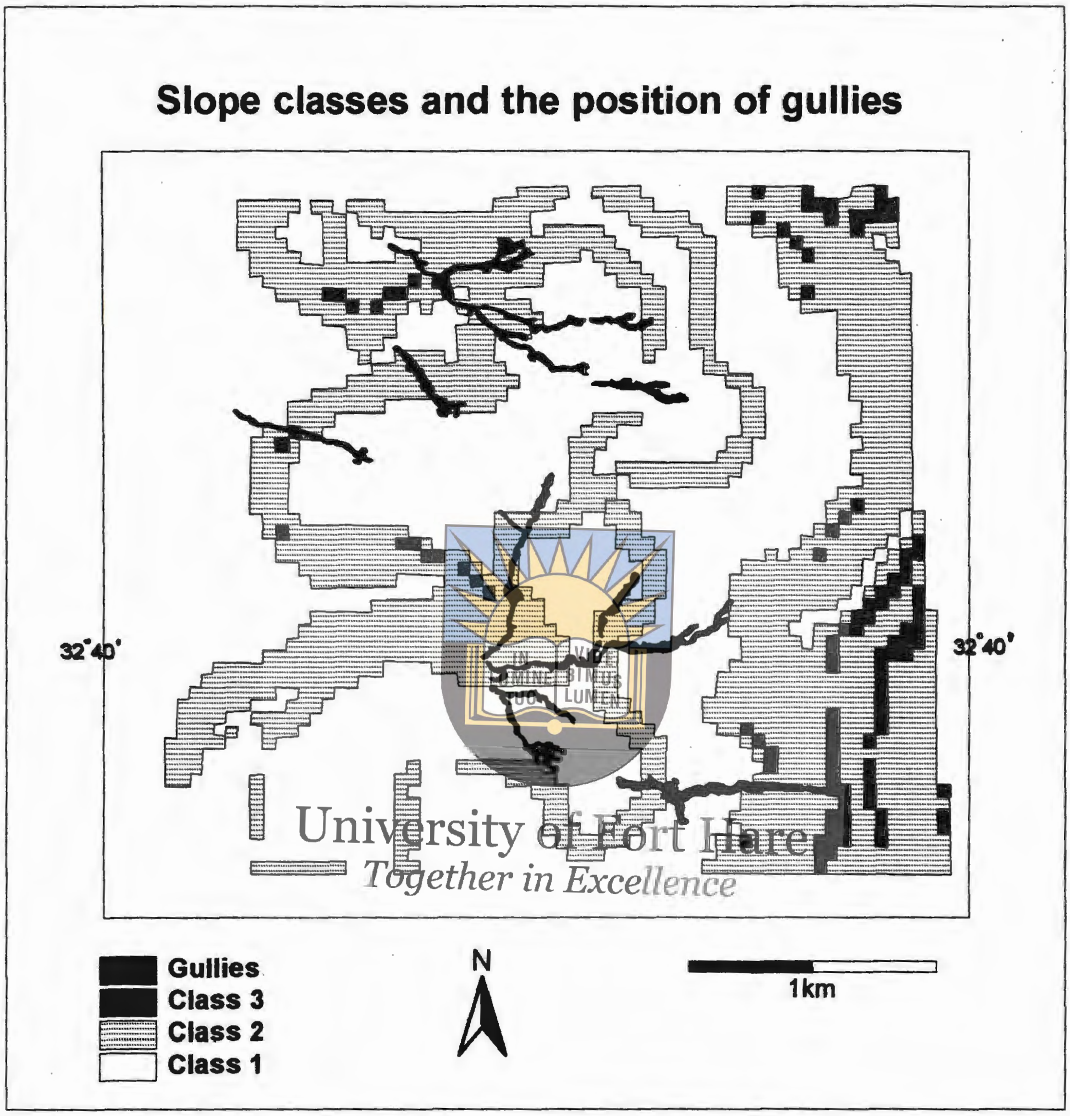


Fig 5.2 Slope classes and gullies

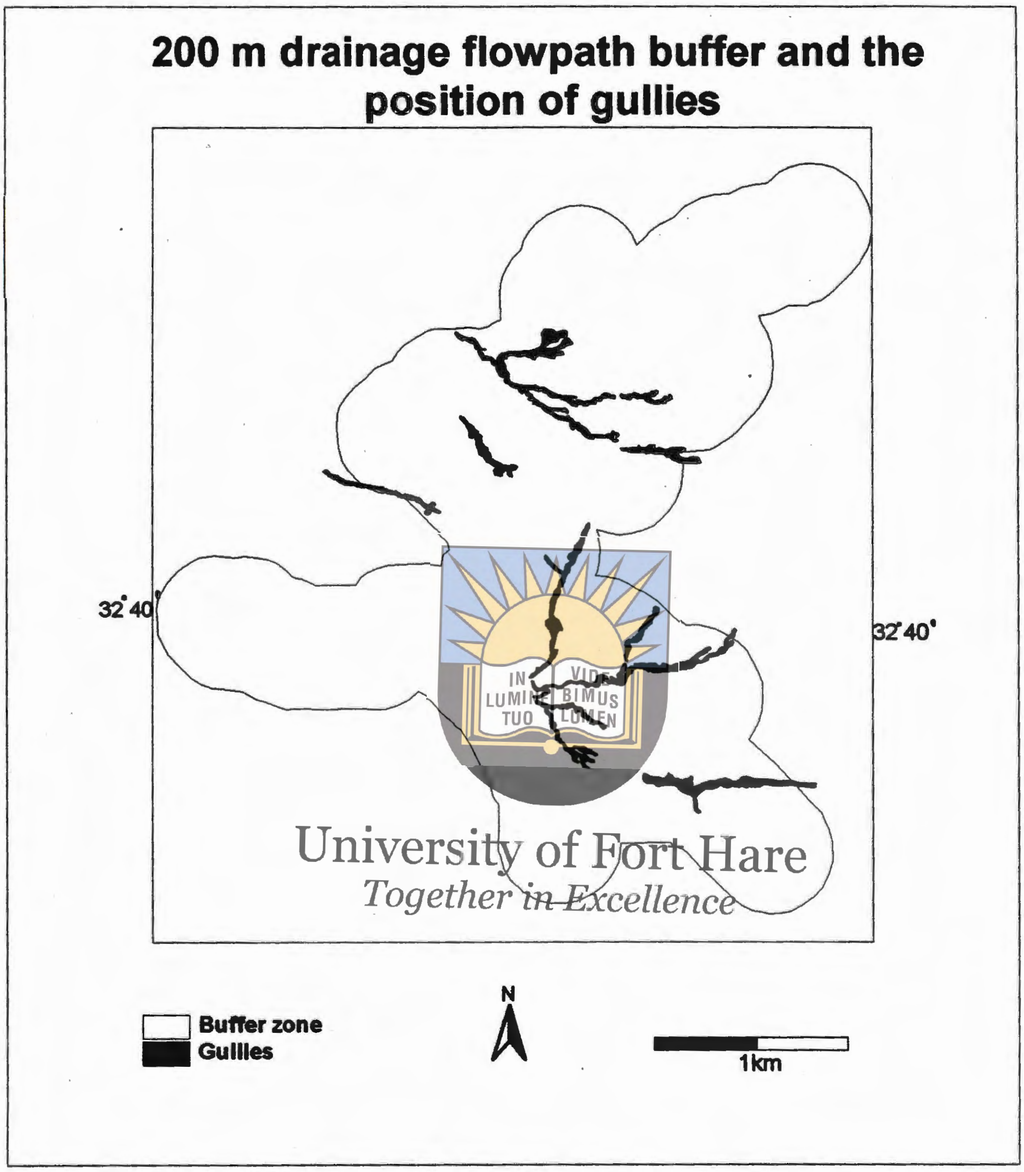


Fig 5.3 Drainage flowpath buffer and the position of gullies

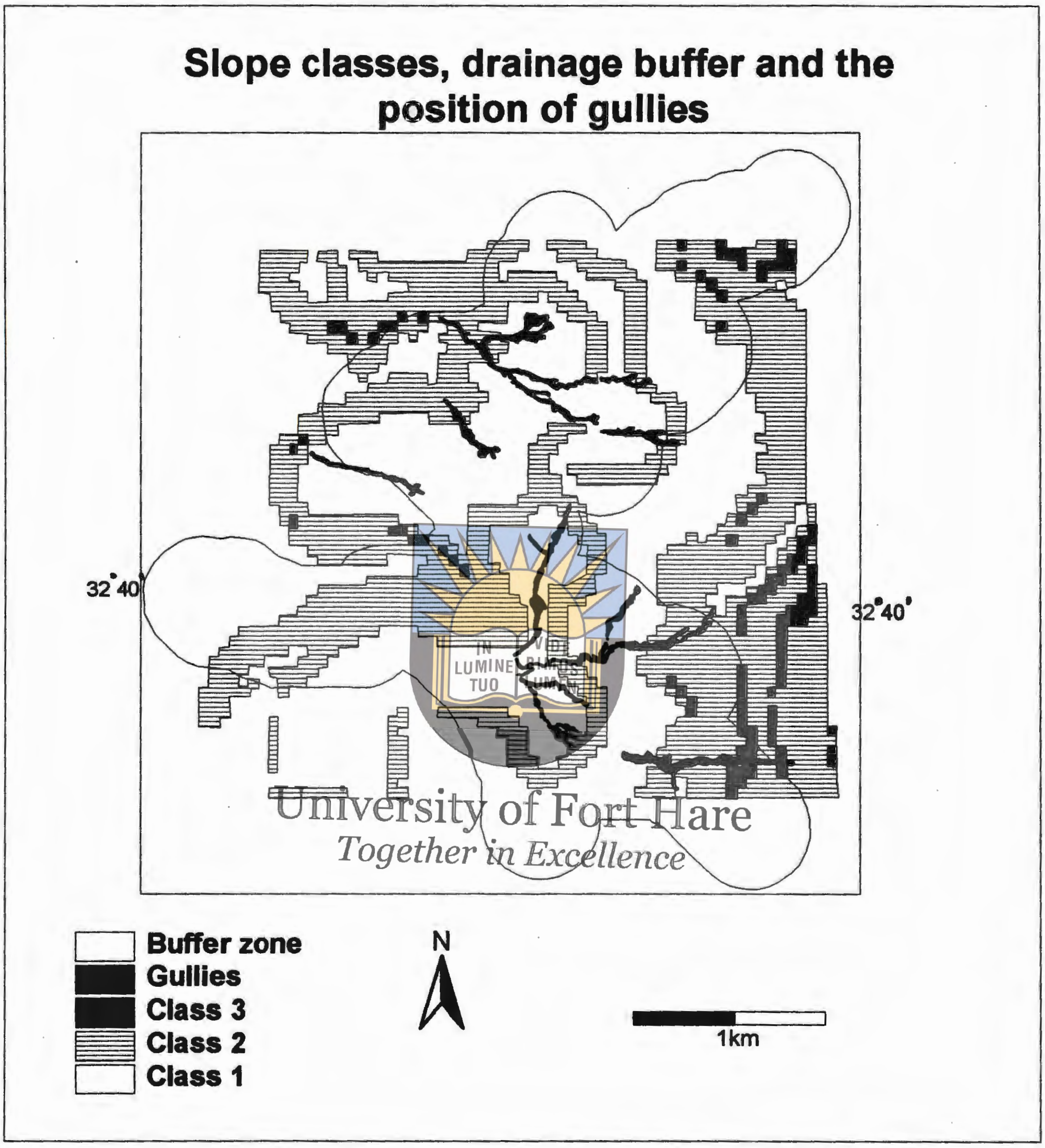


Fig 5.4 Slope, drainage buffer and the position of gullies

Soils and the occurrence of Gullies

The spatial distribution of gullies was a function of the type of soil. From table 4.1 showing erosion classes and descriptions of certain soil types, soils dominated by Mispah, Williamson and Rietvlei had intricate gullies and soils dominated by Rietvlei, Leeufontein and Jozini had rill erosion and slight sheet erosion.

The huge gullies as digitised from the sequential aerial photos and field visits were found to fall mostly into the E1 soil type which only occupies 30% of the study area (see Table 4.2 and Table 5.1).

C1 class soils, which cover parts of Magxagxeni and Sompondo, had small gullies although some category A gullies were also found.

A2 class soils that fall in erosion class 2 of the SARCCUS had very few rills found in them. Mostly seen was evidence of sheet erosion. This soil type is also commonly covered by grass resulting in few serious erosion features. Fig 2.3 showing the soils map can be referred to show the spatial distribution of the different soils.

Table 5.1 Percentage areas covered by gullies in different soil types

Soil Type	% Area covered by gullies	% of study area
A2 **Dominant** Rietvlei (+ moderately deep **Sub-dominant** Jozini (+) **Rare** Jozini (+, dense subsoil) Leeufontein Rietvlei (-)	10	20
C1 **Dominant** Rietvlei (-)**Sub-dominant** Leeufontein (-, moderately deep) **Rare** Klipfontein Williamson	25	50
E1 **Dominant** Williamson **Sub-dominant** Rietvlei (-) Mispah Klipfontein **Rare** Leeufontein Mayo	65	30

Land use and occurrence of gullies

There was a very close relationship between land use type and the occurrence of gullies. Areas that had been predicted as high erosion risk (in terms of land use alone) in the model turned out to be the areas with many gullies. When land use maps were overlaid with the gullies, it was found that the gullies were mostly occurring in grazing areas, part of which was once under cultivation and now arable/abandoned lands. Grazing has now been concentrated in these areas since cultivation activities were terminated. Animals are left to graze on a free range basis. The main active agricultural activity is now basically backyard home gardening. A field visit revealed the presence of animals especially cattle and sheep, which created trails that later developed into rills as water eroded the loose soil left and subsequently forming gullies over time. Fig 5.5 shows the relationship between land use and gully occurrence. Again over 80% of the gullies are found in the grazing category.

Residential and cultivated areas, which were assigned medium soil erosion potential, had less than 20% of the gullies. Areas covered with thick bush had very few gullies occurring in them despite the fact that these bushes were located on steep slopes.

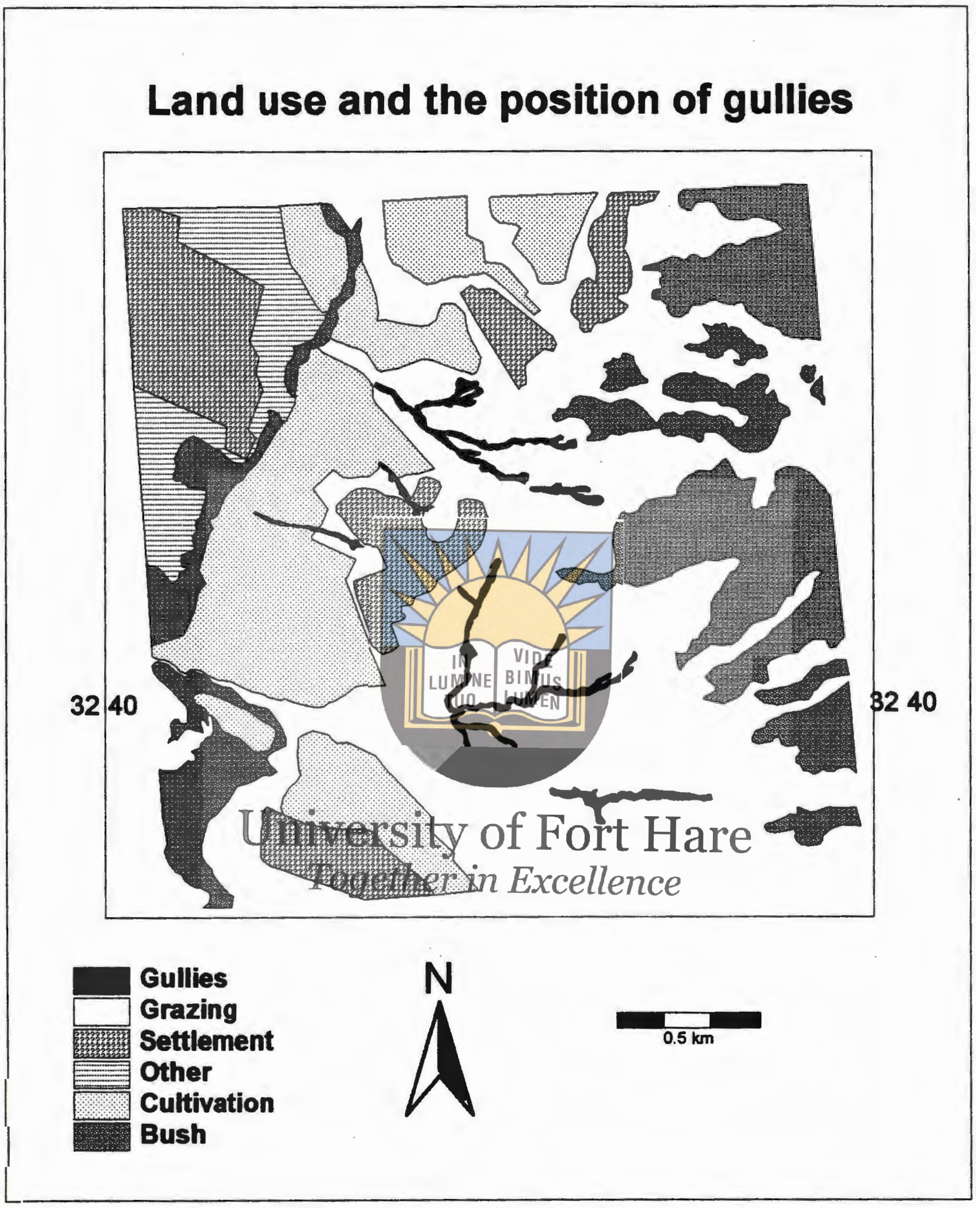


Fig 5.5 Land use and the position of gullies

Occurrence of gullies over time

Gully development in the catchment started as far back as 1938. During this time there were very few gullies that had developed and they were very small. Rills had however started developing in many areas. Plate 5.1 shows the 1938 aerial photograph. The lighter tones which show as irregular polygons are the cultivated areas and those that show as linear features are the roads. The other light tones are the gullies and rills which show as intricate linear features. Other small rills covered by vegetation appear as darker grey shades. The dark to black tones are areas covered by vegetation while the grey shades represent bare ground. The interpretation of the aerial photograph is as shown in Fig 5.6 where the cultivation, gullies and rills have been mapped. Fig 5.6 shows [illegible]onship between gully and rill occurrence with land use. The presence of gullies in 1938 shows that erosion was already taking place, presumably at a rather low rate as the size of gullies are rather small. The rate should have increased with the influx of people and poor land management practices as discussed later.

The 1938 Aerial Photograph

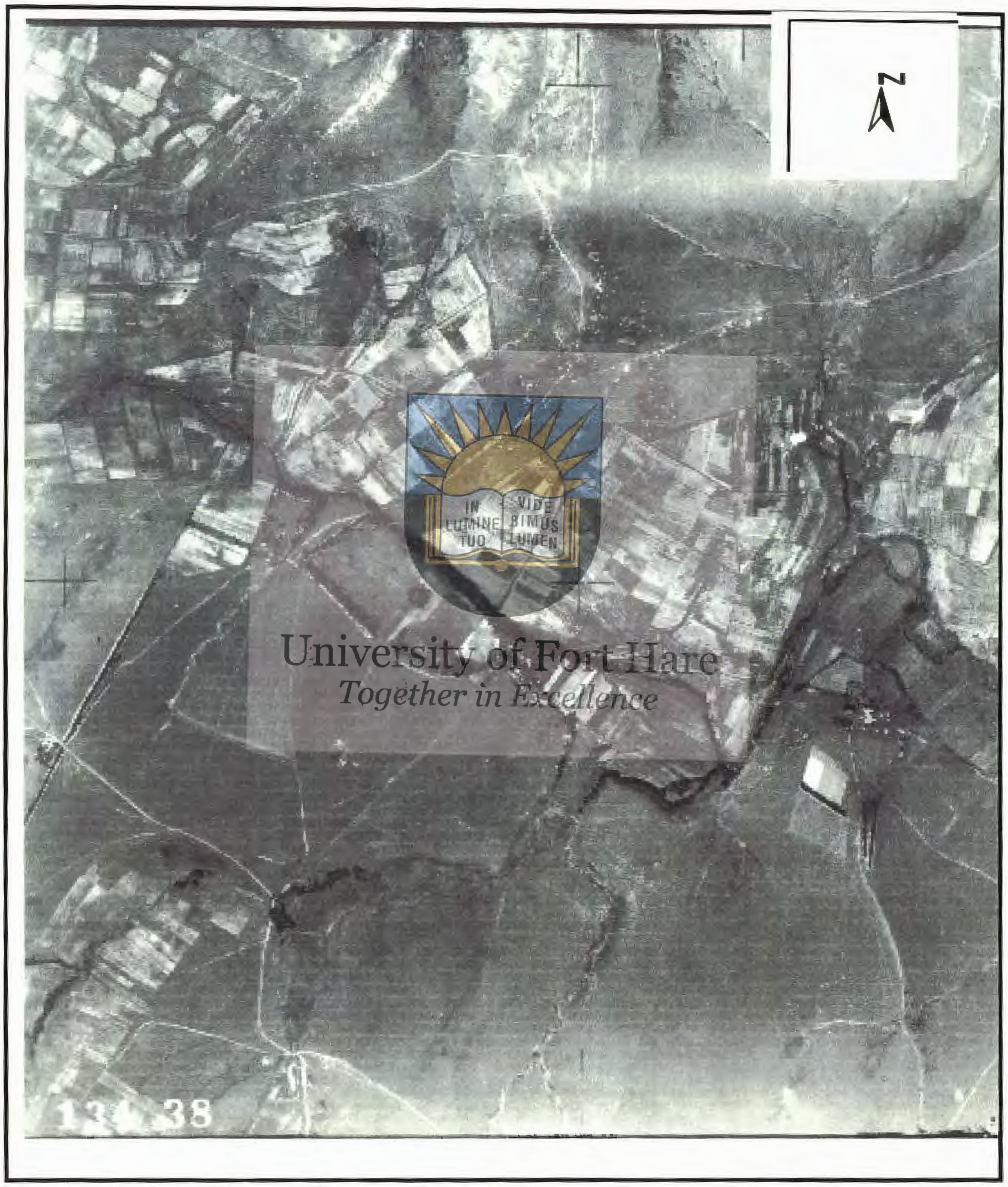


Plate: 5.1: The 1938 Aerial Photograph

2km

Occurrence of Rills and Gullies in 1938

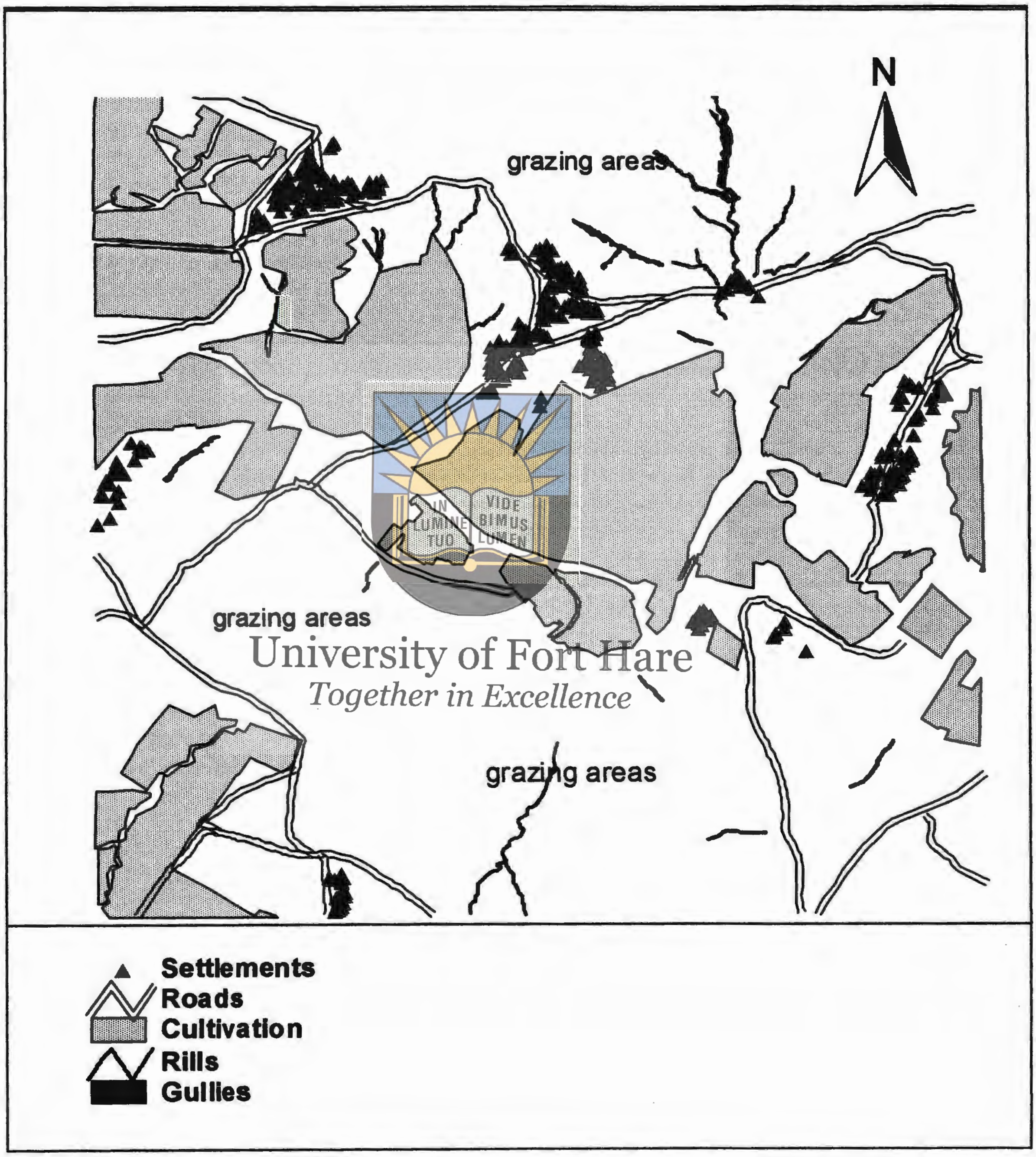


Fig 5.6 Occurrence of rills and gullies in 1938

2km

By 1949 many gullies were already visible on aerial photographs. Gully areas or zones were identified at random to check the rate at which these gullies were extending. The map showing the main gully sites is as shown in Fig 5.7. All the gullies occurring in these main zones were visible as early as 1949, hence the comparison. Some of them had already developed quite significantly to cover areas from about 5000m^2 to 20 000m^2. Gullies changed significantly with time. Gullies digitised within each zone were measured and the areas presented in Table in Table 5.2. Form the 1938 aerial photo (Plate 5.1), gullies were already visible but still very small in size and some covered by vegetation. This study will start to trace the changes in size as from 1949.

Table 5.2: Gully area change over time in the main gully zones

Year	Zone A	Zone B	Zone C	Zone D	Zone E
1949	6034m^2	8651 m^2	18370 m^2	20535 m^2	13642 m^2
1963	8145 m^2	11456 m^2	23743 m^2	25621 m^2	14676 m^2
1985	4925 m^2	-	27038 m^2	29173 m^2	8924 m^2
1996	9663 m^2	17615 m^2	30566 m^2	24904 m^2	22916 m^2
Average Rate of Increase	**77m2/yr**	**190 m2/yr**	**295 m2/yr**	**92 m2/yr**	**197 m2/yr**

A value for Zone B for 1985 was not inserted in the table because the 1985 aerial photo was not very clear to delineate the extents of the gullies with certainty. Analysis of gully change in the different zones is treated on pages 88, 89 and 90.

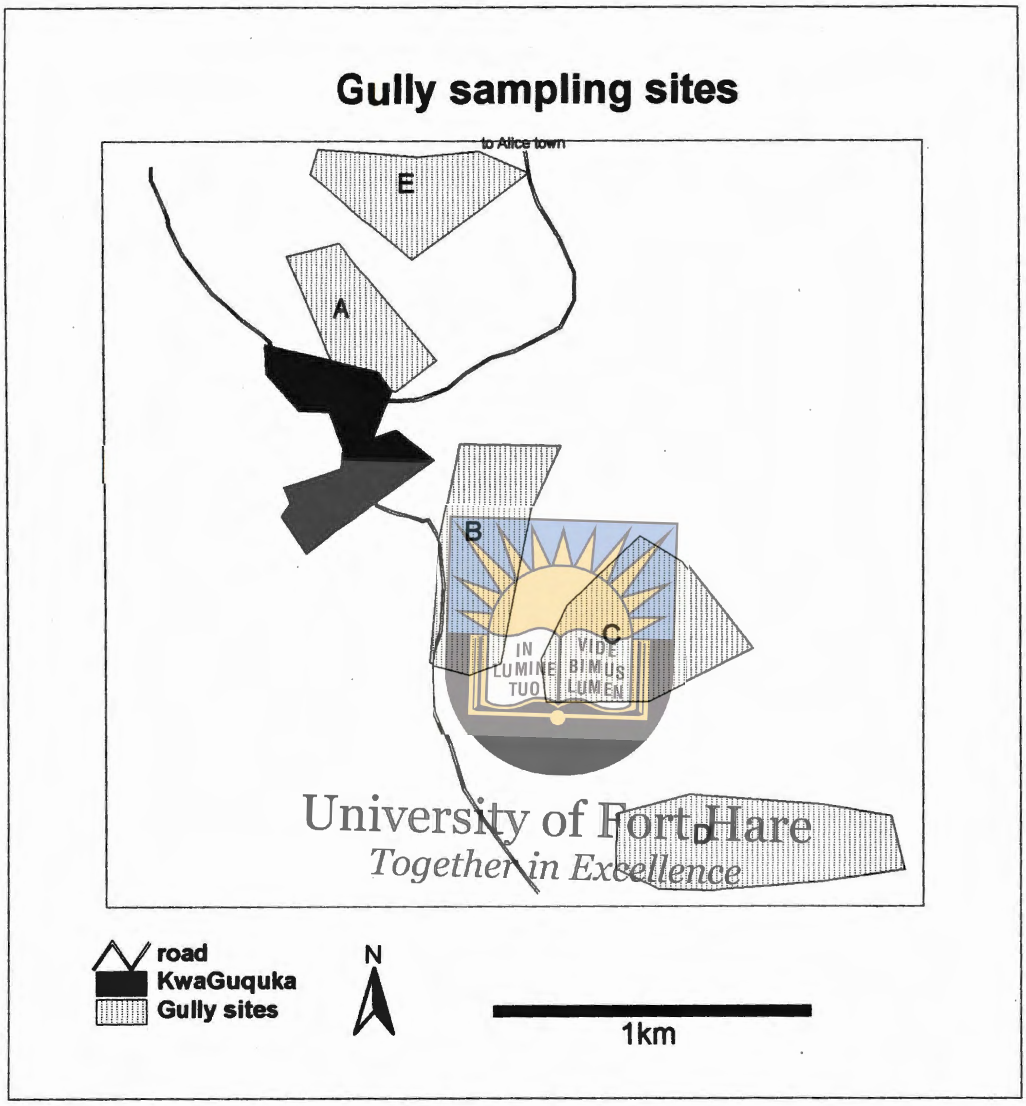


Fig 5.7 Gully sampling sites

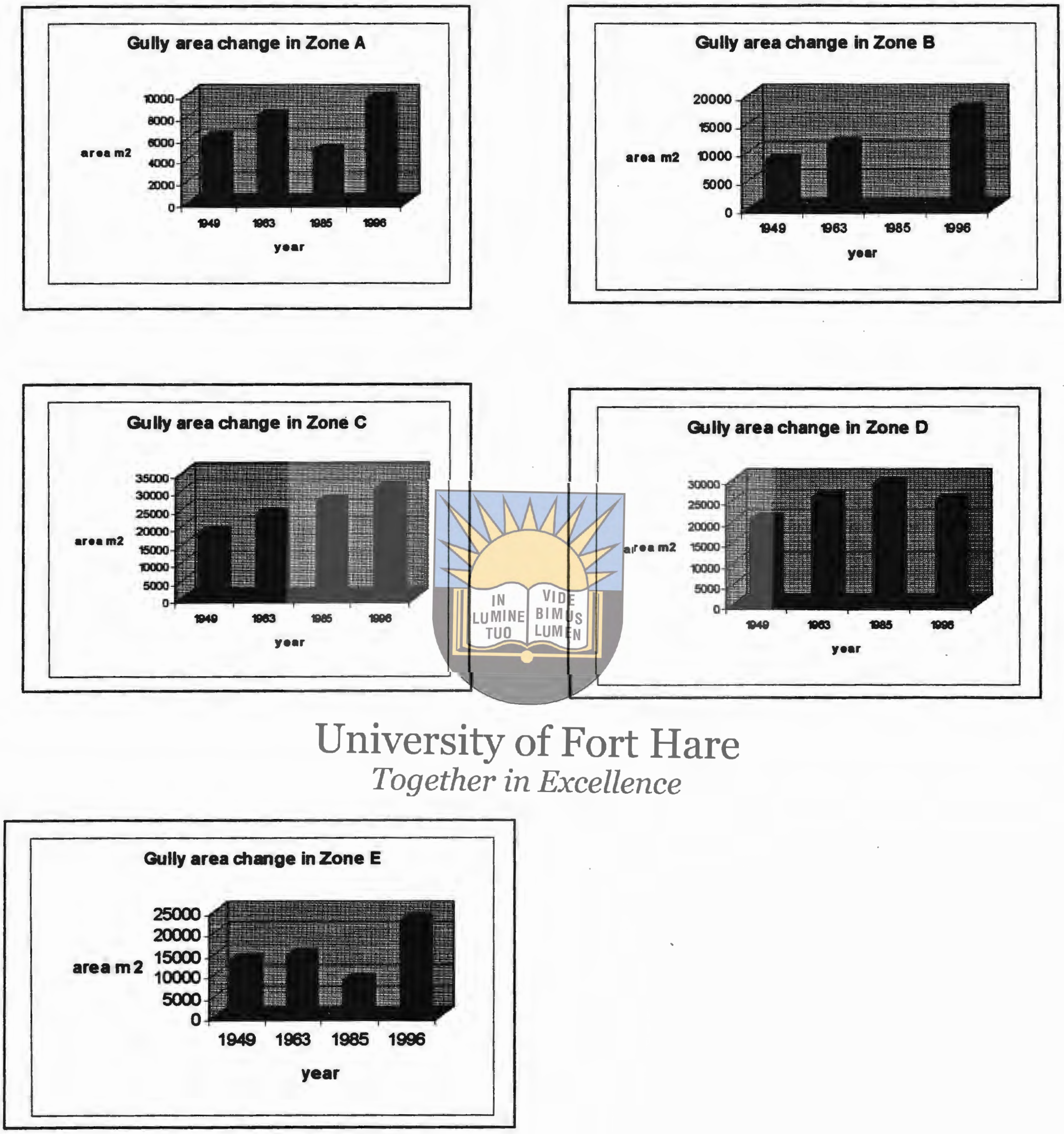


Fig 5.8: Changes in gully size in the different gully zones

Fig 5.8 show changes in area of gullies in Zone A, B, C, D and E. In zone A, gully size increased by over 60% in 47 years. In Zone C a linear relationship between gully development and time exists. Gully area increased by over 66% in this zone with no anomalies. Gully zones B, C and E have relatively higher rates of gully development unlike A and D because of overgrazing in those areas as well as the soil type. The decrease in gullied area in Zone A in 1985 could have been due to self stabilization of the gullies or the poor picture quality for 1985.

Table 5.3 shows the total area that has been degraded, which is about 21.1 ha.

Table 5.3, Areas within 100m buffer for 1996 gullies

Gully zone	Total area (ha)
A	2.0
B	3.8
C	5.2
D	5.2
E	4.9
Total area	21.14

In terms of the width of the gullies, in 1949 in gully zone A, the largest width of the gully was ranging from 28m to 30m. There was very little increase in gully width by 1963 but in 1996, the width exceeded 40 metres.

In gully zone C, which lies at the southern tip of the study area far away from the residential areas, a different scenario occurred. Throughout the whole gully area there was an increase in the gully width. Taking a specific location of the gully, in 1949 the width was about 37m and increased to about 46m in 1963. In 1996, the width had reached 57-58 m. This shows the severity of erosion in this locality. This marked increase in width should be more or less a result of the dispersive nature of soils which promotes lateral development. Grazing and sparse vegetation could have also led to this lateral extension. Slope and drainage factors may not have played an important role as it is a relatively flat area with no rivers flowing through it.

Field visit results

A visit to the study sites was done to [illegible] check the conditions of the gullies. Different size gullies in different stages of development were observed. These were then categorised into the classes as shown in Table 5.4

Table 5.4: Fieldwork gully classification

Category	Description
A	Gullies >25 000m², > 2m depth, still active
A1	Gullies >25 000m², > 2m depth, stabilising (colonised by vegetation)
B	Average size gullies ranging from 10 000m² – 25 000m², mostly active
C	Gullies not in A, A1, B colonised by vegetation and stabilised (not active)

Pictures of categories A1 and C described in Table 5.4 are displayed in Plates 5.2 and 5.4, respectively. Gully depths ranged from 1 to 3 metres. From Plate 5.2, gully depth was about 3 metres. This can be approximated by using the person in the Plate 5.2 as a scale. Assuming a height of between 1 to 1.5 m, the gully depth can be approximated to 3 plus metres. Plate 5.4 shows some of the gullies near to homesteads and the efforts made by the villagers to combat physical land degradation. This was done by throwing old metal car bodies and stones into the gullies.

Plate 5.2 Class A, Gully Zone C (GPS Reading: 32°39' 69" S/26°57 27" E.)

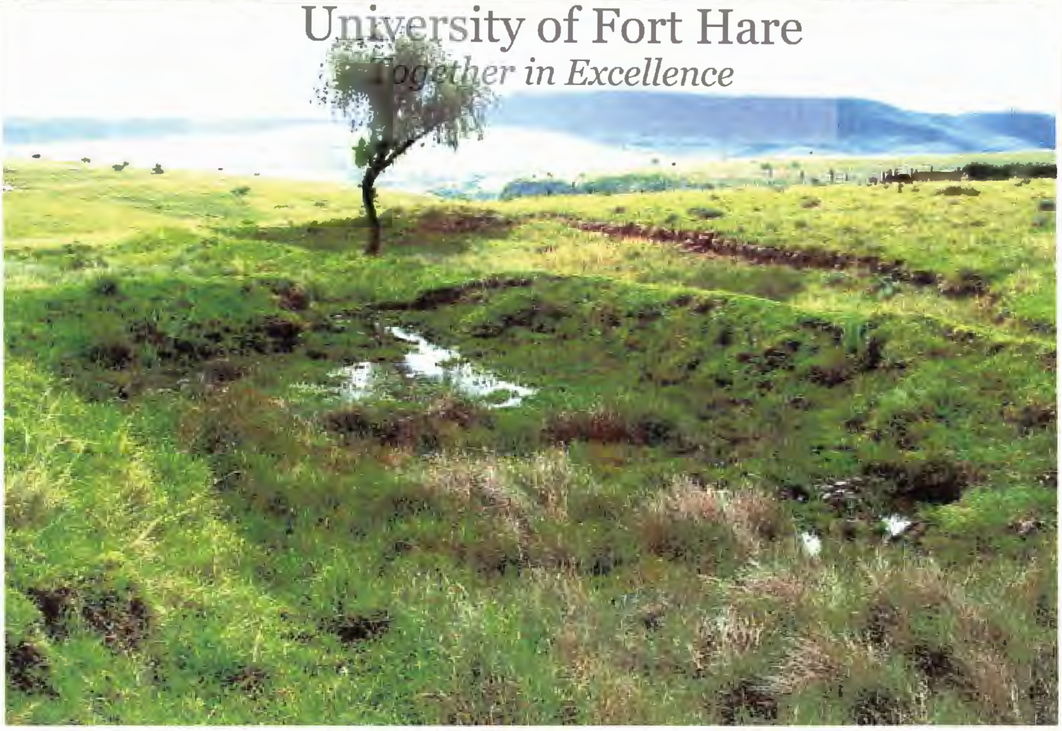


Plate 5.3: Class C Gully (GPS Readings: 32°39′ 56″ S/E26°56′ 82″)

Plate 5.4: Gully in proximity to Guguka homesteads

Table 5.5 Comparison of Predicted model SEP's and Actual/Observed SEP's

Variable	Predicted/Model SEP's	Actual/Observed SEP's	Comment
Slope	Gullies are to form at breaks of slopes (slope class 3)	Most gullies found in slope class 3	Agreement
Soil	Soil types like, Williamson Rietvlei (-), Mispah, Klipfontein, Leeufontein & Mayo develop gullies more than Rietvlei (+) moderately deep & Jozini (+)	Most gullies found in E1 Soil type and few in A2	Agreement
Hydrology	Areas where rivers would develop are also areas of gully initiation	Gullies found within the 200m buffer	Agreement
Land cover	Grazing and arable lands are more likely to have gullies develop than bush and settlement areas	More gullies found in grazing and arable lands	Agreement

Table 5.5 shows total agreement between what the model predicted and what was seen on aerial photographs and the field survey.

(B)Landuse/Landcover trends

Single band image analysis

One of the most important characteristics of an image band is the spatial pattern and distribution of brightness levels which indicates vegetation distribution in the image.

Figure 5.9 shows Landsat TM band 1 for the three images that were used in the study. In the three images all the dark parts of the images are the vegetated areas. Vegetated areas appear dark in TM bands 1, 2 and 3. The areas which are lighter are the sparsely vegetated or bare ground areas. The escarpment and above are well vegetated (pine plantations and indigenous forests) in the three images but with slight changes as can be seen in figure 5.9. In 1995 the escarpment was well vegetated but in 2000 there was some clearing to the east. There is not much difference between the 2000 image and the 2002 image.

The sparsely vegetated areas are clearly visible in all the images but in the 2002 image there are other whiter tones (almost white) that reveal themselves as small spots in the image. These show the degraded areas especially areas where grass has been totally removed. These spots are therefore the gullied areas of the catchment.

Figure 5.10 which shows band 3 of the three images exhibits more contrast than band 1 as can be seen by the sharp black and white contrasts. This is because of the reduced effect of atmospheric attenuation in this band. Comparing the 2002 and 2000 images in Figure 5.10, it can be seen that there is an increase in the areas with the lighter tones especially to the south of the image. This is an indication of the increase in the land degradation in the area. This can be explained by overgrazing in the area due to the closure of the top of the escarpment as a grazing area.

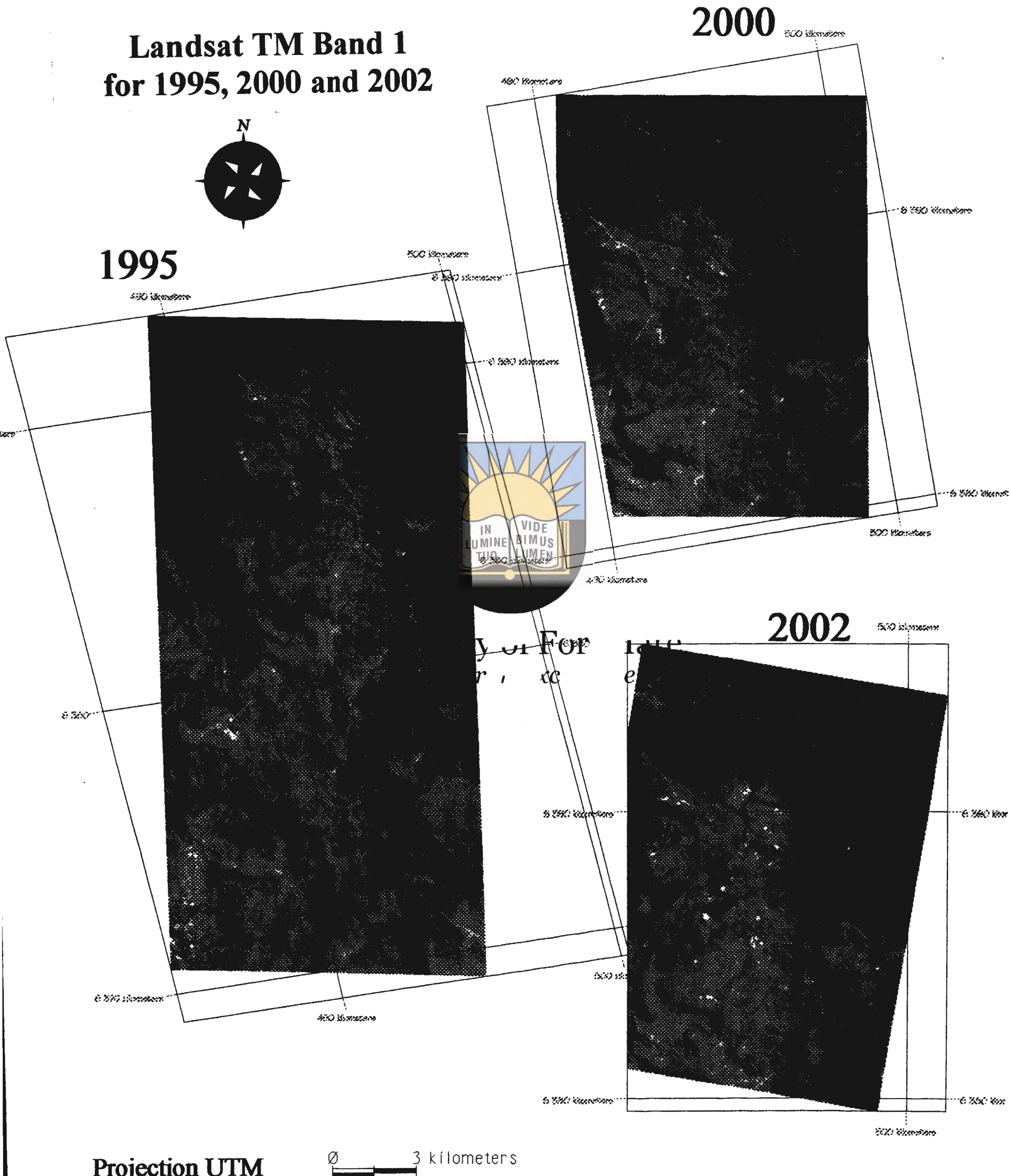


Fig 5.9 Band 1 images

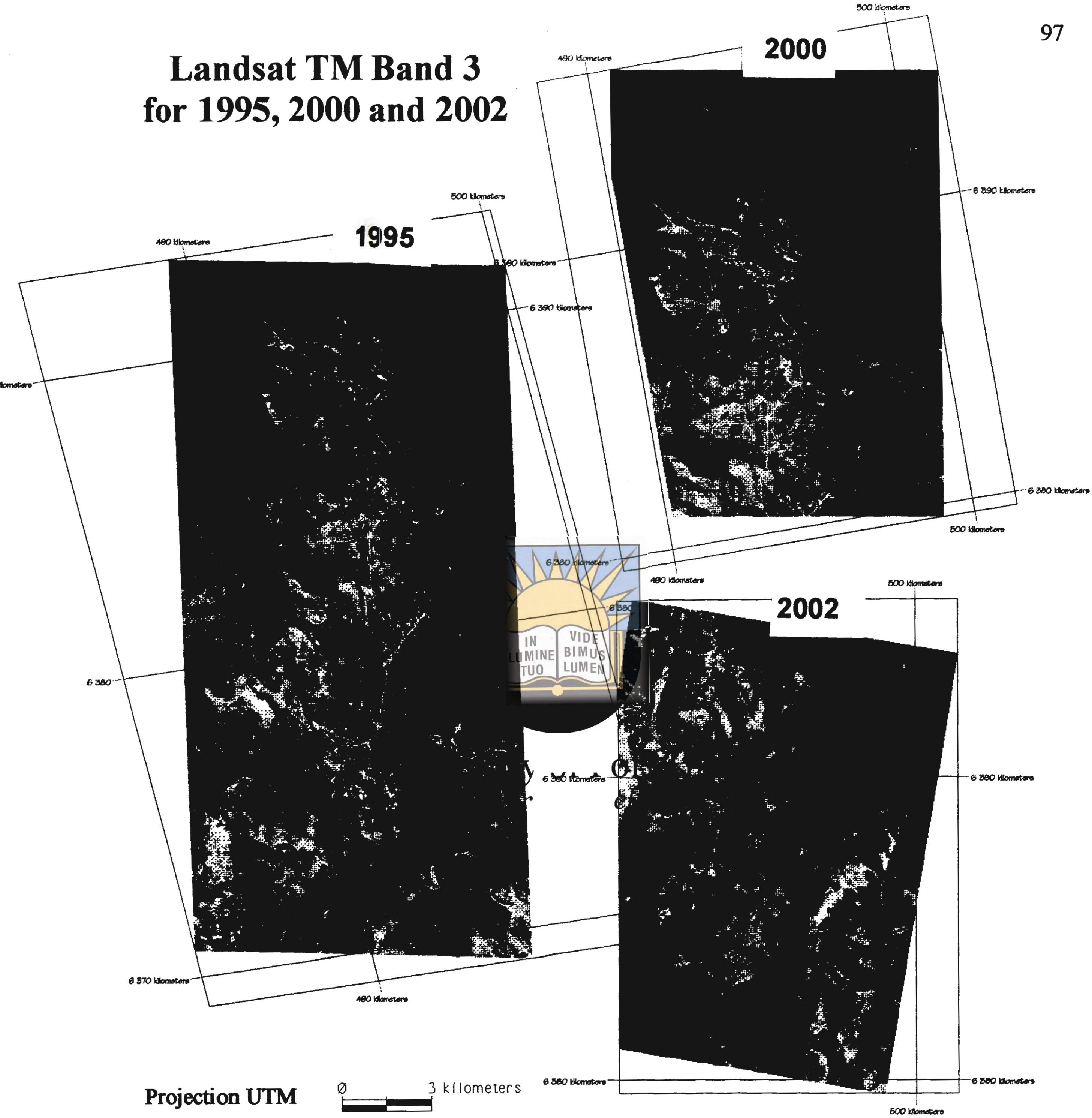


Fig 5.10 Band 3 images

True colour and false colour composites

Band 321 combination which simulates true colour images of the area was displayed to view in general areas with or without vegetation regardless of the condition of the vegetation. Areas with vegetation were green in colour, bare ground shades of grey and brown and the areas covered with water in blue. Above the escarpment where there are pine plantations, the green colour was dominant. Below it, shades of grey and brown were seen showing the bare ground and the soils. Composite images of bands 432 which simulate infrared photos were displayed and were capable of differentiating areas of very active and healthy vegetation which appeared in bright red/pink colours which again coincided with the upper part of the escarpment. The true and false colour composites layouts for the year 1995 a[illegible] in the Appendices.

NDVI Images

The NDVI images for the years 1995 and 2000 as displayed in Fig 5.11 have vegetated areas shown as bright white while the non-vegetated areas (buildings, clearings and river) are generally dark. The 1995 image exhibits more of the white areas which gives the impression that there must have been a decrease in the amount of vegetation during this time period. This can also be attributed to tree felling in the area, especially exotic trees.

NDVI IMAGES

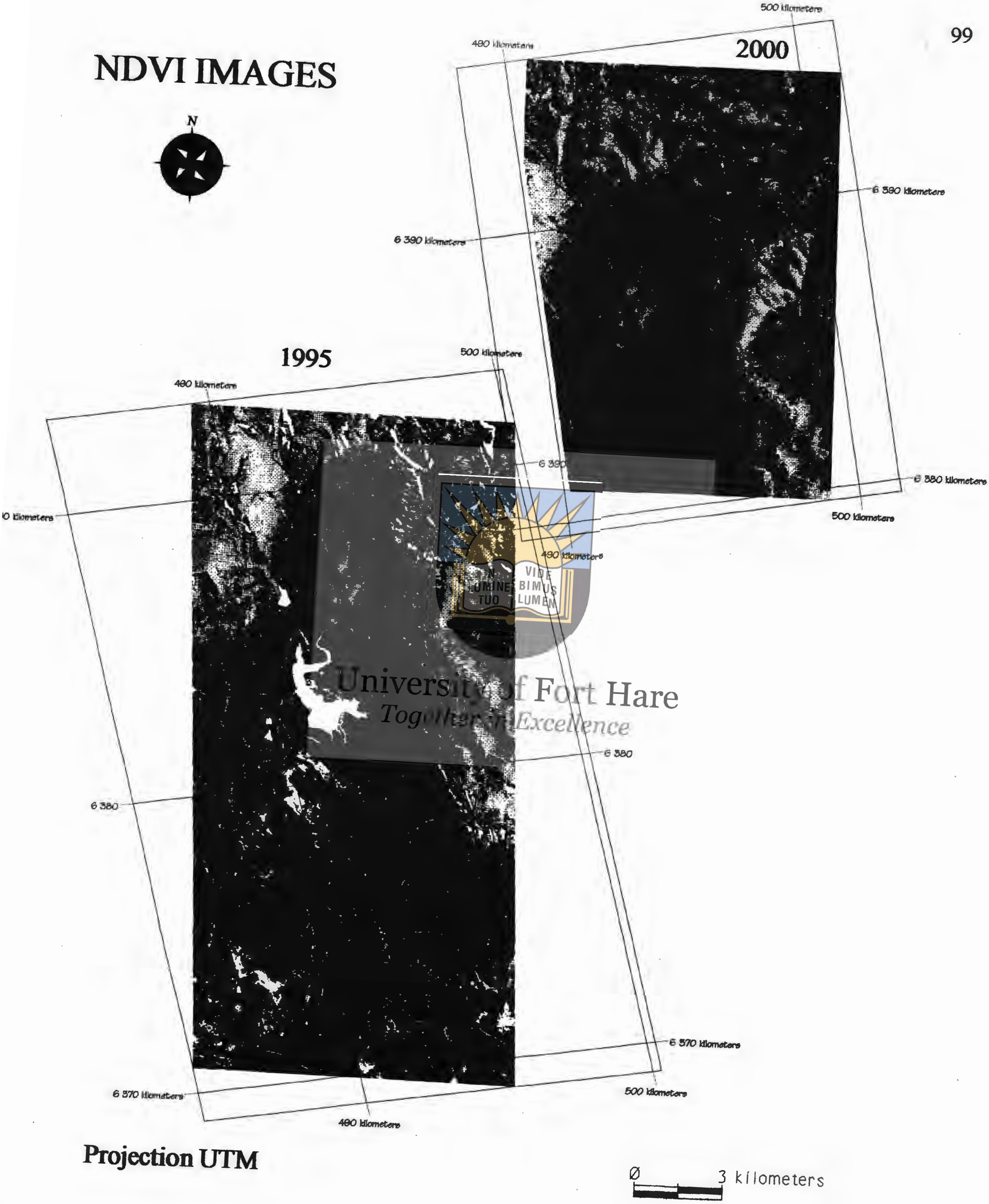


Fig 5.11 NDVI images

NIR/NDVI/GREEN Image

From the computed NIR/NDVI/GREEN images, three main types of vegetation were discriminated in this false colour composite image. The main reason for computing this image was to determine general classes that can be obtained based on vegetation density, areas with vegetation canopies and those with sparse vegetation. The 2000 (Fig 5.12) image was used to illustrate this effect. From the figure, the green areas consist of dense trees with closed canopies. This area on the map coincides with the pine plantation, wattle trees and the few remaining indigenous forests. The bright yellow colour found scattered all over the image are covered with shrubs, grass and trees which are less dense. These areas are mainly indigenous bushes and trees. The dark blue/purple/magenta colours which cover the larger part of the image are areas with very little or no vegetation which form part of the grazing areas and settlements. A visual comparison of the NIR/NDVI/GREEN images for the different years showed that the blue/purple/magenta colours have become more pronounced which supports the occurrence of land degradation.

NIR / NDVI /GREEN = (RGB) IMAGE (2000)

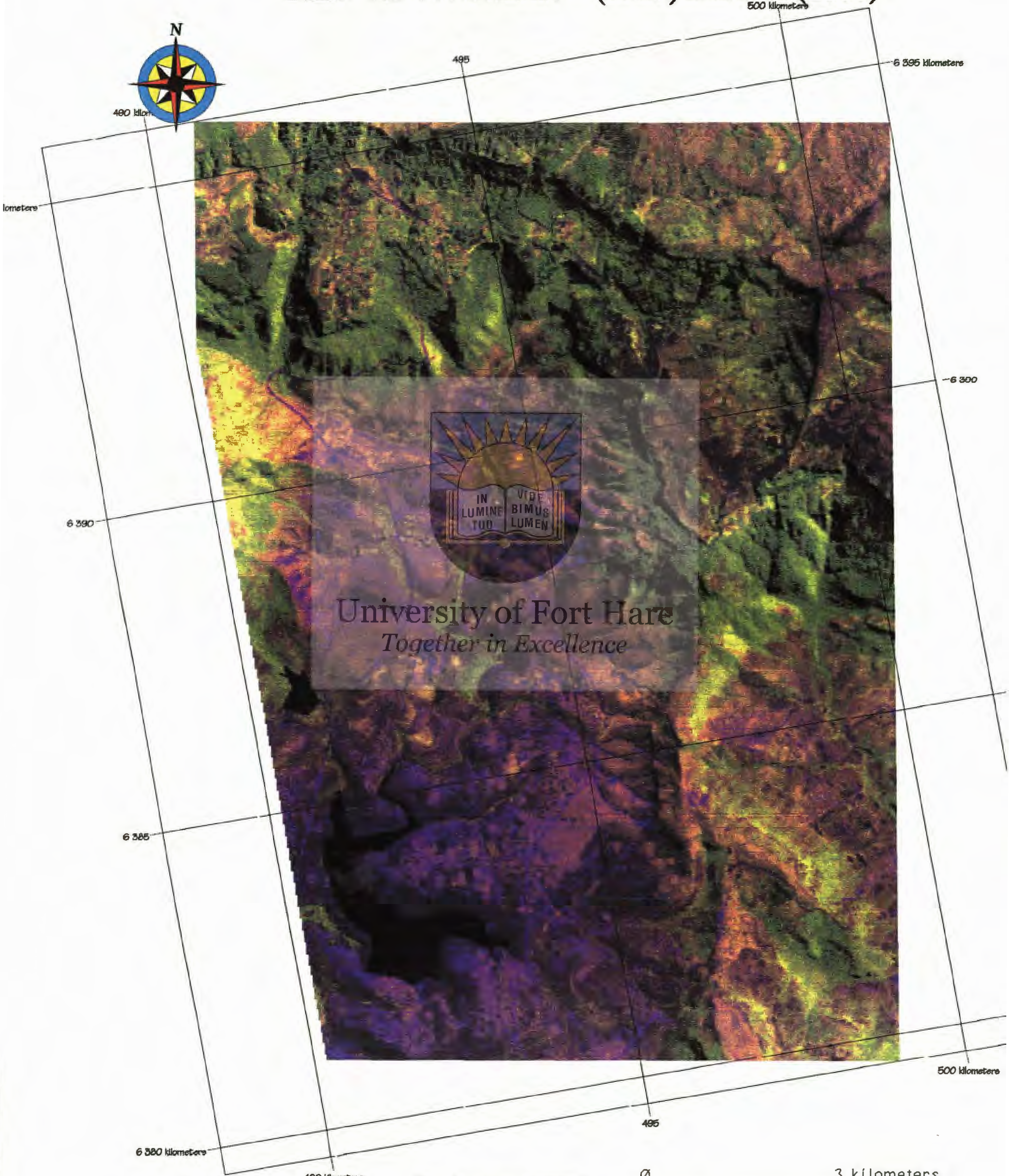


Fig 5.12 NIR/NDVI/GREEN Image

Land cover classes from unsupervised classification

The general distribution of the different classes of land cover computed by unsupervised classification was found be similar, but increases in areas covered by certain land cover classes were observed. Figure 5.13 shows the different land cover classes that were obtained for the three years.

The red/brown colouring on the image which represents bare ground was not that extensive in 1995 compared to 2000 and covers quite a huge area in 2002. This illustrates the continuous degradation of vegetation which can be attributed to overgrazing and the lack of care of the land a result of reduced cultivation.

The dark blue/purple colour on the images shows the forested areas. There is a slight increase in forest density from 1995 to 2000 and a slight decrease in 2002. This can be explained again by felling of the exotic pine and wattle trees which took place around 2000 to 2003. For the 2000 and 2002 images the purplish colours indicate areas with high reflectance like water and roofs. These are buildings and water surfaces.

For the purpose of this study, 5 classes were enough for the required analysis, but if more classes were to be computed then it would have been possible to distinguish the settlements from the water surfaces. The 1995 image shows the water surfaces as white areas.

The light blue areas on the image show areas that are covered in sparse shrubs. Figure 5.13 shows how the different classes of land cover and how these land cover classes have changed spatially over time.

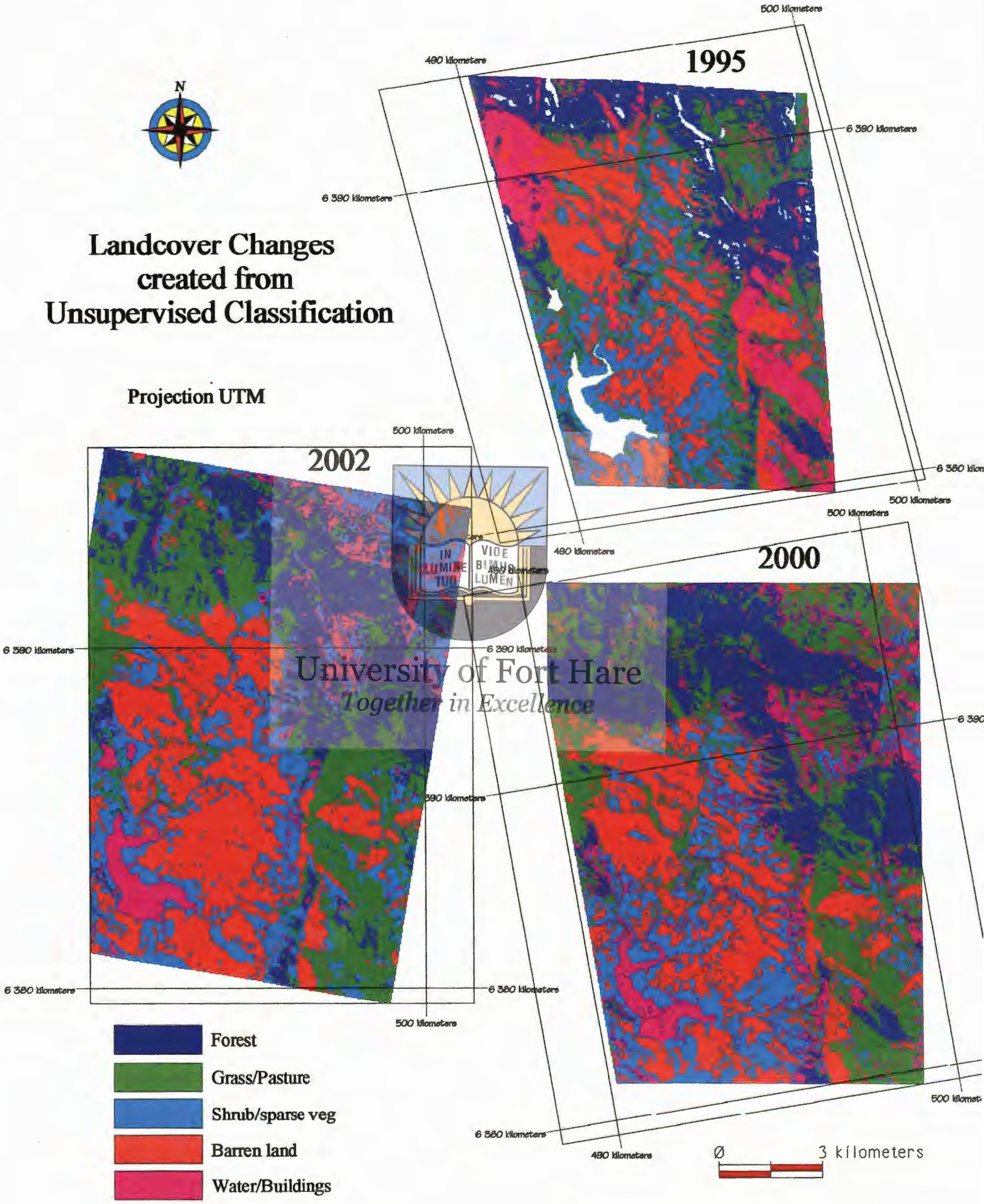


Fig 5.13 Land cover classes

(C) Questionnaire survey

A total of 38 respondents/households were interviewed and their age groups are as illustrated in the Table 5.5 below.

Table 5.6: Age distribution of respondents

Age	No	%
21-35	4	10
36-50	5	13
51-70	17	45
> 70	12	32
Total	38	100

From Table 5.6, it can be seen that the greater percentage of the people interviewed were elderly who could have seen the temporal changes in the study area.

Table 5.7 Residential location of respondents

Location	Option	No	%
Guquka	1	15	40
Sompondo	2 & 3	17	45
Magxagxeni and others	4	6	15

Eighty five percent of the respondents were from Guquka and Sompondo, which are the two main settlements, and the remaining 15% respondents were either visitors from the nearby Hogsback village where they work or the other smaller settlement called Magxagxeni, which is located just below the Auckland Nature Reserve.

It was noted that there was no significant movement of the population from one village to another as the responses for previous and current location questions were the same in most cases. Almost 79% of the sample had not moved during the previous ten years while the remainder cited marriage, landownership and family reunion as reasons for their relocation amongst others. Land use activities in all the locations were generally the same with home gardens being very common to all the villages followed by cultivation and grazing. People in all the locations failed to use the land. Several reasons were cited for failure to use the land. Seventy one percent of the sample failed to use land, the major reason having been the lack of financial resources. For the two main villages, Sompondo had more failures than Guquka (Fig 5.14). This difference in the two locations was tested statistically to see if location was related to failure. If so this would support the notion, that one village had a different set of circumstances, which would imply that all responses given are subject to the effects of location.

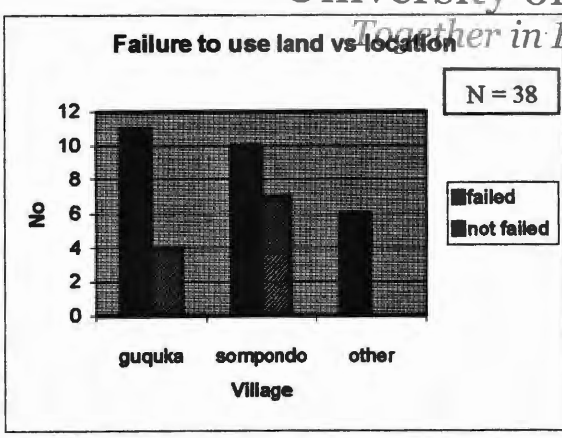


Fig 5.14 Location vs. failure to use the land

The Chi Square Test was done to test whether failure to use land differed by location. The null hypothesis to be tested was that failure to use land was independent of location. Location was used as the independent variable while failure to use land was used as the dependent variable. The expected frequencies **(E)** were calculated using the formula,

E = (column Marginal)(row marginal)/N

where **N** is the total number of cases in the sample.

To test the null hypothesis the Chi Square formula as shown below was computed.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

O = the frequencies observed

E = the frequencies expected

∑ = the 'sum of'

In this analysis, there was only one degree of freedom and the significance level was tested at 5%. The value $\mathbf{X^2}$ obtained was 0.743, which is less than the value 3.84. This implies that if $\mathbf{X^2}$ is less than 3.84 then we cannot reject the null hypothesis, which means that failure to use land is statistically independent of location.

The interviewed people acknowledged a change in the land use over the past decades. They think that productivity was better before 1994. There is a consensus on the occurrence of land degradation and most thought that the rate of degradation had accelerated in the past two decades. Although there was this consensus on the occurrence of degradation, it was not commonly identified as a problem. Fig 5.15 shows that about 10% of the population either did not know or disagreed with the statement that land degradation was a serious problem in the area. These responses were shared equally by the age groups. Those involved in cultivation at the time of interviewing constituted about 24% of the total population and almost all of these cited degradation as having affected them very seriously. About 50% of those not involved in cultivation also cited degradation as a serious environmental problem.

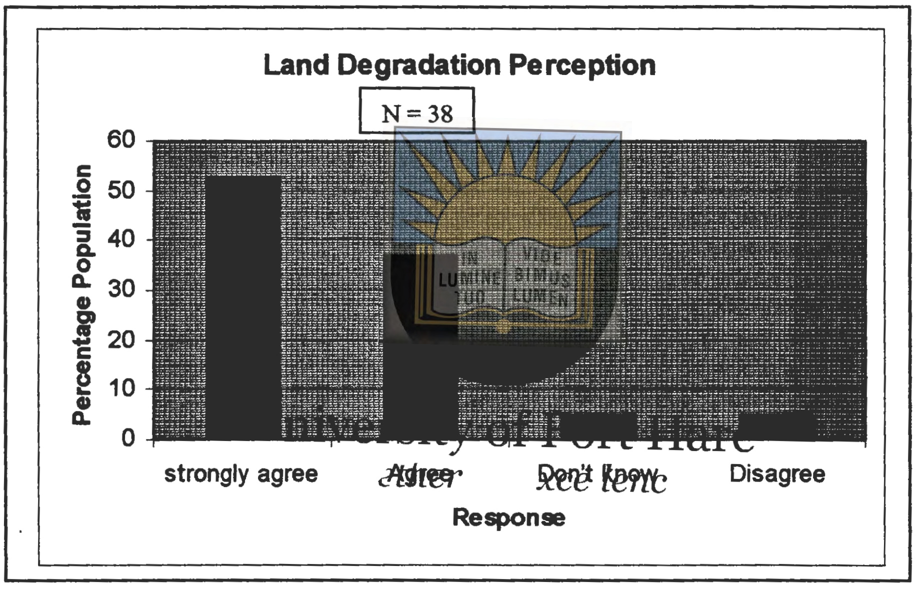


Fig 5.15: Perceptions on land degradation

About 10% of the respondents also said land degradation had not at all affected or not seriously affected their way of life. Most of the respondents were undecided when they were asked whether land use change could have had an influence on the occurrence of land degradation. Upon further questioning the views changed slightly. This was especially noticed when respondents were asked specifically about the activities on the escarpment before the establishment of the pine plantation. Most said it was used for livestock grazing. The introduction of the pines in the late 1960's to early

1970's implied that the land that was then being used for cultivation would now also be used for grazing, creating pressure on the land. This led to a reduction in cultivation activities. The land was then left unattended and livestock could graze freely in the cultivatied areas. This then saw the onset of land degradation in the area. Less than 5% of the respondents cited a reduction in the amount of water from the two waterfalls on the escarpment. The next section relates knowledge of the communities to changes that took place in planning systems, which could have affected the way in which they used land as a resource. Such changes were precipitated by the introduction of Betterment Planning and the Homeland System.

Knowledge about the Betterment Planning scheme

More than 70% of the people interviewed showed knowledge of the Betterment Planning and the Homeland Systems. However, they said that this did not affect them at all though there are people who came and surveyed the land and gave them specific areas to do their cultivation. They were however not moved from their residential areas as happened in other areas. The changes in the layout of land use parcels and settlement dynamics as a result of betterment introduction can be illustrated. Cultivated land parcels digitised for 1949 and 1985 showed differences in their layout (Fig 5.16). The 1949 pattern (unshaded) was rather random while the 1985 (shaded) layout was better organised and had shrinked leaving once utilised land parcels fallow. This can be used to explain the decline in cultivation activities which took place and land parcel organisation could have been the introduction of the Betterment Planning which was not directly or officially introduced in these communities. During the same time there was also an increase in settlements and the road network around the settlements in Guquka (Fig 5.17). See Appendices for a map of settlement area change to explain how settlement changed.

Changes in the organisation of land use parcels

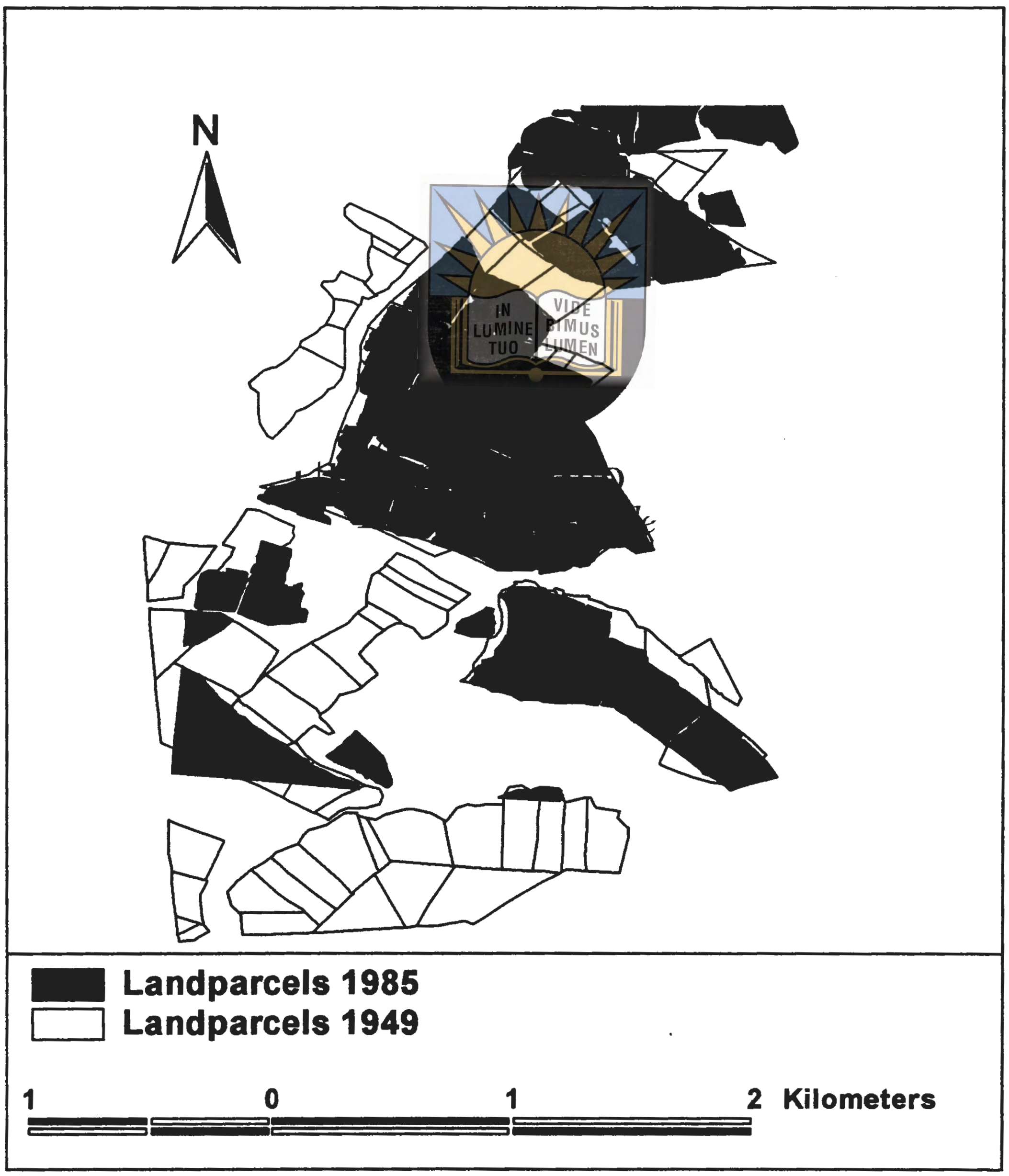


Fig. 5.16: Changes in the organisation of land use parcels

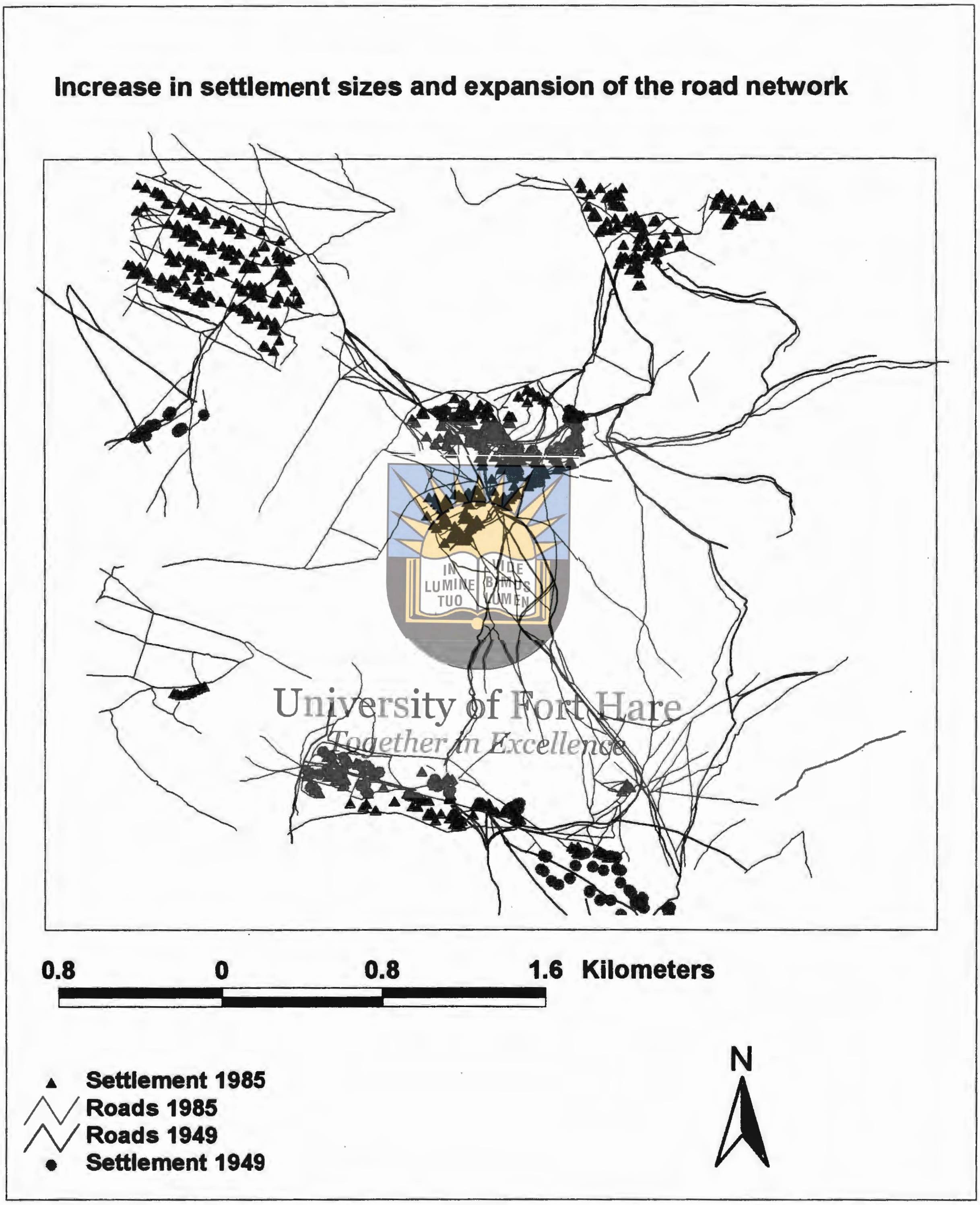


Fig 5.17 Increase in settlement sizes and expansion of the road network

Land degradation a problem or not?

The only problem the respondents saw resulting from land degradation was its destructive effect on the road linking their homesteads and the nearby taxi rank. They now have to walk longer distances to get to the taxi rank.

There was variability in responses on the date of onset of land degradation. Respondents said that land degradation was there a long time ago because gullies were present from way back. Up to 60% thought that degradation started in the past 20 years, which coincides with the time when land-based use activities started to dwindle. Three main reasons cited for the occurrence of degradation were heavy rains, steep slopes and the stoppage of land use activities especially cultivation. Lack of cultivation reduces infiltration into the soil and leaves the land unattended to promoting erosion and subsequent degradation. In general, climate, people and land use activities are seen to be at the centre of the reasons of degradation.

There are theories pertaining to the role of people in the occurrence of land degradation that will be discussed here. The first one being that the number of people living in a given area and dependent on its land resources is likely to affect the intensity of resource use and may be positively correlated to unsustainable and degrading cultivation or extractive practices (Hoffman *et al.,* 1999). The movement of more people into these communities, which has been explained earlier can support this theory. The other theory attributes land degradation to ignorance and improper practice by land users, which can partly be used to explain the occurrence of degradation in the Upper Tyume.

The common reason cited for the development of gullies was ascribed to the heavy rains and the steep slopes. The respondents explained that the heavy rains lead to the flow of water from the mountains leading to the occurrence of both rill and gully erosion. But the other main factor that the people also mentioned was the stoppage of cultivation. Nobody was and is taking care of the land. Respondents were asked if they ever intended to use the land, but they noted that there was very little reward in use of the land. They insisted that they wanted profit-making projects to be introduced that involved the use of the land. The need for projects was sound but the respondents were asked who was going to work in the projects since they had earlier on mentioned the lack of the younger generation. The lack of cultivation was also induced by the introduction of pensions by the government for the aged. The communities are now waiting for these pensions for their livelihoods. There is no need for land use activities because the money from the government is at the moment enough for basic foodstuffs and other household expenditures. In one homestead, there is a possibility of two people receiving these pensions thus making the household financially stable.

When the villagers saw that land degradation was occurring they reacted in the following ways as shown in the pie chart in Fig 5.18.

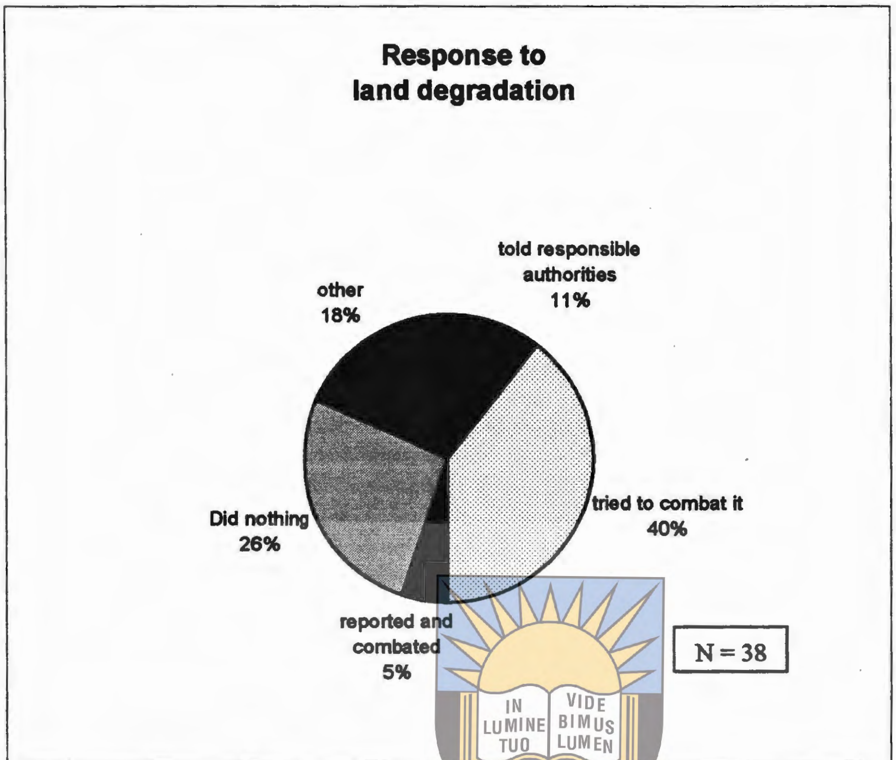


Fig 5.18 Community response to land degradation

These responses are discussed in the next section.

Priorities for the use of the land

From the interviews carried out, it was observed that peoples' desire to practise grazing and land cultivation land use practices had fallen. There was an especially low desire from most of the respondents to own land for farming purposes. Cultivation was opted for only if there was going to be aid in ploughing the fields by the use of tractors. There was however, a strong voice for the need to plough especially from the elderly, as they believe cultivation has always been their way of life. These people insisted that they would want to continue with cultivation and blamed the youngsters for being lazy and refusing to work in the fields. The majority of the respondents were in favour of homegardens. Cabbages, potatoes, carrots were the priority vegetables for home gardening. The main reason for home gardening was to get food from the gardens. They would then sell the surplus to other villagers or even sell the produce to the nearby town of Alice. Homegardens were also described as more manageable than the arable lands used for cultivation.

Focus group discussion

Several focus group discussions took place a route traversing the study area focussed group discussions. As mentioned earlier discussions were conducted at locations in areas of interest with regards to land degradation and land use change.

The first point where a focus group discussion took place was on top of the escarpment lying above Sompondo one of the villages in the study area. This is the area now covered in pine. The GPS reading of this point was S 32 37.452 E 26 57 985 at an elevation of 1186m.

The land use activities prior to the pine plantations were cited as mainly grazing. The area was covered mainly by grasslands without many trees. Respondents noted that (while on the spot) the area was not forested but only the area on the steep slopes was covered in thick indigenous forests which is still evident to date. Wood from the forests was used for the construction of houses but the area was also used for grazing. The respondents confirmed that there was no forest destruction and that the grasslands were burnt by fires at a particular time during the year to regenerate the grazing. This also resulted in the regeneration of berry bushes, which provided the locals with cash which they would go and sell these to the whites in the Hogsback area.

The grazing camps were used by all the communities in the area but especially with those in Magxagxeni, Sompondo and Guquka. The cattle would move up to the grazing areas with or without the guidance of small boys. They would stay up there for about a month and would only move down if they were needed for ploughing. In some instances, small huts were built up on the escarpment where some people would stay to protect the animals especially from thieves. Even until today some people still take their cattle up the escarpment although the numbers are small. The decline in the numbers of cattle was attributed to the introduction of the pine trees above the escarpment. The respondents said that the pines were planted around the 1970s and this shifted the grazing pastures to other areas but this resulted in the stealing of cattle in the new grazing areas. The villagers say the introduction of the pines was a disadvantage as this reduced grazing areas. To date the area is no longer used by the communities mainly because there are no more good pastures. Further north of the escarpment a dam was constructed for fire fighting and control. This dam has resulted in the reduction of water flow to downstream users.

The second focus group discussion was located at the base of escarpment where the arable fields are located. At the occasion it was said that cultivation had gone on for a long time in this area. The main crops that were cultivated were maize, sorghum and wheat. Each person was allocated a plot of land in the arable fields and these were demarcated by the use of four stones. Gullies were already present in these areas but they were not as pronounced as they are to date. These arable fields were also used as grazing fields after harvesting. The respondents said that cultivation was at its peak around the 1960s and then it started to dwindle. By about 1994, very few people were involved in cultivation. The respondents involved in the focussed group discussion had last planted more than five years ago on the day the interviews were conducted. When asked why the lack of interest in cultivation, the reasons cited included ill-health and the exodus of the able bodied to town. The most striking reasons cited were the lack of draught power as the livestock herd had dwindled. The other main reason was the introduction of pensions by the government. This led to reluctance as people knew that they would receive something at the end of the month. They confessed the negative impact of this on the youngsters who after dropping out of school would relax in the knowledge that the elderly would support them. This lack of land cultivation also led to the increase in degradation as no one was looking after the land in preparation for the next growing season. The villagers pointed out that if there could be agricultural projects in the area this would see the use of the arable lands again. The villagers could point out on the maps the routes that were used by livestock up the escarpment.

Erosion rates and main events

The erosion trend in the Tyume was a result of the interplay of geomorphologic and human factors. This section seeks to understand the relationship between erosion rates and the events (especially the establishment of pine trees and betterment planning) that occurred through time.

The introduction of pine trees was a major change in the land use. This change saw the closure of former grasslands for grazing purposes. Communities opted for another grazing area which was met with increased stock theft as this was a distance from their homesteads. This was also coupled with the fact that they were used to just drive the livestock up the escarpment for the days or weeks to later collect them. This led to the use of arable lands and cultivation areas to be used for grazing as well. This brought to bear increased pressure on the land which could have accelerated the erosion process. After cropping, the land would then be used for grazing until the next planting season. The reduction in the amount of water flowing down from the catchment because of uptake by pine trees led to the collapse of small home based agricultural activities which meant the land was left without being taken care of.

Another event is the Betterment Planning which led to the movement of people into homelands creating space for more white commercial farmers. Land management was crippled as the communities now had to travel very long distances to their fields. Simple erosion management practices like contour ploughing and gully filling collapsed leading, to an increase in erosion rates.

CHAPTER 6 (Discussion)

Discussion

The approach to this study which involved modelling, analysis of time series aerial photos and satellite images together with the administration of questionnaires gave an understanding of the land use, social and environmental processes and their effects on Upper Tyume Catchment. Understanding how these processes occur and interpretation of images taken in the catchment should be done with the consideration of the people in the catchment, how they contribute to those processes and the impact of those processes to their livelihoods. Many research projects often do not consider the scientific and social aspects of a problem together. The significance of understanding the relationship between erosion, land cover and community interaction can not be ignored. Human activities and land cover changes have always contributed to changes in geomorphologic and hydrologic processes.

It has been shown in this study that areas with sparse denuded vegetation as seen from satellite images coincide with high erosion risk areas as modelled. Areas that were modelled as high risk have been continuously degrading over time. This has been confirmed by the very high rate of increase of gully sizes in selected areas of the study area. However, this degradation is not perceived by all as a serious environmental problem. It is thus important to understand the needs of the communities and relate these to the geomorphologic processes that occur in their area to understand how they interact and how these interactions can be improved.

It is also important to understand how human attitudes and degradation processes can be brought to harmony. This study has investigated a number of issues and established important facts about the Upper Tyume catchment that may have a bearing on what could be happening in other catchments in general.

Literature review of research on erosion show that rates of soil erosion are based on sediment accumulations measured in reservoirs and on sediments carried to the ocean by streams. Sediments deposited elsewhere enroute to reservoirs are usually not taken into consideration. Sediment yield rates are therefore decidedly lower than actual soil erosion rates (Marsh and Grossa, Jr, 2002). This implies that sediment yield rates actually underestimate erosion rates occurring in catchments. In fact, only 10–30% of soil eroded in most watersheds is actually delivered to streams for export to reservoirs or oceans (Marsh and Grossa, Jr, 2002). The remaining 70-90% gets left in catchments en-route to the oceans. The average rates of increase of gullies in the zones of the Upper Tyume calculated erosion rates range from about 75 to almost 300m^2 per year. These volumes are far too large to be accounted for only by sediment accumulations in reservoirs. Gully extensions by retreat have been seen to eat away productive land in other areas studied. Casasnovas (2003) discovered that a total of 76,5 hectares were affected by gully retreat in the period of 1957 to 1993 in the Penedes region of North Eastern Spain.

Hoffman *et al.,* (1999) discusses two theories on the role of people in the occurrence of land degradation that should be considered here. The first one being that the number of people living in a given area and dependent on its land resources is likely to affect the intensity of resource use and may be positively correlated to unsustainable and degrading cultivation or extractive practices. The second attributes land degradation to ignorance and improper land use practices by land users. The latter theory seems to support the situation in the Upper Tyume catchment which has a relatively low population density. Migrant labour has contributed to the low density.

Land use is the most direct human contribution to land degradation. In communal areas, the status of livelihoods and land policy for most of this century has meant that field crop cultivation, livestock raising and collection of fossil fuel and other plant material have all been contributing to land degradation (Hoffman *et al.,* 1999).

Morgan (1979) in Whitlow (1984) also cited land use changes, mainly through modification of plant cover and soil properties, which in turn change the hydrological responses of catchments. Whitlow (1994) in the Muzvezve catchment of Zimbabwe saw the problems of increased grazing pressure on dambos compounded by the practices of communal herding as being the major causes of the development of gullies. Rossouw (1997) also saw the vegetation pattern of the northern slopes of "Table Mountains" in Cape Town (South Africa) displaying an initial high level of fragmentation due to historical landscape management and policies by local and provincial authorities. Just like the case of Upper Tyume, "Table Mountains" had a history of forestry and alien plant invasion which has led to changes in hydrological responses. Land use change, soil types and grazing pressure are some of the causes of increased land degradation as seen in this study.

Grazing is rarely controlled or monitored in most rural areas and the upper Tyume is no exception. The condition of grazing as a resource for Guquka is poor. Its actual stocking rate is far higher than the recommended stocking rate of 6ha/large animal unit (AU) (ARDRI Newsletter, 1996). Based on a grazing area of approximately 400ha, the recommended number of stock is 65ha/AU. In 1996 Guquka had approximately 30 livestock owners and about 230 cattle (230 AU), 400 sheep (65 AU) and 120 goats (20 AU). Based on the assumed grazing area of 400ha, rangeland at Guquka is 4,9 times overstocked compared to commercial recommendations (ARDRI Newsletter, 1996).

Land cover change analysis using remote sensing data also aids in explaining and monitoring degradation. Maps showing areas of different land cover classes together with the conditions of vegetation over time help to project the conditions of the environment into the future. Stockholm (1995) also classified the Polish

Krutynia and Jorka watersheds using Landsat TM multispectral data in a similar project of land cover analysis.

The trend of land degradation

The ICM approach to land degradation changes over time has shown that the Upper Tyume Catchment of the Eastern Cape Province is in a severe state of land degradation. Degradation has been evident from aerial photography from as far back as 1938. Since then, degradation has been worsening. This is the result of an interplay of a number of factors, which include slope, soils and land use changes. Other factors include loss of vegetation through overgrazing and cutting down of trees for firewood.

The Upper Tyume has experienced the occurrence of land degradation in the form of gully development in the past decades (Mupakati, 2001). Magagula (1999) also cited severe land degradation associated with the physical and chemical properties of the soils. E1 class soils, which had most of the gullies, can be described as having a massive or platey structure, which is conducive to severe erosion. This suggests that the parent material is rather unconsolidated. Alternatively the B horizon of this soil type is badly drained and once it is exposed gullies start to develop

Vegetation degradation was also observed as the occurrence of thick bushes that covered most of the steep slopes showed a decrease over the years as seen on the sequential photos. This decline can be attributed to overgrazing and cutting down of trees for domestic use by villagers. Degradation can be traced back to the 1930s as seen on the 1938 aerial photograph. The rate at which degradation occurred has increased over the decades since then. The distribution of erosion gullies did not change significantly over the years, but already eroded areas showed a marked increase in the sizes of these gullies. This means that the physical controls to degradation are quite marked leaving certain areas at the mercy of degradation and others not being affected at all. To date degradation is continuing without serious efforts to combat it.

In Zone A (Fig 4.8), the slow growth in gully width could be ascribed to the fact that the gullies are very close to homesteads. The villagers may have attempted to stop the gullies from encroaching onto houses by preventative or remedial actions. Gully area for 1996 in Zone A was low and this can be interpreted as self-stabilisation or due to the resilience of the soil.

Zone C lies within the grazing areas away from settlements where gully development is not being checked and does not have any direct and immediate effect on human habitation. The trend of land degradation can be described as linear in the study area. As time passed on, degradation has also been on the increase.

The abrupt and unexpected decrease in gullied area in Zone E in 1985 could have been due to soil resilience and resultant self stabilisation. A more plausible explanation though is the poor picture quality for the 1985 aerial photograph. This means the gullies were not very clear probably due to a shadow effect hence inaccurate digitising. The same year was not represented in Zone B for the same reason.

Erosion perception

The interviews, which form part of the ICM approach of investigation, showed that while the communities in the study area recognized the occurrence of land degradation, it was not one of their main day to day problems though they regarded it as a problem. This in fact contradicts similar interviews that were done with land managers who regarded erosion as a serious problem since it reduces productivity (Pile, 1996 in Brinkate and Harvey 1996). Gully erosion was recognised as a problem in the area as it affected the movement of vehicles and animals, but the presence of sheet erosion was not seen as a problem at all. Sheet wash erosion was clearly evident on aerial photographs and had affected back yard cropping negatively.

In the central parts of the study area, covering the village of Guquka, (Fig 1.2) respondents noticed degradation as it was encroaching onto homesteads but further south degradation mainly occurred in grazing areas and was not seen as problem as livestock could be driven to graze in those areas where land changes were not noticed.

In general the communities were able to attribute the prevalence of gullies to steep slope and the prevalence of heavy rains. It appeared that the communities regarded slope factors and heavy rains as the main factors leading to gully development and not land activities like overgrazing and cutting down of trees for firewood. This emphasises a very important point that, if a soil conservation project in rural areas is to be undertaken, the communities need to be educated on all the possible causes of physical land degradation and that they should not single out one factor as most important. This is very important in any ICM approach to land degradation and restoration as it ensures the involvement of all stakeholders and considers all factors responsible for impacts.

Who is affected by degradation?

The initiation and development of gullies has been traced and degradation has been seen to be continuing. Who is really affected? Several groups of people can be identified who are affected by degradation. The user of the degraded land is affected through the decline of agricultural production levels and the need of farm machinery like tractors to plough across rills.

People residing down slope of areas where degradation is taking place will suffer due to accumulation of sediment in dams downstream. This will affect the capacity of their reservoirs and may lead to water shortages.

The combined effects of land degradation over large areas will affect the national economy. Once land degradation is declared a serious problem of national concern, the government will have to set aside funds to rehabilitate and reduce the occurrence of land degradation.

The findings of this study indicate that serious consideration should additionally be given to the following institutional activities:

- The allocation of residential sites in areas that are already degraded or highly susceptible to erosion should be avoided.
- Major land use changes are not effected before in-depth consultation with all stakeholders.

Reliability and accuracy of the ICM approach

It is often very difficult to get the exact data for any modelling process that really suits all the requirements of a prescribed methodology as well as having access to GIS software that executes all the processes of particular interest. For instance detailed soil coverages and land use maps could have been used in the erosion modelling process. The DEM could also have been created from very dense spot heights and very high spatial resolution digital contours. The DEM created for this study was reasonably accurate which implies that the catchment analysis done is acceptable.

The comparison of degradation levels on aerial photographs was done quite satisfactorily. This is because the temporal resolution of the photos was acceptable and the difference in degradation levels was quite evident because of the temporal resolution that facilitated easy change detection. The fact that the aerial photos were taken during different seasons of the year made comparison rather difficult. However, since the exact dates of most of the photos were known caution was taken during comparison. The main focus was however to map the development of gully erosion. The gullies could be seen clearly as white patches even in aerial photos that were taken during the wet season.

The effort to combine the different sources of information was successful as the different sources produced similar results. The flow charts (Fig 4.1 to 4.3) were followed and processes were executed as presented in the flow charts. In general models are rarely 100% accurate. They are developed and modified over time. In this study the modelling processes were found to be appropriate. What the models predicted to happen was supported by the results of the fieldwork. The importance of such a modelling process is that the model can be used in other catchments to do similar studies. The models can be modified to suit the interplay of other variables within a particular catchment.

The capabilities of remote sensing, GIS and ICM

This research has shown the potential of using models to predict the dynamics of catchments. Such modelling processes can also be further developed for application to a regional scale and even global scale. The abundance of different remote sensing data of different spatial, spectral and temporal resolution makes the generation of soils, geology and land use coverages easier and even more accurate. This coupled by the fact that such data is already in digital format and georeferenced makes it easy to enter the data into any GIS. The utility of GIS is that it can be applied to any discipline. Developments in hardware and software components of GIS have resulted in a much wider application of the technology throughout government, industry and business. GIS has become a tool for understanding global change as various sources of data of a particular area can be combined to understand the complex interactions and operation of the natural system.

Environmental profiles from satellite-based remote sensors in space whose accuracy has been increased by equipping remote sensing platforms with "active" sensors that obtain data from lasers and radar impulses that are transmitted to target areas and reflected back to an on-board detector.

Looking into the future of the digital world we may find the digital world looking right back at us as advances in remote sensing are giving computer networks the eyes and ears they need to observe their physical surroundings.

This study demonstrates the need for integrating methodologies. Most studies have focussed on the physical aspects of erosion and did not include the people of a catchment. The reality is that often people or communities do not buy into plans that they have not helped formulate. This is why ICM has become the internationally accepted approach in studying catchments.

CHAPTER 7 (Conclusions and Recommendations)

Conclusions

The main aim of this study was to trace land degradation trends and examine the role of physical factors and land use changes to degradation on a catchment level. It has been found that it is not possible to separate the human interventions from the geomorphological processes. It is very important to study the physical processes in conjunction with human involvement in the landscape. Soil conservation programmes in non-commercial areas have not been successful because there has been a purely technical approach towards solutions instead of combining both the technical approach and the social settings, which is broadly what ICM focuses mainly on. Brinkate and Hanvey (1996) termed such an approach that brings both the technical and social aspects together as the socio-economic and geomorphological approach. The socio–economic approach evaluates the dynamics of human activity in a given area in relation to soil erosion, perceptions and attitudes of people living in the area with regard to environmental degradation (Brinkate and Hanvey, 1996). The geomorphological approach then uses natural scientific means to investigate the causes and extents of the observed erosion process.

The difference between perceptions of soil erosion and attitudes to soil erosion should be realised. The upper Tyume communities generally perceived erosion as a problem but their attitude to erosion is one of denying their contribution towards it. They mainly attribute soil erosion to natural causes. The natural causes include slope and rainfall intensity which man has little control over. This was also the case with the people of Madebe District in the Northern Province (Brinkate and Hanvey, 1996). To ameliorate land degradation in any area requires improving the socio-economic conditions of the villagers so that they may turn their attention to soil conservation practices and not think of bread and butter issues on a daily basis.

Environmental problems are dynamic, non-linear and spatially distributed and can be described as multi-criteria requiring efficient tools for their analysis to formulate effective solutions. Some environmental problems are so complex that they cannot be addressed by conventional means. Approaches that utilise remotely acquired data and the use of GIS have been accepted internationally and are currently used in projects of various disciplines. This study, which has employed remote sensing and GIS techniques, has managed to trace the erosion severity in the Tyume basin over time and how it has contributed to land degradation. Land degradation is not a new phenomenon in land surface research, but this study has shown how the interplay of various factors can influence the temporal variation of landscape degradation in a sub-unit watershed. The models adopted in this study are relatively easy to use, require readily available input data and can be applied to other areas. The models have been capable of identifying areas of different erosion risk. Acquisition of suitable software is still a problem as these are often expensive to purchase.

The role of land use and slope characteristics as major factors in soil erosion has been evident. Slope breaks as well as uncontrolled land use practices like grazing and cultivation were responsible for the development of gullies that have hindered sustainable land use. The study has also demonstrated that land degradation, if not checked, will continue to degrade productive land. It is thus recommended that plans be put in place to try and reverse or at least minimize the development of the gullies, which has led to the loss of a lot of productive land.

Recommendations for future research in the study area

- Not reported in this thesis was the unsuccessful attempt to develop and run a hydrological model for investigating the effects of land use change on catchment hydrology. Results could not be obtained during the period of this research due to simulation problems and a lack of certain relevant input data sets. This is considered to be a very important research approach as it can help to explain the role of alien vegetation species to decrease surface flow in many catchments. This avenue will be pursued in future by using the Soil Water Assessment Tool (SWAT). SWAT uses specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed in question. Physical processes associated with water movement, sediment movement, crop growth, nutrient cycles, and other variables are directly modelled by SWAT. SWAT has the ability to model watersheds without requiring monitoring data like stream gauge data.

- Investigating the contribution of human population and livestock to the distribution and nature of soil erosion in the Tyume Catchment.

- Studies aimed at investigating the commitment of villagers in trying to control the rate of soil erosion to reduce land degradation in the past and for the future.

- Studies to find ways for the rehabilitation of arable lands in the Eastern Cape.

- Studies aimed at looking at the influence of soil properties, both physical and chemical, on soil erosion.

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APPENDICES

MONTHLY RECORDED RAINFALL AT GUQUKA (1998-1999)

TOTAL RAINFALL RECORD (1998-99): -

YEAR	MONTH	RAINFALL (mm)
1998	July	20
	August	86
	September	72
	October	75
	November	139
	December	98
1999	January	89
	February	69
	March	88
	April	34
	May	10
	June	7
	July	43
	August	9
	September	51
	October	20

RAINFALL DURING SUMMER 1998/99: -

YEAR	MONTH	RAINFALL (mm)
	October	75
	November	139
	December	98
1999	January	89
	February	69
	March	88
	April	34
	May	10
	TOTAL	602

RELIABLE RAINFALL RECORDS FOR PLEASANT VIEW (1930-1968)

YEAR	YEARLY TOTAL (MM)	SEASONAL TOTAL (MM)
1930	551.6	
1931		674
1932	726.7	
1934		538.1
1935	473	
1936		596.9
1937	657.7	
1938	489.5	574.6
1939	745.8	657.9
1942	472.9	453
1943	785.3	662.1
1944	848.1	659.2
1947	629.7	467.5
1948	646.1	616.5
1950	456.4	457.6
1951	977.8	681.7
1952	450.1	763.2
1953	626.3	544
1954	892.8	525.4
1955	446.8	915.1
1956	426.6	461.4
1957	640.7	425.3
1958	405.7	640.3
1959	647.9	429.2
1960	751.7	752.3
1961	615.5	620.3
1962	667.9	710.2
1963	635.7	702.2
1964	775	659.9
1965	734.6	851.9
1968	668	648.3

STATISTICS FOR YEARLY TOTAL	
Mean	637.35
Standard Error	28.11
Median	643.4
Mode	#N/A
Standard Deviation	148.74
Sample Variance	22122.14
Kurtosis	-0.39
Skewness	0.27
Range	572.1
Minimum	405.7
Maximum	977.8
Sum	17845.9
Count	28
Confidence Level (95%)	55.09

RELIABLE YEARLY RAINFALL DATA FOR PLEASANT VIEW (1937-1968)

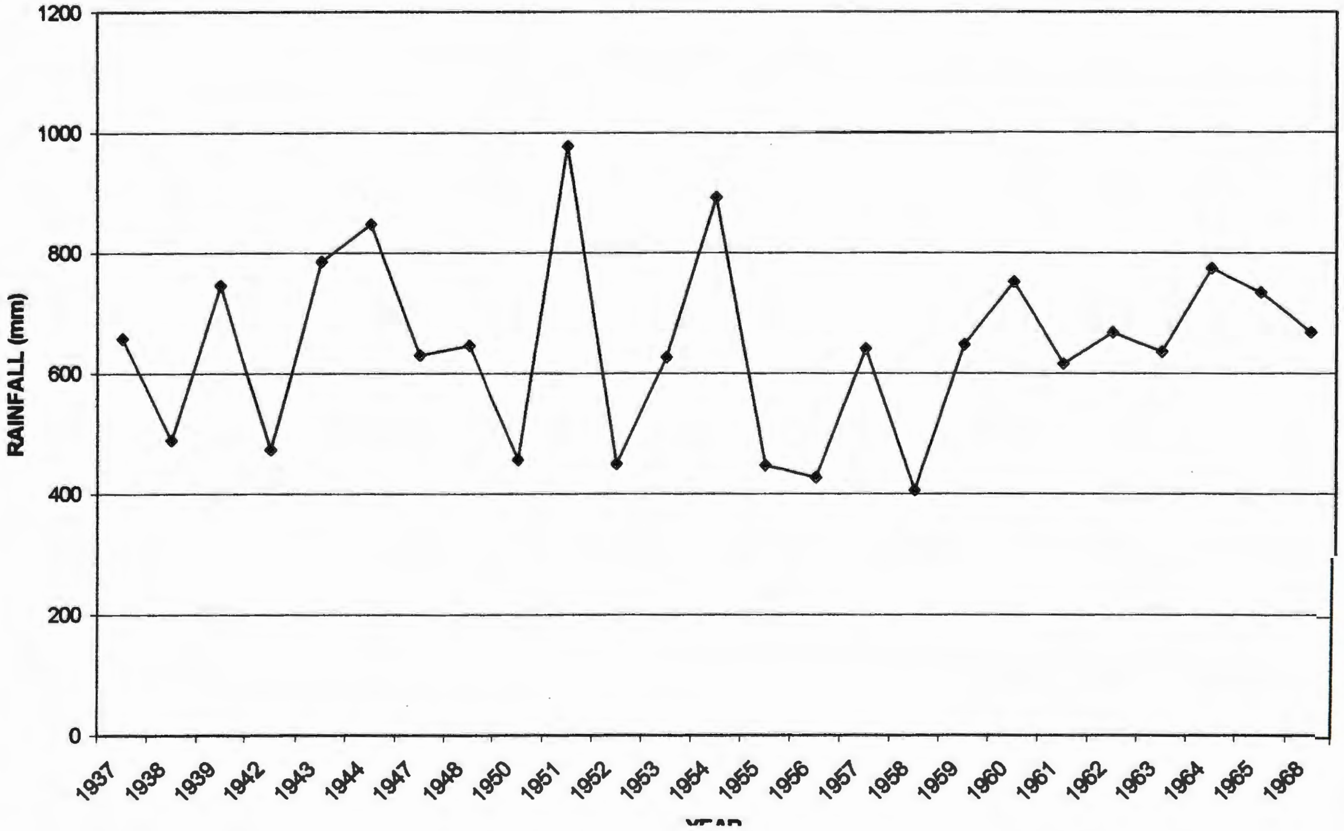
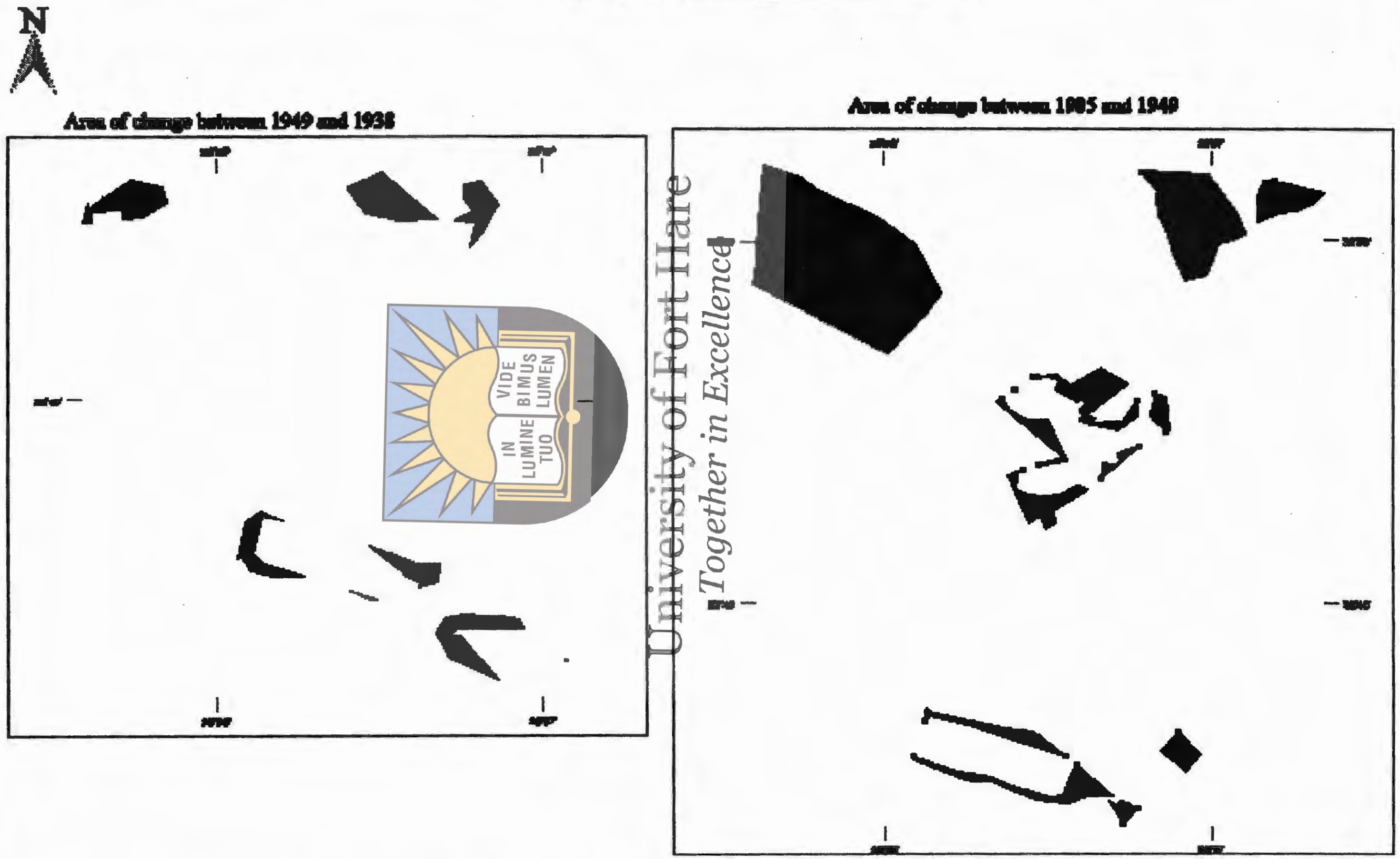


Figure 15: Two Maps of Settlement area change



Central Meridian - E 27 , Gauss Conformal , Clarke 1880 (Africa)

Hogsback Monthly Rainfall

(HMR1)

```
  STATION    LAT    LONG    ALT. RECORD  COMPLETE      LOCATION/CONTRACT
MAP
   I.D.                      (M)    SPAN  DATA YEARS

========================================================================
============
0078755 W   3235   2656   1265 1885 2000   87          HOGSBACK (BOS)
1210.9
 1980  84.5 137.8$ 79.7  49.8  17.1  16.9  30.2  45.8 173.3 110.2$119.4
$100.3  965.0
 1981 217.3 164.0 168.8  33.8 109.8  94.4  11.4  92.9  32.7  83.8 108.0
190.5 1307.4
 1982  58.6 127.1 110.6  68.9    .9  88.0  64.0  30.1  58.6 138.6  72.9
74.9  893.2
 1983  44.3  44.2  30.0  61.7  34.5  31.5 102.7  20.0  84.1 129.4 165.9
208.9  957.2
 1984 101.1  61.5 190.9  64.7  56.7  48.5  66.4  31.2  50.5 114.2 208.2
102.1 1096.0
 1985 115.0 215.6  15.5  46.5  37.0  29.1  25.1   9.9  55.1 186.0 346.6
318.5 1399.9
 1986 209.9 125.6  86.1  53.4  10.5  26.7  19.5  47.0  92.2 220.8 153.5
106.4 1151.6
 1987 123.6 150.1  65.7  56.0  26.2  30.4  20.2  58.3 168.9  63.1  64.0
90.8  917.3
 1988  83.5 110.7 193.7  40.1  85.1  32.1  43.5  28.1  58.3    .0 164.0
232.1 1071.2
 1989  98.9  92.3  92.2 187.2  56.0  29.2  34.0   3.4  34.8 210.3 351.6
77.9 1267.8
 1990 171.2 179.1 160.4  60.4  20.2  28.1    .4  90.5  58.0 209.5 110.5
62.9 1151.2
 1991 171.0 137.0 128.3  20.5  71.1    .0    .0   2.0  28.0 309.0 147.2
115.0 1129.1
 1992 121.5 100.1  92.1  42.2  21.7  27.9  18.5  69.8  35.3  52.3 148.5
54.6  784.5
 1993 152.7 224.0  73.9  84.8   6.4  45.3  14.1  44.5 105.2  89.6 181.8
268.6 1290.9
 1994 211.0 185.4  73.7  24.3  21.5  32.0  76.2  84.8  15.4 126.1  48.0
259.8 1158.2
 1995 162.3  84.6 108.6  81.0 -99.9M-99.9M-99.9M-99.9M-99.9M-99.9M-
99.9M-99.9M 436.5+
           STATS ON OBSERVED DATA
MEAN 132.9 133.7 104.4  61.0  38.3  37.3  35.1  43.9  70.0 136.2 159.3
150.91102.7
MEDN 122.6 132.1  92.1  54.7  26.2  30.4  25.1  44.5  58.0 126.1 148.5
106.41129.1
STD   54.3  51.6  52.5  38.2  31.3  24.5  29.8  30.3  47.8  79.1  89.0
86.7 173.6
C.V.  40.8  38.6  50.3  62.7  81.7  65.5  85.0  69.1  68.2  58.1  55.8
57.5  15.7
SKEW    .1    .1    .3   2.3    .9   1.3    .9    .3   1.2    .4   1.1
.6   -.1
YRS     16    16    16    16    15    15    15    15    15    15    15
15    15
           STATS ON OBSERVED AND PATCHED DATA
MEAN 132.9 133.7 104.4  61.0  38.3  37.3  35.1  43.9  70.0 136.2 159.3
150.91102.7
MEDN 122.6 132.1  92.1  54.7  26.2  30.4  25.1  44.5  58.0 126.1 148.5
106.41129.1
STD   54.3  51.6  52.5  38.2  31.3  24.5  29.8  30.3  47.8  79.1  89.0
```

(HMR2)

												86.7	173.6
C.V.	40.8	38.6	50.3	62.7	81.7	65.5	85.0	69.1	68.2	58.1	55.8	57.5	15.7
SKEW	.1	.1	.3	2.3	.9	1.3	.9	.3	1.2	.4	1.1	.6	-.1
YRS	16	16	16	16	15	15	15	15	15	15	15	15	15

Wolfridge Monthly Rainfall (WMR1)

STATION I.D.	LAT	LONG	ALT. (M)	RECORD SPAN	COMPLETE DATA YEARS	LOCATION/CONTRACT	MAP
0078879 W	3239	2700	1006	1899 2000	82	WOLFRIDGE (BOS)	1071.6

1900	109.2	110.6	77.5	25.6	10.1	14.7	20.1	49.1	33.3	96.0	47.9	211.7	805.8
1901	65.5	151.3	124.7	66.1	40.7	10.5	19.8	41.7	119.8	160.1	91.3	20.9	912.4
1902	102.1	79.0	106.7	95.6	4.6	134.9	25.4	86.8	117.9	53.0	49.1	136.2	991.3
1903	55.8	106.3	128.6	187.7	96.3	60.5	38.4	69.3	22.9	166.2	246.0	144.5	1322.5
1904	201.5	198.9	98.0	19.1	23.8	10.1	23.6	23.7	55.1	155.0	18.4	65.7	892.9
1905	60.5	154.2	86.7	59.5	82.3	60.6	13.2	62.7	169.7	238.2	86.5	189.7	1263.8
1906	78.3	174.0	128.6	110.4	43.7	36.6	8.8	7.6	124.0	234.9	154.1	165.6	1266.6
1907	176.8	151.6	93.7	171.8	82.6	16.0	4.3	10.1	45.1	81.1	85.3	217.7	1136.1
1908	68.0	170.8	102.2	43.8	32.4	55.1	5.0	54.7	103.9	251.4	144.4	107.0	1138.7
1909	157.0	209.6	111.4	124.1	72.3	.0	11.5	21.8	123.1	82.4	71.6	131.9	1116.7
1910	136.3	255.2	134.6	15.8	120.7	24.2	40.1	15.2	56.0	178.9	102.4	217.6	1297.0
1911	230.5	124.0	248.7	139.3	155.9	28.9	9.4	36.2	99.7	160.4	140.3	27.8	1401.1
1912	101.1	178.7	80.8	61.3	7.6	49.2	50.8	18.0	41.2	72.7	67.1	181.4	909.9
1913	119.2	207.1	165.2	17.2	15.0	20.6	28.4	58.9	248.9	68.3	68.1	68.4	1085.3
1914	180.8	195.6	139.4	53.0	55.3	43.4	3.8	77.2	82.6	57.1	160.7	100.6	1149.5
1915	186.1	115.9	29.9	99.8	37.1	14.3	45.8	5.5	38.9	105.4	121.9	167.3	967.9
1916	89.6	7.6	195.4	40.0	115.6	1.3	.0	22.7	39.9	129.3	71.5	219.3	932.2
1917	113.0	119.9	158.5	80.0	25.4	102.4	103.4	44.6	120.6	269.8	225.5	146.6	1509.7
1918	229.3	124.9	217.3	45.6	44.8	42.4	38.1	53.9	96.3	106.0	40.6	133.1	1172.3
1919	69.5	150.1	127.9	99.3	37.9	22.7	8.6	7.6	21.9	93.6	134.1	69.0	842.2
1920	125.0	329.8	168.0	39.8	29.0	10.8	14.4	18.0	35.7	71.4	102.9	195.2	1140.0
1921	124.2	101.6	225.1	192.7	47.0	17.6	23.1	17.3	66.2	70.6	181.2	191.4	1258.0
1922	153.1	81.4	56.6	75.2	76.6	47.3	15.8	73.9	124.8	131.2	348.3	71.4	1255.6
1923	280.4	95.1	108.3	47.1	33.5	26.6	76.2	7.9	35.0	54.0	72.1	100.8	937.0
1924	116.1	108.5	112.4	23.6	28.3	11.7	3.5	67.4	49.1	22.6	71.3	191.3	805.8
1925	87.3	93.2	272.6	146.8	47.3	23.1	19.1	9.2	104.8	51.9	122.6		

(WMR2)

140.7 1118.6

1926	56.1	98.7	220.5	12.7	11.4	58.9	16.5	15.2	117.9	68.7	162.3	141.2	980.1
1927	90.2	59.5	200.0	80.0	35.8	.0	9.3	23.1	18.6	84.5	37.6	46.2	684.8
1928	109.5	105.6	234.9	58.0	24.6	28.8	20.3	63.0	68.0	140.7	105.8	204.0	1163.2
1929	72.0	101.3	144.8	19.5	62.8	100.0	52.6	48.7	169.2	131.0	94.6	94.5	1091.0
1930	123.2	157.0	179.0	25.9	44.7	57.6	28.9	146.2	48.4	135.3	47.0	117.0	1110.2
1931	158.6	88.9	68.2	117.5	1.0	42.1	217.8	10.1	20.2P	127.8	107.9	179.7	1139.8%
1932	124.3	104.1	75.7	.0	58.0	5.3	62.5	16.5	197.7	127.0	220.9#	86.7	1078.7
1933	58.9	124.6	161.8	89.1	26.9	19.6	3.3	39.7	67.4	62.5	140.3P	107.9	902.0%
1934	177.3	172.7	247.2	50.8	34.6	32.4	96.7	3.3	51.3	119.1	55.2	102.7	1143.3
1935	127.1	70.1	140.4	160.8	228.4	50.0	.0	42.8	35.1	66.5	93.0	115.3	1129.5
1936	110.8	122.4	165.0	9.1	88.4	16.0	69.9	2.8	73.9	169.3	194.4	69.1	1091.1
1937	108.5	109.7	156.2	10.3	32.3	8.9	27.0	11.9	93.3	95.3	157.6#	216.4	1027.4
1938	172.4	89.7	90.9	107.8	39.1	39.7	21.6	67.5	73.2	138.0	194.9	157.0	1191.8
1939	168.8	239.4	143.3	41.3	18.0	8.1	69.0	41.2	128.8	151.8	71.1	117.8	1198.6
1940	125.4	232.7	193.3	54.6	79.8	3.6	35.8	6.1	156.4	63.2	146.2	94.0	1191.1
1941	135.9	201.6	88.0	112.1	12.5	39.3	20.3	4.8	29.2	128.1	63.4	132.9	968.1
1942	209.6	160.3	125.6	93.4	62.0	7.6	19.1	48.3	75.7	115.7	228.2	115.5	1261.0
1943	97.2	119.2	66.4	125.1	32.7	60.4	3.8	76.7	62.3	81.6	222.0	168.6	1116.0
1944	79.4	145.8	187.4	46.8	91.7	52.4	33.9	7.7	119.0	92.4	51.5	51.9	959.9
1945	141.3	77.8	79.7	29.7	21.4	23.7	17.3	7.6	7.1	132.1	26.9	80.6	645.2
1946	159.0	139.1	169.8	35.2	57.0	24.4	37.3	38.9	47.8	99.4	126.8	75.2	1009.9
1947	171.5	59.6	122.2	53.4	27.5	47.8	37.5	14.5	99.0	71.9	161.0	120.3	986.2
1948	146.8	101.0	161.6	266.4	24.4	25.9	43.8	.3	39.6	92.1	96.1	65.5	1063.5
1949	115.7	68.8	48.0	61.5	22.9	.0	4.6	29.5	60.7	61.3	121.7	73.9	668.6
1950	89.9	118.9	162.6	38.4	189.5	.3	27.7	71.0	43.0	158.4	107.7	214.9	1222.3
1951	120.0	80.8	51.6	20.8	11.5	26.5	50.9	46.3	88.1	49.4	4.8	31.3	582.0
1952	124.6	170.0	87.6	63.1	4.1	29.1	16.7	12.3	110.1	51.8	87.1	118.3	874.8
1953	82.5P	134.6P	100.3P	100.5P	30.5	33.8P	23.6	145.0P	114.8	273.3P	185.9P	165.4P	1390.2%
1954	88.4P	101.3P	206.0	27.8P	82.3	60.6P	36.1	15.5	55.6	88.0P	82.8	74.2P	918.6%
1955	123.7	125.6P	69.3	34.5	31.2	50.0	4.8	20.7P	41.1P	67.6	168.9P		

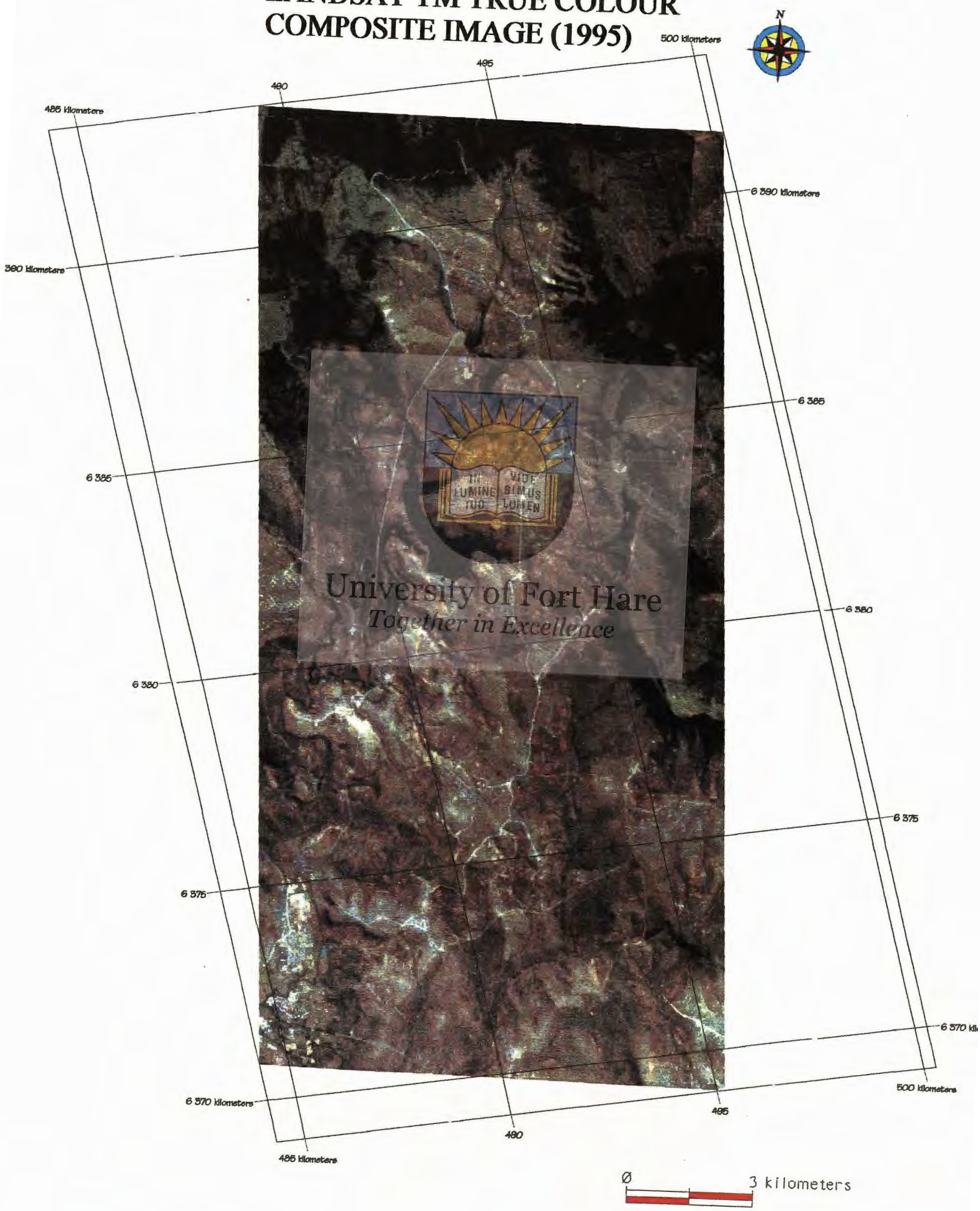
(KKNR3)

												55.9	793.3%
1956	85.1	111.9	189.5	58.4	64.1	2.1	4.1	19.5	89.6	91.2	171.6	192.6	1079.7
1957	90.9	149.7	186.8	69.5	43.5	36.0	10.5	22.5	44.9	77.8	82.8	85.4	900.3
1958	212.1	89.0	154.0	75.6	54.7	14.0	.0	34.9	92.8	60.8	142.0	197.9	1127.8
1959	124.1	46.0	203.0	175.0	143.0	.0	155.0	57.0	58.5	65.0	179.5	221.5	1427.6
1960	177.5	96.5	134.0	86.0	31.5	13.0	52.5	77.0	91.0	95.5	169.0	181.7	1205.2
1961	95.3	102.1	205.7	55.0	96.5	42.0	7.5	68.0	39.0	71.0	173.0	111.0	1066.1
1962	106.3	194.0	252.8	68.0	58.0	12.7	10.6P	16.2	21.0	176.5	122.0	93.0	1131.1%
1963	284.5	127.9	276.6	125.6	23.5	17.2	97.2	16.5	24.9	163.8	130.0	119.4	1407.1
1964	130.7	220.5	130.9	102.8	8.7	133.1	12.5	57.1	135.0	82.5	60.2	139.2	1213.2
1965	88.3	66.3	98.6	49.3	76.8	88.3	27.3	31.0	55.7	224.3	170.4	76.0	1052.3
1966	136.5	125.5	88.0	64.8	60.4	8.8	1.0	75.0	64.0	31.5	190.2	93.4	939.1
1967	117.3	68.0	175.2	158.7	101.0	43.5	36.5	44.5	43.5	63.5	112.0	52.3	1016.0
1968	45.5	49.5	123.8	159.8	22.7	62.1	2.5	61.8	168.6	93.5	105.7	82.7	978.2
1969	60.2	177.5	165.7	59.9	[illegible]	[illegible]	32.0	43.9	22.1	130.1	135.3	51.4	946.0
1970	75.1	178.2	16.4	33.6	33.6	84.4	12.1	342.3	38.5	106.0	86.3	275.3	1281.8
1971	162.7	195.1	114.0	126.4	55.3	3.5	107.5	132.0	36.3	105.9	146.5	90.2	1275.4
1972	150.5	171.4	133.9	40.0	16.3	45.3	6.5	16.0	48.1	86.2	125.9	54.2	894.3
1973	71.2	172.7	186.3P	54.9	26.1	.0	10.4	85.1	47.6	70.3	190.8	102.0$	1017.4%
1974	274.8	149.0	274.4	32.5	187.0	31.9	4.0	108.0	19.5	67.1	166.7	80.8	1395.7
1975	90.5	150.9	87.4	26.5	7.0	65.5	27.3	28.0	185.6	12.4	108.8	266.0	1055.9
1976	139.8	218.9	322.1	59.0	103.7	18.5	51.5	28.2	57.8	267.0	143.0	105.2	1514.7
1977	98.9	221.2	27.1	92.0	93.5	30.5	3.0	32.7	111.0	103.2	162.8	229.1	1205.0
1978	103.7	60.6	69.6$	162.2$	36.2	44.0$	2.3	29.8$	54.7	142.3	91.8	153.5$	950.7
1979	141.3	126.5$	82.6$	41.1	75.2$	16.9	141.4	212.5	46.6$	95.3	66.8	79.5$	1125.7
1980	91.3	96.5$	73.7$	37.3	23.4	15.0$	40.6	46.9	89.6$	90.2$	89.9	107.2	801.6
1981	257.2$	157.1	158.2$	37.4	133.6$	45.0$	8.5	82.2$	29.2	80.4$	88.8	117.8$	1195.4
1982	56.4$	126.4	112.9$	71.0	4.5$	78.0	53.5	20.0	51.9	180.8$	54.5	69.0	878.9
1983	41.5	35.0	39.0	47.5	17.5	20.5	109.0	7.0	87.0	244.3	97.5	166.5	912.3
1984	61.5	71.0	115.5	97.0	14.5	40.5	55.0	17.0	21.0	105.7	164.0	42.0	804.7
1985	169.3	156.5	20.5	56.0$	14.5	32.0	6.3	7.5	48.0	224.5	235.0		

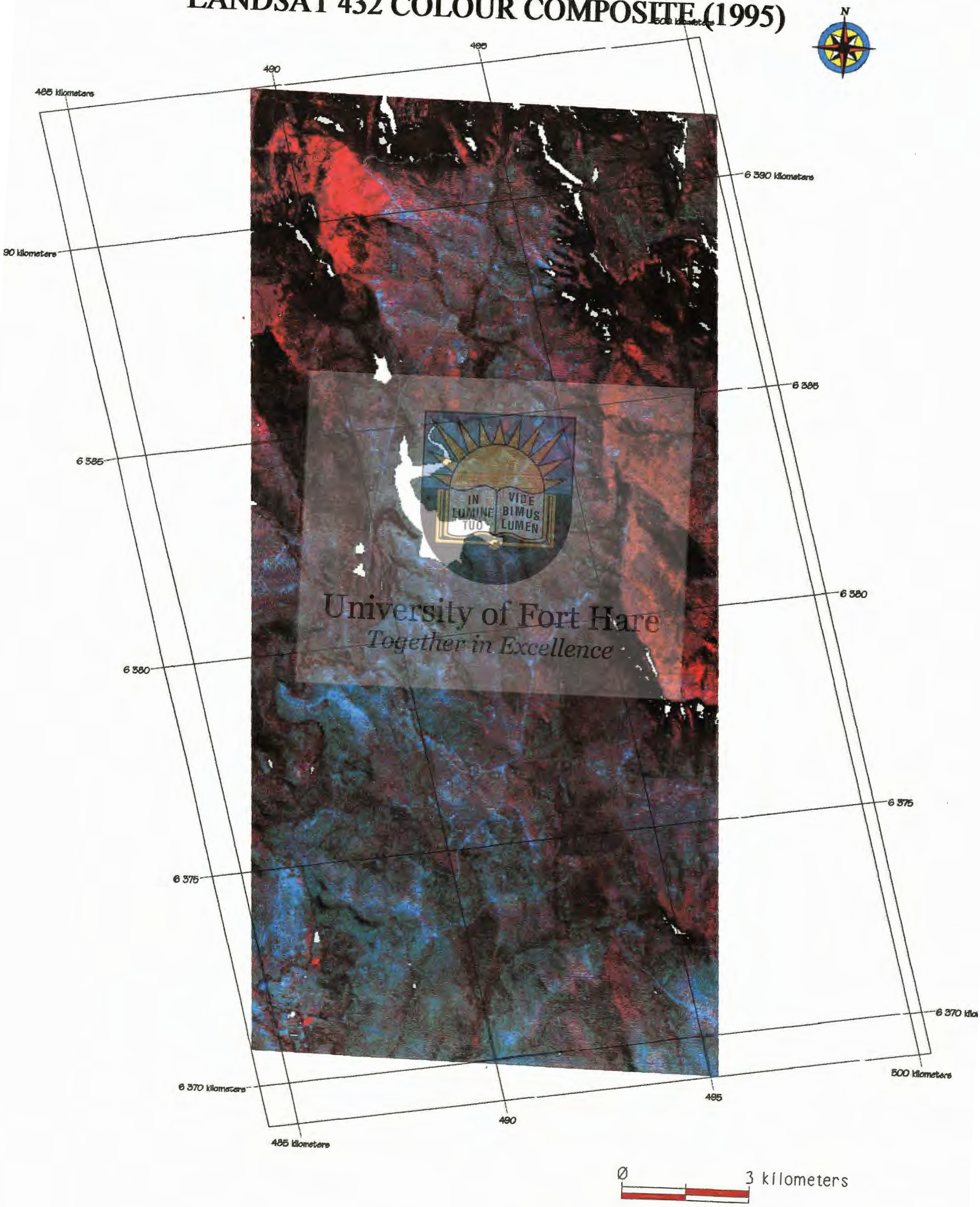
(WMR4)

```
262.0 1232.1
 1986 143.0 104.6  83.0  79.5   4.0  22.0  18.5  42.5  72.4 242.0 121.5
53.5$ 986.5
 1987 125.0 123.0  83.3$ 37.5  14.0* 47.5  14.5  62.1 188.0  76.0    .0*
104.5  875.4%
 1988  81.0 150.5 159.0  48.5  67.5$ 26.5  45.0  28.5  64.0  95.4 145.5
210.0 1121.4
 1989  60.0  99.1 142.5 158.5  20.6  98.0  20.7   1.5  33.0 220.9 356.4
73.2 1284.4
 1990 155.0 145.5 149.0 148.9  13.0   8.0  10.0  50.5  41.2 180.5  84.0
87.5 1073.1
 1991 154.4 135.0  86.3  20.0    .0  22.0    .0  58.5  39.5 281.5 114.5
158.0 1069.7
 1992  75.0 108.5  56.5  48.0  27.0  18.0  14.0  63.5  35.5  90.4  78.9
120.0  735.3
 1993 102.0 124.0  50.2  44.0    .0  66.5  15.0  34.4    .0M   .0 163.2
353.5  952.8+
 1994 171.1 173.5 102.0  25.9  17.6  26.1  83.5  68.3  12.5  70.8  34.1
85.0  870.4
 1995 100.5 103.6 151.0 -99.9M-99.9M-99.9M-99.9M-99.9M-99.9M-99.9M-
99.9M-99.9M 355.1+
                STATS ON OBSERVED DATA
MEAN 125.8 132.2 134.5  73.5  49.6  33.9  32.5  44.1  74.3 115.2 122.6
128.11070.8
MEDN 119.6 124.0 128.6  58.4  35.2  26.5  20.3  34.9  58.2  95.4 112.0
115.51082.5
STD   53.0  53.7  63.5  50.5  43.9  28.2  36.8  46.3  47.6  61.6  63.7
63.8 191.9
C.V.  42.1  40.6  47.3  68.8  88.5 [illegible] 113.0 104.9  64.1  53.5  52.0
49.8  17.9
SKEW   1.0    .6    .5 [illegible] [illegible] 1.4  2.4  3.6   1.2    .9   1.1
.8   -.1
YRS     94    93    94    93    94    93    94    93    92    93    91
93    86
                STATS ON OBSERVED AND PATCHED DATA
MEAN 124.9 131.8 134.7  73.3  49.3  34.2  32.3  44.9  73.4 116.5 122.6
127.91066.6
MEDN 118.2 124.3 128.6  58.4  34.6  26.6  20.3  34.9  56.9  95.4 114.5
115.51079.2
STD   52.7  53.0  63.2  50.3  43.9  28.0  36.6  47.0  47.5  63.1  64.1
63.5 191.5
C.V.  42.2  40.2  46.9  68.6  89.0  81.9 113.4 104.6  64.8  54.1  52.3
49.6  18.0
SKEW   1.0    .7    .5   1.2   1.7   1.4   2.4   3.4   1.2    .9    .9
.8    .0
YRS     96    96    96    95    95    95    95    95    94    95    95
95    94
```

LANDSAT TM TRUE COLOUR COMPOSITE IMAGE (1995)



LANDSAT 432 COLOUR COMPOSITE (1995)



Questionnaire Number	80

MSc Research – UFH 2002
Geography and Environmental Science Dept

A Chronological Study of Land Degradation and Land Use Trends using Remote Sensing and GIS Techniques in the Upper Tyume Catchment of the Eastern Cape

QUESTIONNAIRE

DATE: 08/08/02

Target Respondents

Old age people (the big timers) who have better knowledge about the history of the study area. It would be more beneficial if this group would include people who were once headmen's or chiefs. These will have a better chance to remember some of the major events in the history of the area.

Introduction

We are conducting a research on landuse changes here in the Upper Tyume Catchment. Your village/homestead falls within this area. We are a team from the University of Fort Hare in the Geography and Environmental Science Department in conjunction with the Agriculture and Rural Development Research Institute (ARDRI), a research institute also at the University of Fort Hare. We would like to ask you a few questions and ask for your ideas related to the research we are working on. The information that we are seeking generally pertains to the way(s) in which you have been using the land for the past five to six decades. We intend to make this information available to people involved in landuse planning with the hope that they will refer to this information when making decisions. The information you will give us will be held confidential. I hope this interview will take not more than 20 minutes. Thank you very much for your cooperation.

1. In which of the following age ranges do you fall into? *Tick where appropriate. (NB) You may not ask this question if you feel the respondent may get offended. If the respondent is willing to give his/her exact age you can write in the exact age in the age range that it falls*

(21 – 35) yrs		1
(36 – 50) yrs	X	2
(51 – 70) yrs		3
Above 70 yrs		4

2. Where do you live? *Tick were appropriate*

Guquka	X	1
Magxagxeni		2
Sompondo		3
----		4
Other *(specify)*		5

Interview carried out in Sompondo

3. Where did you live about 10years ago?

Guquka	X	1
Magxagxeni		2
Sompondo		3
----		4
Other *(specify)*		5
Not Applicable		6

4. What made you change your place of residence? *(Ask this question only if the respondent moved from elsewhere)*

Family Reunion		1
Landownership		2
Forced by political situation		3
Marriage		4
Other *(specify)*		5

5.How were you using the land as a resource before you moved to this place?

Cropping		1
Home Gardens		2
Grazing		3
Settlement		
Other *(specify)*		4

N/A

6.How are you using the land as a resource today?

Cropping		1
Home Gardens	X	2
Grazing		3
Settlement	X	
Other *(specify)*		4

7. For how long have you been using the piece of land for this same landuse type? (*the landuse stated in question 6, If the respondent knows the exact time write it on other)*

Past (0-5) yrs		1
Past (6-10) yrs		2
Past (11-20) yrs		3
Other *(specify)* Since long back		4
Do not know		5

8. Was there a time when you failed to use the land for a certain purpose due to financial, political and or economic constraints?

Yes	X	1
No		2
Do not Know		3

9. If yes what was the constraint?

Economic		1
Political		2
Financial	X	3
Other *(specify)*		4

10. When was that and what had happened? *(Ask this question if the answer to question 9 has either options 1, 2 and or 3)*

1993–95 –
– Breadwinner Lost job.

11. Has your household landuse changed for the better or worse since 1994 and why?

Better		1
Worse	X	2
No Change		3

really worse

12. Some say land degradation is a serious environmental problem in this area. What is your feeling about this statement?

I agree strongly with this statement		1
I agree moderately with this statement	X	2
Undecided		3
I disagree moderately with this statement		4
I disagree strongly with this statement		5

13. When do you think land degradation started to occur in this area? ***(Ask this question if the answer for question 12 is positive)***

Past (0-5) yrs	X	1
Past (6-10) yrs		2
Past (11-20) yrs		3
Other *(specify)*		4
Do not know		5

14. How has land degradation affected your way of life and your neighbours? ***(Ask this question if the answer for question 12 is positive)***

Very seriously	X	1
Seriously		2
Not seriously		3
To a very little extent		4
Not at all		5

15. What do you think could have caused degradation? ***(Ask this question if the answer for question 12 is positive)***

rains which are heavy
- Cause of ploughing

16. A piece of land can be used for particular purpose today, but this can change with time. This is referred to as *landuse change*. Do you think Landuse change could have contributed to land degradation in this area?

I agree strongly with this statement		1
I agree moderately with this statement		2
Undecided	X	3
I disagree moderately with this statement		4
I disagree strongly with this statement		5

17. What else do you think could have caused land degradation in this area?

Nothing

18. When you (as villagers) discovered that the land was degrading, what did you do?

Told the responsible people		1
Tried to combat it	X	2
Did nothing		3
Other (*specify*)		4

but not very successful

19. Do you know anything about the Betterment Planning and or the Homeland System?

Yes		1
No	X	2

20. What was it all about (Betterment Planning and or Homeland System) and how did it affect the way you were using the land as a resource?

N/A

21. **What used to happen on top the escarpment where we now have pine plantations and when?**

Just natural forest

22. **When did that change take place and how did it affect you?**

Do not know

23. **Would you want to go back and live before the 1960s and 1970s and continue with the landuse types and livelihoods therein?**

Strongly agree		1
Agree		2
Disagree	X	3
Strongly disagree		4

24.If you were to be given a new piece of arable land today here in the Upper Tyume, what would you use it for and why?

Landuse Type	Category	Reason
Cropping	1 X	Does not have a place to plough
Home Gardens	2	
Grazing	3	
Settlement	4	
Other *(specify)*	5	

25. Is there anything else that you would want to say about landuse/land degradation that we probably did not discuss together today?

– need for gvt intervention to help villagers

Name of Respondent —

Sex of Respondent MALE

Comments OK.

THANK YOU VERY MUCH FOR YOUR TIME.

Xhosa Translation of Questionnaire

1. Ukoluphi uluhlu lobudala?

2. Uhlala phi?

3. Ingaba ubusakuhlala phi kwiminyaka elishumi edlulileyo?

4. Yaba yintoni unobangela wokuba utshintshe indawo yokuhlala?

5. Nasakuwusebenzisa njani lo umhlaba, njengenye yendlela zokuphila, phambi kokuba nizokuhlala kuwo.

6. Niwusebenzisa njani umhlaba njengedlela yokuphila kulemihla?

7. Lingakanani ithuba usebenzisela lo mhlaba kulandlela ingasentla yokuphila?

8. Ingaba lakhe lakhona ixesha apho ungazange ukwazi ukuwusebenzisa umhlaba entweni athile ngenxa yokunqongophala kwemali, yemeko yezopolitiko okanye imeko yezoqoqosho.

9. Ukuba kunjalo, ingaba yayiyintoni kanye?

10. Kwakunini kwaye kwakwenzeke ntoni?

11. Ingaba indlela ubukade uwusebenzisa ngayo umhlaba yaphucuka na okanye yadodobala na emva konyaka ka-1994?

12. Inxalenye yoluntu kulendawo ithi ukumosheka komhlaba yingxaki enkulu kokusingqongileyo. Wena ulubonanjani oluluvo?

13. Ingaba, xa ucinga, ukumosheka komhlaba kwaqala nini kulengingqi?

14. Ingaba olumosheko lomhlaba luyichaphazele njani indlela yakho kunye nabamelwane bakho yokuphila?

15. Ucinga ukuba lwabangelwa yintoni olumosheko lomhlaba?

16. Umhlaba uyakwazi ukusetyenziselwa into ethile namhlanje, kodwa ethubeni oku kungatshintsha. Oku kubizwa *ngotshinsho lusebenziso mhlaba*. Ingaba ucinga ukuba *utshintsho lusebenziso mhlaba* lubenayo indima oluyudlalileyo ekumoshakaleni komhlaba kulendawo?

17. Yintoni engenye ocinga ukuba ibenako ukubangela umosheko mhlaba kule ndawo?

18. Ngethuba nina (nje ngabahlali balendawo) nanifumanisa ukuba umhlaba uyamoshakala, manyathelo mani enawathabathayo?

19. Ingaba likhona ulwazi onalo malunga nesicwangciso sokwenza ubomi ngcono kunye/ okanye inqubo yamaphandle?

20. Zazimalunga nantoni ezi zinto zingentla kwaye zayichaphazela njani indlela enanisebenzisa ngayo umhlaba njengendlela yokuphila?

21. Kwkusakwenziwa ntoni phaya ngaphezulu entabeni apho ngoku kukho ihlathi elityaliweyo lom-*pine* kwaye kwakunini?

22. Yatshintsha nini le nto yayisakwenzeka kwaye yanichapazela njani?

23. Ukuba bekungenzeka, ungathanda na ukubuyela uphile kwiminyaka engaphambi ko-1960 no-1970 usebenzise umhlaba kwaye uphile ngendlela ewakuphilwa ngayo?

24. Ukuba bekunokwenzeka unikwe uhlaba namhlanje apha kumantla eThyume, ungawusebenzisa entweni, ngazizathu zini?

25. Ingaba kukhona okuthile okungokunye ongathanda ukuthetha malunga nosetyenziso lomhlaba nomosheko lomhlaba mhlawumbi esingakhange sikuxukushe kunye namhlanje?

SIBULELA KAKHULU NGEXESHA LAKHO.
UKWANDA KWALIWA NGUMTHAKATHI.!!!!