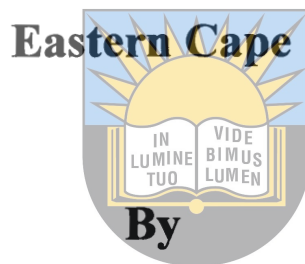


**Land Use, Vegetation Types and Erosion Patterns in
Selected Catchments of the Keiskamma River Basin,**



University of Fort Hare
Together in Excellence
Petunia Lebogang Pheto

**Submitted in fulfilment of the requirements for
the degree of Master of Science**

**In the
Faculty of Science & Technology at the
University of Fort Hare
Eastern Cape**

2003

**SUPERVISOR: Prof L M Magwa
CO-SUPERVISOR Mr D. R Walker**

Declaration

I Petunia Lebogang Pheto do hereby declare that the work contained in this thesis is entirely my own work.

Signed _____ at _____ this _____ day of _____



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ACKNOWLEDGEMENTS

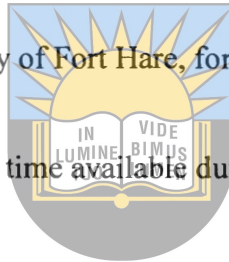
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ABSTRACT

The southern African region is designated as an area which is susceptible to soil erosion. This is particularly true for the former Ciskei, where it is estimated that 47 % of the area is moderately to severely eroded (Ciskei Commission, 1980). The Keiskamma River Basin is located entirely within the borders of the former Ciskei in the Eastern Cape, South Africa. The river basin is populated by rural settlements with limited water resources.

Five small catchment areas with a variety of environmental conditions were selected for study. The following aspects were assessed for each catchment selected. These were namely, land use, soil type(s), contours (slope) and vegetation type(s). All these were presented in the form of maps, using a technique called Geographic Information System (GIS). Water samples collected from each catchment were analysed for total suspended sediment (TSS). TSS values measured may imply catchment erosion as the sediment source (Colloty, 1997). There was no significant difference in TSS concentration under different weather conditions.



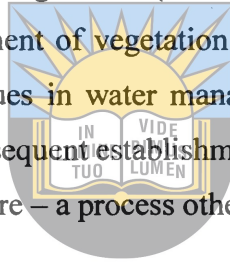
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TSS values ranged from 0 to 380mg/l with the highest concentration found in the Middle reaches of the Keiskamma River Basin. High variability in TSS was found between catchments and also within the same catchment depending particularly on the variables such as soils, land use practices and slope. Catchments with the lowest vegetation cover gave correspondingly high concentrations of TSS and *vice versa*. Vegetation type was also used as an indicator of veld deterioration.

Keywords: Keiskamma River, total suspended sediments (TSS), erosion, land use, catchment, Geographic Information Systems (GIS).

INTRODUCTION

Fundamental to the existence of man, is the availability of water in a sufficient and sustainable manner and the efficient utilization and management of land. The development of our society, our growing population, and the legitimate demands of the disadvantaged majority for access to that most crucial resource - water - have placed new demands on what is, although renewable, a limited resource that can easily become polluted or over-used. The availability of clean portable water stands out as one of the most important indices of development. To this end, the scarcity or lack of water emerges as a precondition for defining underdevelopment. Although renewable, water remains a finite resource, which occurs unevenly, both geographically and through time (Basson, 1996). The importance of good land-use practices, including management of vegetation cover, avoidance of overgrazing by animals and good cultivation techniques in water management cannot be overemphasised. The removal of vegetation and the subsequent establishment of human settlements often leads to the weathering of the top soil structure – a process otherwise referred to as erosion.



The main sources of water on earth are rivers, oceans and other water bodies built by man, for example dams. The sustainability of the use of this water by man however, depends on good management practices. Apart from quantity, important also is the quality of water available for whatever purpose it is meant for. The Department of Water Affairs and Forestry (DWAFF, 1994) states that " water... sustains the natural environment, which is why it is not only the quantity of water available which is critical, but also its quality". The importance of the availability of water as an essential condition for development has received considerable attention, from individual researchers and government alike. In 1986, South Africa's Department of Water Affairs outlined its mission as: "To ensure the ongoing equitable provision of adequate quantities and qualities of water to all competing users". Quibbel, *et. al* (1977) stated to this end that "in spite of approximately 40 years since the implementation of effluent standards, the quality of many of South Africa's surface and ground waters have continued to deteriorate".

South Africa is regarded as one of the world's water scarce countries, located largely in a semi-arid region, with an average rainfall of 497 mm, compared to a world average of 860 mm. Rainfall is also unevenly distributed with 65% of the country receiving less than 500

mm of rain annually and 21 % receiving less than 299 mm (Rabie and Day, 1994). In addition, the main metropolitan and industrial centres are often remotely located from the main river courses. Supply and demand thus have to be balanced by extensive impact on the environment. The result is that water is often a limiting resource for development in many parts of South Africa. Also, of significance is the effect of crippling droughts or devastating floods on the rural poor. Where available, water resources are often inequitably distributed and sometimes inappropriately used.

Many of the causes of poor water quality are linked to bad land management practices (DWAF, 1996). Where poor practices are followed the topsoil is washed into rivers silting up dams and increasing the turbidity of the water. Animal grazing and cultivation seriously impacts on land, exposing the land to erosion. Overgrazing aside, continuous animal and human trampling (footpaths) also weaken the soil structure thereby leading to soil erosion. Felling of trees and the removal of vegetation makes the soil susceptible to erosion. Sufficient plant cover limits the amount of soil erosion, as leaves and stems cushion the impact of rainfall, and the roots help to hold the soil in place.

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This research project concentrates on one aspect of water quality, viz. sediment concentration, and the factors that influence it. For the purpose of this study, 5 small catchments within a range of 171 171 m² and 767 676 m² of the Keiskamma River Basin were chosen for investigation.

The Keiskamma River Basin is located on the south-eastern freeboard of South Africa between latitudes 32⁰ and 34⁰ South and longitudes 26⁰ and 28⁰ East (HKS, 1977). The River Basin comprises approximately one-third of the formerly proclaimed homeland of the Ciskei. The total area of the river basin is 2,700 km² of which approximately 85 % experiences an annual rainfall of less than 700 mm and approximately 60 % in the lower and middle reaches experiences an annual rainfall between 400 mm and 600 mm. Each small catchment selected for this study is drained by a single watercourse with the stream integrating and reflecting the characteristics of the catchment (Davies & Day, 1986). As each catchment has different land uses, vegetation, and soil characteristics, it was possible to compare these factors with respect to their influence on sediment production.

The hypothesis tested was that if the catchment is well managed and the vegetation cover kept intact, then there would be less erosion and consequently less suspended sediments in the water. The area is underdeveloped and characterised by scattered villages, which lack conventional forms of water supply, sanitation or other services. Inhabitants eke out an existence from traditional farming methods largely based on livestock production, cropping for domestic consumption and the income from migrant workers (Godden, *et. al* 1984). With the realisation that over 70 % of South Africans live in the rural areas, and also considering that the Keiskamma area is a representative microcosm of the entire rural former homeland situation in South Africa, the information presented here may well be applicable to other parts of South Africa that are faced with similar problems.

This study was, therefore, an initiated attempt to address the following:

- ◆ To assess vegetation cover and its effect on the sediment concentration in the stream draining each small catchment.
- ◆ To examine land use practices within each catchment through mapping and by administering a questionnaire to local residents and to determine the effects of these on the sediment concentration in the stream draining the catchment.
- ◆ To produce GIS maps by making use of data produced by Hill, Kaplan, Scott (1977). The maps produced will show change over time with regard to vegetation, rate of soil erosion and land use practices. Baseline information pertaining to soil type was not foreseen to have changed overtime and so soils were not sampled nor measured for this study. The maps produced will again be compared with maps produced from the investigations carried out in 1998.



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LITERATURE REVIEW

Clean, fresh water is essential to life for biological activities. A well-nourished person can survive for about six weeks without food, but for only a few days without water. The main reason people live longer today than they did 2000 years ago is clean water. The water available to us is constantly replenished and cannot be depleted unless we use and contaminate it faster than it is cleaned up by human or natural processes.

In relatively arid areas of South Africa, it is necessary to recognise the dynamics of the ecosystems with regard to the water cycle and the interdependence of its elements, where evaporation, clouds and rainfall are linked to underground water, rivers, lakes, wetlands, estuaries and the sea. Water in nature is continuously moving, even though in some cases it may move very slowly over millions of years, trapped in rocks deep below the earth's surface. Not only is water continuously moving, but, it is also continuously changing its state between a liquid, a gas and a solid. This continual movement and changing of water is known as the water cycle (Figure 1). The water cycle is indivisible and all parts of it are inter-related.

When rain falls, it can sink into the ground, where it might be used by plants, or flow through the soil to a river or lake, or be stored as groundwater. If it does not sink into the ground it might run off over the surface to a river or lake, although, most of it evaporates. There are basically no freshwater lakes in South Africa, and exploitable water supplies are, therefore, confined to rivers, artificial lakes behind dams and groundwater. In South Africa, runoff from mountain catchments is the main source of water for the rivers (Rabie, 1989). On the other hand, South Africa has one of the lowest conversions of rainfall to runoff.

The average annual rainfall for the country as a whole is only 497 mm, compared to a world average of 860 mm (Department of Water Affairs, 1986). Rainfall is also unevenly distributed, with 65 % of the country receiving less than 500 mm of rain annually and 21 % receiving less than 200 mm. The total runoff for South Africa is estimated at 53 500 million m³ per annum, of which about 33 000 million m³ (62%) could practically be exploited (Department of Water Affairs, 1986). To yield the maximum quantity of water of the highest

possible quality, without reducing plant cover and the variety of the species, optimal management of mountain catchment areas becomes necessary (Rabie, 1989).

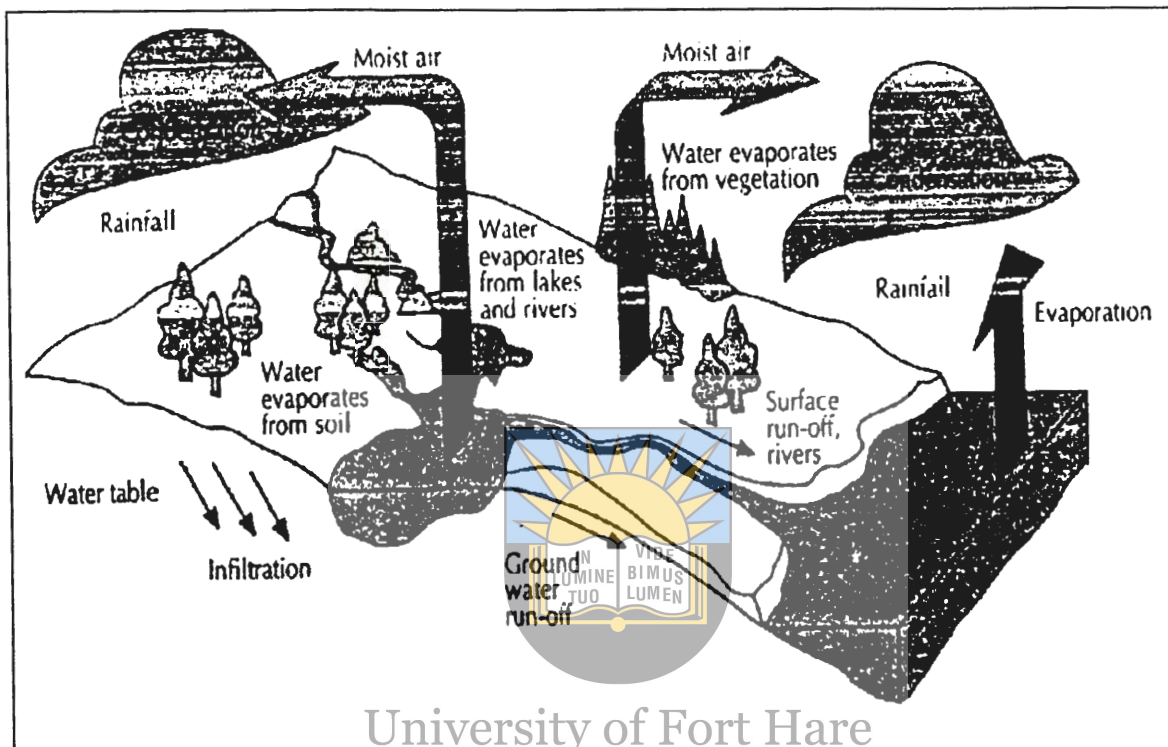


Figure 1 The Water Cycle. Source: "Conserving Water", The Star, Johannesburg, March 1996

The River Ecosystem

Rivers are complex four-dimensional systems, comprising longitudinal, lateral and vertical spatial components, and time-scales within which communities must exist and respond to environmental variables (Ward, 1989; Poff & Ward, 1989). All rivers transverse multiple geographic boundaries, which introduce numerous factors such as altitude, climate, topography, geochemistry, hydrology and catchment land-use to the already complex dimensions and system (Davies & Walker, 1986). All these, in turn and by combination influence the distribution of species, communities and habitats (Minshall *et al.*, 1983; Ward & Stanford, 1989).

Although rivers take up a small % of the land surface, their impact on landscape development extends beyond the channel itself. Whilst eroding and shaping their own channels, rivers also convey the water and sediment, which is carried off the hill slopes (Rabie, 1989). Rivers are

therefore ultimately responsible for the long-term evolution of many of the world's landscapes. Fluvial processes can be all too easily affected by human activity, either directly within the channel or indirectly on the hill slope. This, therefore, means that an understanding of fluvial processes is necessary for the sustainable management of drainage basins and their river channels (Rowntree & Dollar, 1996).

Humans are the intermediaries between the destruction, management, and the integrity of any ecosystem. Humans are also the architects of their survival through the methods of exploitation of resources in their environments. Rivers and their catchments are valuable resources and because of this, their exploitation is inevitable (Rowntree & Dollar, 1996). In the Eastern Cape pressures on the land have led to significant increases in the amount of water-borne sediment in the former homeland areas. These pressures are due to the general lack of effective conservation measures, **overgrazing** and the mismanagement of cultivated lands (Rowntree & Dollar, 1986).



Thousands of organisms sustain the essential biotic functioning of river ecosystems and are important for maintaining water quality. It is, therefore, safe to concede that if the viability of a river is to be conserved as a sustainable resource, it is essential to take into account the geomorphological processes, which maintain it and learn to manage the river in such a way that the impact on these processes is minimised. To understand the geomorphology of our rivers it is necessary to consider both the natural conditions and the extent to which they have been impacted by human settlement (Rowntree & Dollar, 1996).

River Channel Morphology And Its Related Vegetation Types

Depending on geomorphological characteristics, a generalised cross-section of a river reveals numerous habitats that depend on some form of river flow. River channels, according to Hupp (1990), are generally composed of six units. These are the channel bed, channel bar, channel shelf or berm, channel bank, bank edge and flood plain. Within each are populations and communities that interact, both actively and passively, by movement of the organisms between the channel and the adjacent riparian floodplain system, as well as by exchange of nutrients and organic matter (Ward, 1989, 1992).

The channel bed of a perennial stream is the surface that is wholly or partly covered by flows below mean discharge. Thus, at least part of the channel bed of a perennial stream is inundated at all times (Hupp, 1990). In contrast, the channel bar is an area of accretion raised slightly above the mean low water levels. This part of the channel is inundated for about 40 per cent of the time (in perennial streams) and provides a habitat for herbaceous plants such as reeds and herbs, which are rooted in the substrate.

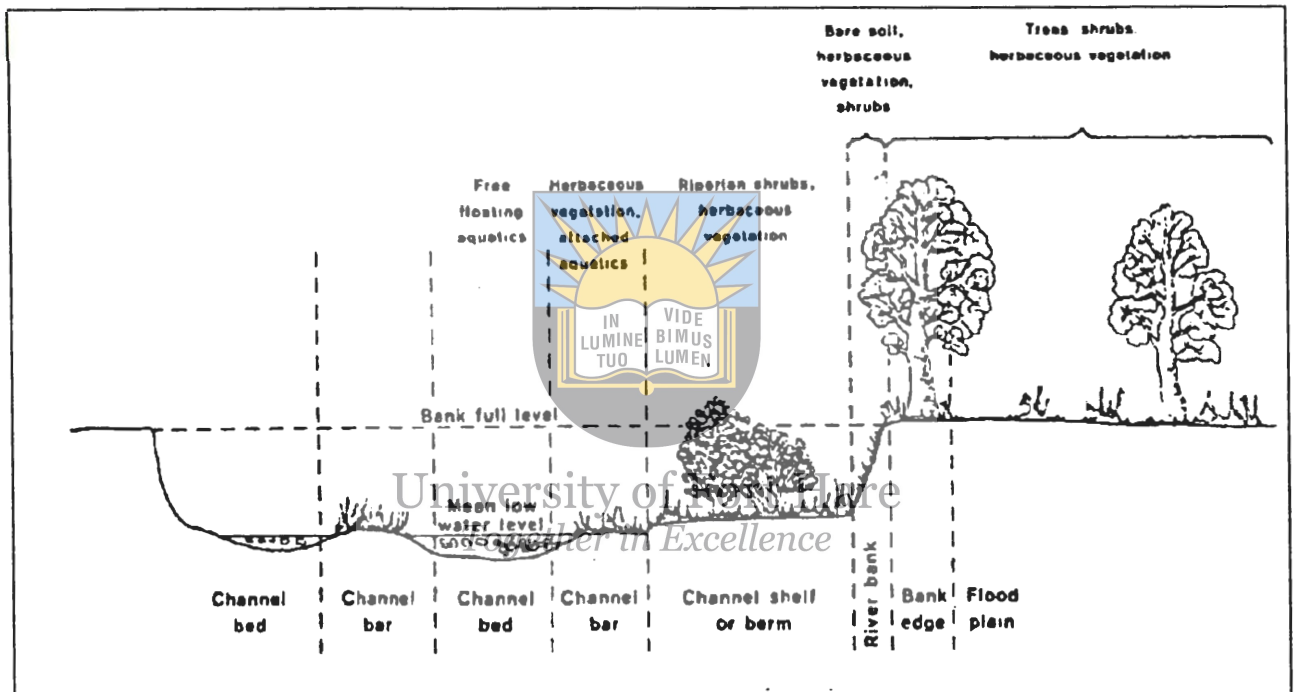


Figure 2 Riverine geomorphic features and associated vegetation types (Hupp, 1990)

The channel bed and bars are the areas most affected by sediment transport processes and undergo continual modification due to scour and depositional processes. The degree of erosion or deposition depends on the balance between the erosive force of the flow and the erodibility of the substrate, both of which can be affected by vegetation (Rowntree, 1991). The erosive force of the flow is affected by the aerial parts of the vegetation through its effect on boundary roughness. The vegetative parts projecting into the flow increase flow resistance (Cowan, 1956; Petryk & Bosmajian, 1975). In homogeneous stands of vegetation the effect is to reduce velocities, dampen turbulence and aid deposition, whereas for isolated plants or groups of plants, the increased flow vortices around the obstruction may lead to local scour. This is especially true of woody vegetation (Thorne, 1990).

The channel shelf, a riparian feature, is an accretional feature which lies between the low water channel and the river bank. It is inundated for 5 to 25 per cent of the time and provides habitat for herbaceous vegetation and riparian shrubs (Hupp, 1990). The channel shelf also protects the banks from basal erosion and trees growing here can aid stability through slope buttressing and soil arching (Thorne & Osmand, 1988; Rowntree, 1991). However, due to increased roughness, dense vegetation may reduce channel capacity during floods, leading to more frequent over bank flows (Eschner *et al.*, 1983).

The river bank is the morphological unit which separates the main channel from the flood plain. The slope gradient of this area varies from nearly vertical to gently sloping. Steep banks are generally devoid of vegetation whereas moderately to gently sloping banks may be covered with grass or shrubs. The bank edge is described as the strip immediately adjacent to the bank. It is the zone where vegetation has a direct impact on bank stability and extends for a few metres beyond the bank. Bank vegetation will reduce nearbank velocities, decreasing shear stress on the banks and promoting sediment deposition on the channel shelf. The roots of the vegetation here bind the soil, increasing its resistance to erosion by one or two orders of magnitude (Smith, 1976; Gray & MacDonald, 1989; Thorne & Osmand, 1989). To be effective against erosion, the vegetation must extend to at least the average low water plane; otherwise the water will undercut the root zone during high flow events (Rowntree, 1991).

The flood plain is the more or less level surface, which is inundated at frequencies of between 1 and 3 years for rivers in humid areas, possibly less frequently in semi arid-areas. Although inundated infrequently, flood plains can be considered to be part of the active channel as they are continually being altered through processes of erosion and deposition. Flood plain vegetation may include the full range of life forms from herbaceous plants to trees (Rowntree, 1991).

Hydrological Processes in River Channels

Natural sediment production is related to rainfall, slope gradient, soils and vegetation. High potential sediment production occurs as a result of the combination of highly erodible soils, a sparse vegetation cover, dense rural settlement and steep valley side slopes due to a rejuvenated system (Rowntree & Wadeson, 1999). Water entering a catchment becomes intercepted by vegetation and subsequently evaporates or reaches the ground surface as

through-fall and stream-flow. In the absence of vegetation, the precipitation reaches the ground directly, although interception by surface litter may still occur. At the soil surface, water infiltrates the soil or is retained as surface storage. The surface water may move downslope as surface run-off or may slowly evaporate. The river channel receives variable contributions of surface run-off, through-flow and inter-flow, and base-flow which are routed down-stream and together contribute to the time-variant out-flow hydrograph of the drainage basin.

Surface water that moves through this system of stores and transfer pathways, can in the process modify its quality. Often the quality of the water leaving the drainage basin will be considerably different from that of the moisture entering the catchment as precipitation. It should be noted that there are many processes controlling stream water quality. If this delicate balance is slightly modified in the catchment, such a change might generate significant changes in the functioning of the river thereby changing the quality of the water.

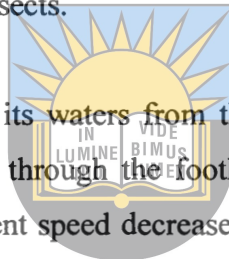
The quality characteristics of surface run-off consists of two main process mechanisms: firstly, the incorporation of soluble material at the surface and secondly, the entrainment of sediment particles which may make the water muddy or turbid and produce high suspended sediment concentrations. The entrainment of sediment particles is, according to Gower, (1980) clearly related to the processes of sheet and rill erosion, which in turn depend on the energy associated with the raindrop impact and the erodibility of the soil.

Discussions on these erosion processes are traditionally associated with downslope movement of soil particles, but in the water quality context, attention must be focused on the transportation of material in suspension and the resultant sediment concentration in the water. In addition, the sediment particle size characteristics may be of significance, particularly since adsorption mechanisms are preferentially associated with fine-grained material and colloids. Changes in particle size characteristics of the sediment transported in surface run-off, may also result from deposition, where flow velocities are reduced by vegetation or decreased slope.

The River Continuum Concept

Davies and Day (1986) classified the river into three ecological units. These are namely, the upper, the middle and the lower zones.

The upper zone, found at the tops of the mountains is characterised by clear fast-flowing water free of silt. The water is rich in oxygen because as it tumbles over boulders and stones, it incorporates bubbles of air from the atmosphere. Trees may cover the slopes, forming a canopy over the stream so that it is in perpetual semi-shade. Plants growing in this area are characteristically little plants growing under the shade of dense trees on the banks of the river. Animals using these areas for habitat are normally small fish adapted to fast flowing water and feeding on dead leaves and insects.



The middle zone is the zone receives its waters from the mountains (i.e. upper zone). As water leaves the mountains and flows through the foothills its bed widens as more water arrives from tributaries, while the current speed decreases owing to the gentler slopes of the bed. The effect of the gentler slopes causes the water to have less oxygen. Even though trees may still line these middle reaches, the stream is wider so that some sunlight reaches the water and consequently makes the water warmer. Patches of vegetation can occur where sufficient sediment has accumulated between rocks, for example, reeds. Water in this zone is slightly more turbid compared to the upper zone, as there is more soil on the riverbanks that can be washed into the river. Because the current speed is lower and the streambed tends to be smoother, the water is less turbulent so that less oxygen is available. This zone therefore supports a reasonable amount of both animal and plant life.

The lower zone is characterised by low slope. The slow-flowing water no longer erodes sediments but begins to deposit the particles it is carrying. Because the water is less turbulent, the water has a very low oxygen content. This zone is more exposed to light than all the other zones. This therefore means that the water receives more sunlight (but can be reduced by sediments) and can therefore support a lot of vegetation and animal life, as it is indicated by Table 1 below.

Table 1 Characteristics of river ecological zones (Adapted from Day *et al.* in O’Keeffe, 1996)

Zone	Physical	Vegetation	Animal
Upper	<ul style="list-style-type: none"> - steep slope - fast, cold, clear -high oxygen content - rocky bottoms - low nutrients -little sunlight 	<ul style="list-style-type: none"> - little -low nutrient and lack of sunlight which is blocked by dense trees on the banks of the river 	<ul style="list-style-type: none"> -adapted to fast water -small fish -plenty of insect larvae -fish feed on insects and dead leaves
Middle	<ul style="list-style-type: none"> -shallow slope -slower, wider -warmer -less oxygen -less rocky -more nutrients -more light 	<ul style="list-style-type: none"> -much more vegetation -some reeds 	<ul style="list-style-type: none"> -large fish -molluscs -insects
Lower	<ul style="list-style-type: none"> -lower slope -slow, wide muddy bottom -high nutrients -low oxygen -lots of light (can be reduced by sediment) 	<ul style="list-style-type: none"> -more vegetation -larger 	<ul style="list-style-type: none"> -large and small fish -more fish species -many bottom feeders



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Catchment Preservation

There is a close relationship between soil conservation, vegetation and the (harvesting) quality of water from catchment areas. Soil conservation is promoted by dense vegetation, which inhibits soil erosion, delays storm run-off and encourages infiltration. However, because plants need water to sustain themselves and some of the water is lost through evaporation and low rainfalls, there tends to be a decrease in the total runoff. This, therefore, means that there is more runoff from bare soil surfaces, but because of reduced infiltration, flood peaks are raised and percolation, which feeds the rivers during dry seasons, is decreased, and the runoff is consequently less sustained. Increased soil erosion from bare surfaces greatly aggravates the silting of storage works (DWAF, 1986).

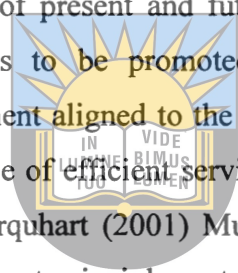
The state of catchment conservation, with reference to vegetation cover, farm practices etc. has an important bearing on sediment loads of rivers as well as on evaporation capacities of filled gullies and subsequently exposed water surfaces. Where vegetation cover is satisfactory and rainfall is high, sediment loads are usually low. Tendencies to soil erosion, with consequent increases in sediment content of river water, are in some areas aggravated by the nature of the geology which contributes to silting (DWA, 1986). Siltation of rivers gives rise to turbidity in water bodies. Elevated turbidity is often associated with the possibility of microbiological contamination as high turbidity makes it difficult to disinfect water properly (Van Loon, 1982; *Quality of Domestic Water Supplies*, 1998).

The most important reason for the disturbing condition is the deterioration in the state of conservation in many catchments and drainage areas found in primitive and inefficient farming practices, which are still being applied in the country. An example is the seasonally injurious burning of mountain slopes, which exposes the slope surfaces of river headwaters and allows increased surface runoff at the onset of rainfall. This is further exacerbated by injudicious ploughing and planting of less retentive root crops. The logging of trees also has an effect with regard to bank erosion, which can eventually increase sediment loads in the water (DWA, 1986).

It is encouraging that official efforts to change the status quo are forthcoming. The Department of Environmental Affairs is developing a catchment bio-system management

model, which is aimed at obtaining the maximum production per unit of water, the optimum preservation of the natural ecology and minimisation of soil erosion. However serious deterioration is still occurring in some catchments where the Agricultural Resource Conservation Act 1983 (Act 43 of 1983), the Forest Act, 1984 (Act 122 of 1984) and the Mountain Catchment Areas Act, 1970, are not actively implemented (DWAF, 1986).

Water resource management in South Africa has recently gone through a period of change. This is reflected in two fairly new acts, the Water Services Act (Act No. 108 of 1997) and the National Water Act (Act No. 36 of 1998). The National Water Act recognises that sustainability and equity are fundamental principles in the protection, use and control of water resources. Basic human needs of present and future generation should be met and social and economic development is to be promoted through the use of water and establishment of sustainable development aligned to the principles of Agenda 21. Both acts are essentially founded on the principle of efficient service delivery and the sustainable use of natural resources. According to Urquhart (2001) Municipalities are legally required to comply with the sustainable development principles set out in Section 16 (4) b of National Environmental Management Act (Act 108 of 1998).



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There are a number of implications regarding water if local communities who are dependent on this water do not adhere to the stipulations of the acts. Water abstractions in the upper reaches will decrease the quantity of water available to the people down-stream. On the other hand, runoff from agricultural lands will decrease the quality of the water by introducing sediments and residues from the use of pesticides into the water.

Pesticides carry nitrate which cause significant nitrate contamination of drinking water. The potential health risk of nitrate in water has led to increased stringency in nitrate monitoring of water because it can be reduced to nitrite, which has been linked to the conditions known as methaemoglobinemia in infants and pregnant women (Bush & Mayer, 1982; Canter, 1987). High nitrate levels also stimulate algal growth (Fried, 1991; WRC, 2000) and also play a role in eutrophication (Fatoki *et al.*, 2001).

Phosphates are equally undesirable anions in water. Though they normally do not pose a health threat in domestic water, they are the limiting factor in eutrophication and result in adverse ecological effects that could render the water unsuitable for other uses (DWAF, 1986; WRC, 2000).

The Effect of Change in the Natural Catchment System

Ongoing discussion has established that the natural state of the catchment can be affected by a number of factors either directly or indirectly. Very often these effects lead to the erosion of soil in the surrounding area either on the banks of the river channel or outside the banks. Such erosion may finally lead to increases of the sediment loads in the water in the channel and in some instances may also have an effect on the quantity of water found. The reason for the decrease in quantity is the increased surface area of the water that is susceptible to evapotranspiration.



Channel processes are particularly significant in controlling suspended sediment concentrations in stream-flow through the process of erosion and deposition. Bank erosion may occur during flood events as a result of increased water storage and velocity. This can provide a very important source of suspended sediment, which in many streams may outweigh the supply associated with surface run-off. Where deposition occurs, suspended sediment concentration will decrease and selective deposition of the coarsest fraction will cause a shift in the particle size distribution (Davies *et al.*, 1993).

From the headwaters to the mouth of any river, there is a gradation of physical and chemical conditions that elicits a series of responses within the constituent population, which in turn, results in a continuum of biotic adjustments and consistent patterns of loading, transport utilisation and storage of water and matter along its length (Davies *et al.*, 1993).

It is necessary at this stage, to consider the history of erosion in the development of the South African landscape and sift any benefits, if any, from the process through to the natural environment.

Soil Erosion

Soil erosion is a gradual natural process that occurs when the actions of water, wind and other factors eat away and wears down the land, causing the soil to deteriorate or disappear completely. It becomes a problem when human activity causes it to occur faster than under natural conditions. Soil erosion is and has always been a serious environmental problem in Southern Africa (Stocking, 1978). This is particularly so in eastern Southern Africa with agriculturally based communities in the homelands.

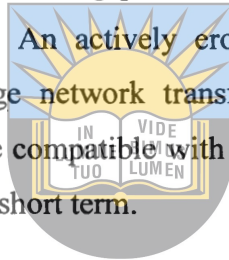
Extrinsic variables such as human interference (e.g. poor farming practices, foot-path erosion) are also cited as important factors contributing to soil erosion, due to the destruction of the topsoil layer (Stocking, 1978; Garland, 1985; Beckendahl *et. al*, 1988 and Marker, 1988). One of the prime reasons for this erosion is the removal or destruction of the protective cover of natural vegetation. There are, however, many other features that render the South African landscape vulnerable to erosion. These are seasonal or periodic high rainfalls, steep topographies, long slope lengths the destruction of the natural vegetation and the occurrence of highly erodible soils (Coetzee, 1995). Almost 60 % of the country is composed of topsoils with very low organic matter content (i.e. less than 5 % organic carbon). Furthermore, over 30 % of the country's soil is composed of sandy soils (i.e. less than 10 % clay) which, according to Scotney and McPhee (1990), are particularly vulnerable to wind erosion.

Braune and Looser (1989) estimate rates of natural erosion in South Africa to be between 0.5 and 1.4 cm per 1 000 years. They further give the rate of accelerated erosion as 1.2 cm per 1 000 years. This implies that the current soil losses may be more than 20 times the rate of soil formation in South Africa. This, according to Van Oudtshoorn (1992), is much higher than the world average of 3 cm per 1 000 years. The Department of Water Affairs and Forestry (1986) estimated the amount of sediment entering South African rivers to be more than 120 million tons annually. These characteristics make the South African landscape extremely susceptible to water erosion and results in the deposition of large amounts of suspended sediment in rivers (Scotney & McPhee, 1990). This pressure is precipitated by an increase in the human population growth in the rural areas coupled with increasing deforestation and agricultural development (Birkhead *et al.*, 1995).

Soil erosion is particularly prevalent in some areas of the former Ciskei (Marker, 1988). As a result, about 47 % of the area is either moderately or severely eroded (Ciskei Commission, 1980). These areas were characteristically areas of high production potential dominated by poor soils, which are easily eroded (Hill Kaplan Scott, 1977).

Forms of Erosion

Erosion can take a numbers of forms, including sheet wash, rilling and gullying (Rowntree, 1988). Sheet wash and rilling represent the means by which sediment is transported across the slope by overland flow. These forms of erosion are regarded by King (1963) and Carson and Kirkby (1972) as important slope forming processes in semi-arid areas. Gullies are in contrast, part of a drainage network. An actively eroding gully represents an unstable landform, which is part of a drainage network transformation (Schumm *et al.*, 1984). Whereas sheet wash and rilling may be compatible with a stable slope system, gully erosion must represent instability at least in the short term.



Schumm *et al.*, (1984) consider gullies to be part of a broader group of incised channels, which include both entrenched streams and gullies themselves. “Entrenched stream” is a term given to the deep incision and widening of a pre-existing channel situated in the gully floor, whereas a gully is an extension of the drainage network into an area where no channel previously existed and, therefore, represents an increase in drainage density, either as an extension of the main channel or as lateral gullies into the valley slopes. The colloquial term ‘donga’ would, according to Rowntree (1988), include both types of incised channel.

Processes Involved in Soil Erosion

Processes involved in erosion essentially entail water and wind erosion and finally the deposition of the soil elsewhere. The following is a detailed description of the different processes as suggested by Rowntree (1998).

Water erosion

There are basically four types of water erosion. These are namely, sheet erosion, rill erosion, gully erosion and stream bank erosion.

- Sheet erosion is the removal of thin layers of soil by water acting on the soil surface. Raindrop splash and surface flow cause sheet erosion, with splash providing most of the detaching energy and flow providing most of the transporting capacity. In the Ciskei, sheet erosion takes place in drier parts of the area, mainly as a result of overgrazing and/or inadequate veld management (Van Oudtshoorn, 1992). Also, larger portions of land which were normally ploughed are often left fallow. This, according to Barrow (1991) results in a decline in soil fertility and eventually soil erosion. According to Dunne (1977), Elwell and Stocking (1976) and Snyman (1986), a ground cover of between 20 and 30 per cent is critical to erosion by sheetwash.
- Rill erosion is the most common form of erosion. It occurs mostly on recently cultivated soil where runoff water concentrates in streamlets as it passes downhill. This water has a much greater scouring action than sheet flow and can move soil from the edges and beds of the streamlets. Rills frequently occur in relatively straight lines between crop rows or along tillage marks.
- Gully erosion occurs when run-off in the rills become deeper and wider and are therefore often regarded as advanced stages of rill erosion. These gullies continue to be active as long as erosion keeps the sides of the channel bare of vegetation, and inactive when they have been stabilized by vegetation.
- Stream-bank erosion occurs following the splash-rill-gully erosion sequence. Following this sequence, fast moving water undermines the outside bank of the channel, causing it to collapse and this results in the widening of the channel.

Wind erosion

Wind erosion, according to Matthee & Van Schalkwyk (1984) is responsible for exceptionally high soil losses in ploughed fields. Even with natural vegetation, in low rainfall areas, soil losses caused by wind erosion may be extremely high. Fine textured topsoil (less than 10 % sand) with sparse cover and under dry conditions, are particularly vulnerable to wind erosion when critical wind velocities (20km/h) are exceeded. During wind erosion soil particles are transported by three mechanisms, namely :-

- creep (rolling along the ground surface),
- saltation (bouncing into air and landing some distance away) and
- suspension (taken up into the air and blown over large distances).

The next phase is the deposition of the soil some place else, except at the place of origin.

According to Branson *et al.* (1981), an important relationship exists between water and wind erosion, vegetative cover and annual rainfall. These are particularly relevant to South Africa since about 60% of the country receives less than 500 mm rainfall per annum (Van Oudtshoorn, 1992). The following relationships are depicted by Fig 3 below.

Curve A represents natural veld and shows water erosion increasing from arid to semi-arid conditions. It therefore decreases as rainfall and vegetative cover improve. Curve B reflects water erosion from bare soil. Curve C and D relate to wind erosion and reflect very different relationships. Wind erosion in arid areas, even in natural veld, can be very severe, especially where sandy soils predominate. When the amount and distribution of rainfall as well as vegetative cover improve, the hazard of wind erosion is greatly reduced, even for bare soil (Van Oudtshoorn, 1992).

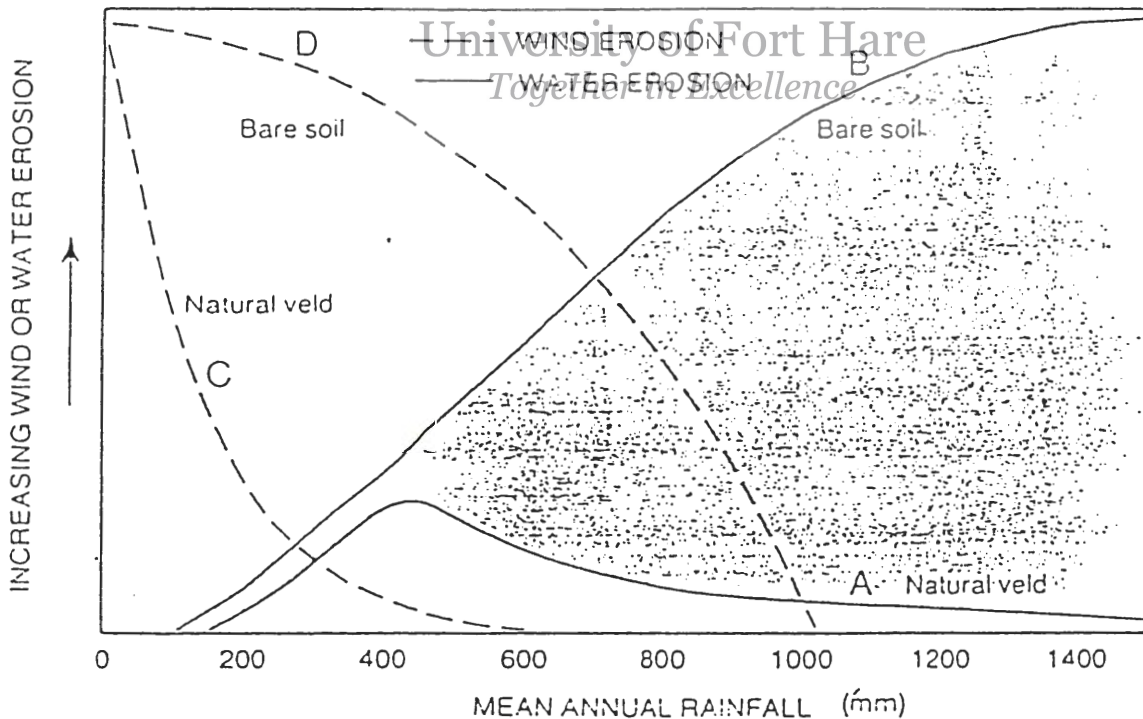
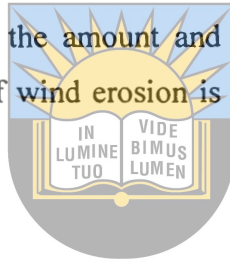


Figure 3 Relationship of water and wind erosion for bare soil (B, D) and natural veld (A, C) with increasing rainfall (Van Oudtshoorn, 1992)

Factors Responsible For Erosion

According to Marker (1988), water is an agent of erosion. Whether water flow, commences as surface or subsurface flow, is determinable. The factors responsible for this, thus, provide primary control on the nature of the subsequent processes operating in, or contributing to, accelerated erosion. The following factors have been considered by Beckedahl *et.al* (1988), as being the factors responsible for erosion:-

- climate (influencing the effectiveness of hydrodynamic or aerodynamic processes),
- rainfall energy,
- parent (or host) material (primary influence being the presence or absence of erodible material),
- vegetation cover (influencing runoff, infiltration, interception, peak discharge),
- nature of surface or subsurface sediment texture (influencing infiltration capacity, infiltration rate, patterns of inter-flow),
- presence or absence of a surface or near surface impermeable layer (influencing infiltration, seepage, solution or dissolution of surface or subsurface materials, and hence the potential for development of surface cracking, piping, tunnels or cavities),
- human interference (overgrazing, building practices, land-use),
- ecological balance (a loose term to describe the extent to which vegetation, land use etc. contribute to disequilibrium conditions), and
- rock strength, which influences the penetration depth and rate of operation of erosion processes.

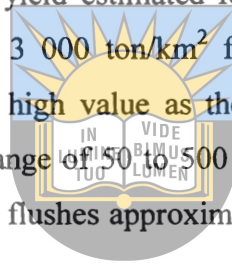
Morgan (1986) also lists the following as major controlling factors of the workings of soil erosion. These are:-

- the erosivity of the eroding agent,
- the erodibility of the soil,
- the slope of the land and
- the nature of the plant cover.

According to Fournier (1972), the average soil loss per rain event increases with the intensity of the storm. However, the amount and intensity of precipitation affect the amount of soil that can be eroded and the volume and flow rate of surface runoff (Soil and Water Conservation Society, 2003). The Soil and Water Conservation Society further state that as the

accumulated quantity of rainfall increases during precipitation event, the capacity of the soil to absorb the precipitation (infiltration rate) decreases and surface runoff ensues. Initially, runoff water flows uniformly across the surface; soon, however, runoff forms roughly parallel rills that coalesce into small channels of concentrated flow, which, in turn coalesce into larger channels, eventually entering a stream. Runoff volume, depth, and flow velocity all increase with increasing volume and intensity of precipitation.

Rainfall intensity and land use patterns however, appear to be the most important determinants of sediment yields due to erosion. A generalized sediment map of Southern Africa has been developed and updated by Rooseboom et al (1992). Perusal of this map indicated that the maximum sediment yield estimated for intensively cultivated areas (and overgrazed areas) in South Africa, is 3 000 ton/km² for one of the Caledon River sub-catchments. This is an exceptionally high value as the sediment yield potential of most catchments is more frequently in the range of 50 to 500 ton/km² per year. The Keiskamma River Basin by comparison, yields and flushes approximately 100 000 m³ of topsoil (silt) to the sea (HKS, 1977).



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Rainfall Intensity

Rainfall intensity is affected by two factors. These are rainfall erosivity and soil erodibility.

- *Rainfall erosivity*

Rainfall erosivity is the potential of rainfall to cause erosion and combines rainfall intensity with the energy of raindrops (Morgan 1986). Erosion is defined as the process of soil particle detachment and movement. Water flowing across the soil surface (surface runoff) is the most important detachment and transport mechanism (Soil and Water Conservation Society, 2003). The erosive power of surface runoff is determined by depth of flow, flow velocity, and the number and energy of particles flowing with the water. The capacity for surface runoff to carry soil particles increases as flow depth and velocity increases. As such Fournier (1972), states that the average soil loss per rain event increases with the intensity of the storm event. High rainfall, often experienced as discrete storm events, results in sudden increases in runoff and therefore sediment transportation. In turn, these cause rapid changes in river levels. Where the volume of the river flow exceeds the channel capacity, the river will over-run the riverbanks and flood the surrounding areas.

According to Wischmeier and Smith (1978), rainfall erosivity is strongly correlated to the product of total rainstorm energy and the maximum 30-minute-rainfall intensity during a storm. During rainstorm events, considerable quantities of topsoil may be eroded from the exposed surfaces and lead to a dramatic increase in the loads of suspended sediment carried in the rivers (DWAF, 1995). Conversely, the progressive decline in rainfall from the wetter to drier months results in declining river flows with lower suspended sediment loads (DWAF, 1995).

- *Soil erodibility*

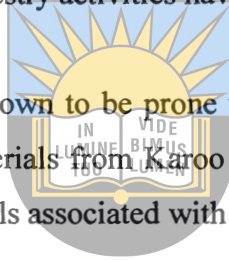
The basic erodibility of soil is the soil loss per unit of rainfall erosivity. The amount of soil removed depends on the steepness and length of slope, the erosivity of rainfalls, the erodibility of soil and the type and degree of vegetation cover (DWAF, 1995). The relative erodibility of different soil types is often approximated as a direct function of the fine sand content. According to Rowntree and Wadeson (1999), soil depth, texture and structure together determine the infiltration capacity, waterholding capacity and permeability of the soil. According to the above authors, the ability of soil to store and transmit water is a major factor in determining storm response and therefore the potential for surface runoff, soil erosion and the generation of storm flow. They further state that soils which inhibit infiltration produce rapid surface runoff and are also prone to surface erosion.

Soil erodibility is also partly a function of the potential of the soil to generate surface runoff, but is also a function of the ease with which soil particles can be detached. The most erodible soils tend to be poorly structured silts and fine sands. The dispersive nature of many South African soils makes them particularly prone to erosion by both surface and subsurface processes (Beckendahl *et al.*, 1988). Non-dispersive clay soils with greater structural development and increased cohesion may be less erodible. Soil organic matter (a component of topsoil) is an important soil constituent associated with increased aggregate stability and decreased erodibility. Organic matter and structural development are to some extent dynamic properties of the soil, which can be significantly altered by land management.

The erodibility of a soil may therefore alter over time. Nonetheless, soils can be broadly grouped by soil form according to their erodibility classes. Schmidt and Schultz (1989) have categorized South African soils according to their hydrological response.

Richter and Negendank (1977) found that soils with 40 to 60% silt content were the most erodible. On gentle slopes, the surface soils are usually freely drained and can have a high potential for agriculture. According to Van Oudtshoorn (1992), soils with above average erodibility should not be cultivated on slopes greater than 3 and 5% and as erosion hazards become serious on slopes greater than 5%. Soils with below average erodibility can be cultivated in slopes up to 6 and 7%. Erosion rates are, generally, accelerated where road cuttings have been incised or where forestry activities have taken place (DWAF, 1995).

Certain geological deposits are also known to be prone to erosion. These are, according to Brink (1985), dispersive colluvial materials from Karoo rocks (e.g. the Beaufort Group and Molteno Formations) and expansive soils associated with weathered dolomite and diabase.



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Effect of Topography

Slope length and steepness are combined in a topographic factor for the purpose of soil loss prediction. Areas with steeper slopes are expected to have the greatest runoff potential with relatively low rates of infiltration, particularly where total rainfall or rainfall intensities are high (Moon & Dardis, 1988). Areas of steep slopes tend to contribute larger quantities of suspended sediments, salts and nutrients to receiving rivers (Rooseboom *et al.*, 1992).

Few studies have examined the influence of vegetation type or cover and slope on erosion. Slope shape (linear, concave, convex), length and gradient are all known to influence erosion. There is also some indication that slopes greater than 15° and 18° do not exhibit greater surface erosion than lower slopes (10° - 15°). Slope form may be more important than slope length with concave slopes, prone to rill and gully formation owing to a convergence of flow (Morgan, 1979). Agricultural activities conducted on areas with intermediate (8-15 percent) and steep (above 15%) slopes can lead to a dramatic increase in erosion potential, which increases with increasing rainfall intensity (Rooseboom *et al.*, 1992).

Landscape slopes less than 8%, tend to have a much smaller run-off potential, with correspondingly greater infiltration (Moon & Dardis, 1988). Provided that the vegetative cover remains intact, they will only contribute significant quantities of suspended sediments and dissolved salts to nearby rivers via surface flow when rainfalls are very heavy. Steepness has greater influence than slope length. For instance, for a 30 m slope length, an increase in slope from 2 to 8 percent will result in a five-fold increase in soil loss. By comparison, an increase in slope length from 30-120 m on a 5 percent slope will result in only a two-fold increase in soil loss.

Land Use Patterns

- **Vegetation Clearing And Clearfelling**

According to Rowntree & Wadeson (1999), vegetation plays an extremely important role in protecting the soil surface from erosion by rain splash and surface runoff. A dense vegetation cover reduces the energy of raindrop impact, thus inhibiting particle detachment and surface sealing and aids infiltration through maintaining a porous surface horizon and improving soil structure through the addition of organic matter. A good vegetation cover can reduce erosion by an order of magnitude when compared to that from bare soil. As the density of the ground cover decreases, erosion increases commensurately, with a sharp increase being observed for cover densities below 30% (Rowntree & Wadeson 1999).

Although the role of vegetation is recognised as being critical, the relationship between vegetation cover and erosion rates is difficult to quantify. The protective effect of vegetation depends not only on the percentage cover *per se* but also on the species composition and the structure of the vegetation. A good ground cover of grass is far more effective than the equivalent aerial cover offered by shrubs because of the lack of surface protection. Where a ground cover or a litter layer is absent in a forest, the tall trees may enhance splash erosion through leaf drop. These must be taken into account when modelling the effect of vegetation on both storm runoff and erosion.

The influence of vegetation on the distribution of runoff and sediment production is complicated further by the secondary relationship between climate and both runoff and vegetation discussed above. High effective precipitation results in a dense vegetation cover

and high infiltration capacity. This means low runoff intensity and, as a result, low drainage density. Moreover, vegetation influences such aspects as interception, evapotranspiration and soil moisture movement, which further complicates the interrelationship between vegetation and runoff.

The quality of water from mountain catchment (river-source) areas with undisturbed indigenous vegetation has generally been found to be excellent, with all (negative) variables present in low concentrations (Lickens *et al.*, 1977; Swank & Waide, 1988; Lynch & Corbett, 1990; Van Wyk & Lesch, 1992). The effect of vegetation cover is so dominant in erosion control, that it is imperative that the farmer carefully evaluates the effect of his management on veld conditions. Where the vegetation has been removed for purposes of cultivating the land or on footpaths, sediment is delivered to nearby rivers via surface runoff. Generally, vegetation serves to retard runoff and increase infiltration, thereby decreasing concentration time, attenuating flood peaks and increasing the period of flow (DWAF, 1995). This has a direct (positive) impact on water quality as it reduces soil erosion and sediment loads.

The clearing of wooded vegetation has been proved to run counter to the general forestry codes of practice around the world. The major change in water quality following logging or clearfelling of forested catchments is an increase in suspended sediment concentrations (Beasley, 1976; Ursic, 1977; (Campbell & Doeg, 1989).

- **Betterment Planning**

The application of specific agricultural techniques and practices, particularly those causing a sudden change in catchment characteristics, for example vegetation cover, may have dramatic influence on runoff, sediment yield and consequently drainage density. Runoff and sediment yield vary markedly with land use differences between catchments of similar lithology and climate (Richards, 1982). Major differences occur between forest, pasture and cropland, and the contrasts in sediment yield are greater than those in runoff. According to Lusby (1970), an increased bare area in an overgrazed basin could cause a 30% increase in runoff and a 45% increase in sediment yield. Clearly, changes of land use or management will affect runoff and sediment yield.

In South Africa the effects of land use are further complicated by the history of settlement and resettlement of different population groups in the country. The distinction between white owned commercial farms and traditional black homeland areas is important to the understanding of the distribution of land degradation in the country. Severe erosion in the former homeland areas is ubiquitous due to a high density of rural populations combined with a breakdown of the rural economy and local controls on resource use. In the white commercial areas erosion has also been widespread due to a combination of inappropriate farming methods, the use of monocultures and overgrazing. The more arid areas such as the Karoo and Swartland have suffered from particularly severe erosion in the past (De Wet, 1989).

The physical environment of a village, and the pattern of land use, have been substantially transformed as a direct result of the implementation of Betterment planning. The old residential clusters, scattered along the hillsides, and strategically located in relation to resources such as wood, water, arable and grazing land, have disappeared. The village area (was) now divided into three physical separate kinds of areas, which are fenced off from each other, namely, residential, arable and grazing areas, with the boundaries of forest plantations remaining unchanged. In many cases, the result was that people had to walk further to fetch wood or water, or to get to their fields, than they did before Betterment (De Wet, 1989).

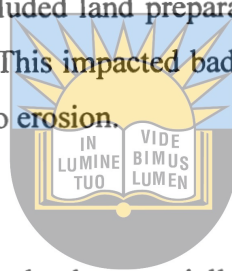
Given that Betterment planning has set aside only a limited area for residential purposes, it would have been a matter of time before the available space in these residential areas was taken up. When the 'surplus' population could not be accommodated elsewhere, the planners had to accommodate them within the rededicated (re-demarcated) residential areas as best as they could. As a result, Betterment could not accommodate an increase in population (De Wet, 1989).

By moving people into concentrated residential areas, Betterment increased human and animal pressure on these areas and as a result has increased rather than decreased erosion. Large sections of the residential areas were devoid of any ground cover (e.g. grass). The fencing off of separate arable, residential and grazing areas meant that it was no longer possible to extend residential areas into grazing land, or to convert arable land into grazing

land, or *vice versa*. By taking the flexibility out of the land use pattern, while not taking away the previous animal or human pressure off the land, Betterment has accelerated the deterioration of the soil it was intended to protect.

- **Migrant workers**

The advent of the migrant worker also brought with it some influence on erosion especially on cultivated lands. Traditionally, men were responsible for cultivating lands, but many male adults sought employment in the cities. It was estimated that 40 to 60 percentage of the male heads of households worked in the urban areas, far away from their homes, thus placing a heavy labour burden on the women, who already had various other household tasks to perform. Tasks especially affected included land preparation and weed control, resulting in lower crop yields (Bembridge, 1987). This impacted badly on the land due to a reduction in vegetation cover and subsequently led to erosion.



Grazing Practices

Grazing can increase erosion from grasslands, especially when stocked near or above their carrying capacities (Owens *et al.*, 1996). The carrying capacity of a veld refers to the potential of an area to support livestock and/or game through the utilisation of vegetation, without the deterioration of the ecosystem in the long term (Van Oudtshoorn, 1992). Maintenance of good vegetative cover on pastureland reduces surface run-off and soil loss when compared with bare or nearly bare soil surfaces.

In a study on soil loss done in Eastern Kenya, Zobisch (1993) showed that 40% grass cover was the level at which soil loss became a problem. Also, many unimproved pastures have livestock-accessible streams that run through or originate within the pastures. In many situations of this nature, much of the soil loss comes from erosion of the grazed stream banks (Davies *et al.*, 1991).

Streambank fencing has therefore been suggested as a management practice. This management practice keeps livestock and streams separate. According to Owen *et al.* (1996) this management practice has proven to have the potential to decrease soil loss by preventing the mechanical breakdown of the streambanks.

Adequate fencing is a prerequisite for controlled grazing, as it does not allow stock to enter other grazing plots, which are to be used later. However for this system to work properly, over-stocking must be avoided. This according to Danckwerts (1989) means that stock allocated per plot size should not be above the carrying capacity of the land. Tainton (1988) defines carrying capacity as the area of grazing land required to maintain an animal in good productive condition for a year without vegetation or soil erosion. The recommended stocking rates given, assume that the carrying capacity of the veld remains constant through time and therefore represents an average condition. The rainfall and the composition of usable plant species occurring in the area is the determining factor of the carrying capacity of an area.



- Rotational grazing

Rotational grazing is the successive occupation of different areas of land by a group of animals during the year so that not all the veld is grazed simultaneously (Tainton, 1981). The most recommended grazing system on pasture lands is the rotational grazing system. The use of different forms of rotational grazing depends upon the condition of the veld and its dominance by Decreaser species, a combination of high production grazing and high utilization grazing veld. Grasses can be classified as increaser and decreaser grass species. Increasers are those grass species, which decrease when the veld is under- or overgrazed. Increaser I's are grass species, which increase with under- or selective grazing, and Increaser II's are grass species, which increase with overgrazing (Van Oudtshoorn, 1992).

When the veld is dominated by Increase 1 species, high utilization grazing must be applied to reverse the grassland succession back to the Decreaser stage and *vice versa*. This system requires that stock be rotated around or between demarcated grazing lands and has come to replace continuous grazing over a wide area which tends to lead to selective utilization of the most palatable species (Dolar & Rowntree, 1995).

Rotational grazing can basically take two forms, namely, High Production Grazing (HPG) and High Utilization Grazing (HUG). HPG is the occupation of a camp by grazing animals until the acceptable and desirable grass species have been grazed to a stage that will ensure

rapid regrowth and a high production of forage. HUG is the occupation of a camp by grazing animals until all grass species have been heavily grazed (Trollope, 1986).

The use of these different forms of rotational grazing depends upon the condition of the veld and specifically the dominance of the different categories of grass species i.e. *decreaser* and *increaser* species (Dollar & Rowntree, 1995). As, such decreaser tend to dominate in good veld but decrease with mismanagement, whilst increaser grass species dominate in poor veld but increase with either overstocking or understocking. Increaser I species would therefore increase with under- or selective grazing, whilst Increaser II would tend to increase with overgrazing (Van Oudtshoorn, 1992).

- Rotational Resting

Rotational resting is the successive withdrawal of camps from grazing on a rotational basis for specific purposes. The principal reasons for resting veld are seeding, restoration of vigour and providing fodder reserve for periods of scarcity, thereby allowing regrowth and subsequently reduce soil erosion.



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A seeding rest and the restoration of plant vigour are applied when *decreaser* species have declined in the grass sward and is appropriate when either *Increaser I* or *Increaser II* grass species dominates the veld. *Themeda triandra* is the most important and widely distributed *decreaser* species in the Ciskei. The applicable rest period for veld in this condition in the Ciskei is from January to January of the next year (Trollope, 1986). In the sweetveld areas, resting the veld to restore plant vigour is practised for a full year. Restoration of plant vigour in the mixed and sourveld areas is comprised by a short period between summer and autumn (January to April).

The implementation of a rotational resting programme is better implemented in a livestock production system where the grazing area has been sub-divided into grazing camps. Under these circumstances, one third of the grazing area would be rested annually in sweetveld areas and for one quarter in sourveld areas.

Soil Erosion Damage

Erosion as a result of man's activities, has been so severe that the recent decrease in sediment yield can be ascribed to the reduced availability of erodible material as a result of the washing away of alluvial valleys and the stripping of topsoil from sensitive soil profiles (DWAF, 1986). The most apparent damage caused by water erosion is the removal of soil from erodible surfaces. While erosion from land, covered with trees and grass amounts to only a fraction of a ton per hectare annually, erosion caused by cultivated fields may exceed 450 metric tons per hectare a year (Grant, 1975). The loss of any soil is cause for concern, but the topsoil is the most important component of the soil. The topsoil is also said to be more friable and more permeable to water, air and roots than deeper soil material and it contains more organic matter and has greater fertility than the subsoil.

Soil Erosion and Soil Type

Soils in the Ciskei are predominantly underlain by mudstones, sandstones and shales of the Beaufort Series (HKS, 1977). These have in some areas been penetrated by Karoo dolomite in the form of sills and dykes. According to the above study, because of the resistance of these soils against weathering, these intrusions often rise above the surrounding landscape and give a characteristic rocky outcrop. There is a significant difference between erosion of soils underlain by dolomite and those underlain by shales and mudstones of the Beaufort group. Mudstone are according to Mountain (1952) and Berzak (1986), often more heavily eroded than shale. Soils with a high clay content and a well structured A-horizon (e.g. Milkwood, Mayo, Arcadia and Shortlands) tend to show relatively low levels of erosion.

Duplex soils with restrictive horizon (e.g. Valsrivier and Sterkspruit) and shallow soils with low permeability (Mispah and Glenrosa) exhibit higher levels of erosion (Eloff, 1973; d'-Huyvetter & Laker, 1985). Sheet, rill and gully erosion are especially prevalent in the eastern parts of the Karoo (e.g. near De Aar and Middleburg). This is because of the association of these erosion types with duplex soils with poor surface infiltration and dispersed subsoils (Ellis and Lambrechts, 1986).

Soil Erosion and Vegetation Type

The importance of the structure and composition of the vegetation in controlling erosion has been stressed by a number of authors (Roux, 1981; Thornes, 1985). Comparing erosion losses from slopes, Roux (1981) substantiated the widely held belief that a grass cover is more effective against sheet erosion than shrubs. Selby and Hosking (1973) pointed to the importance of separating the effects of vegetation on runoff generation and surface resistance when considering gully erosion. Like Roux (1981), they found that, compared to scrub, grassland provided greater resistance to simulated gully erosion, but also produced a greater runoff volume and was therefore more intensely gullied.

The Moist Upland Grassland (Acock's Dohne Sourveld) comprises a dense grassland with a basal cover exceeding 30 % (Acocks, 1975). This veld type is often evident in disturbed, ploughed or heavily overgrazed and degraded sites (Lubke *et al.*, 1988). Poor grazing management of these grasslands encourages unpalatable grasses and the invasion of herbaceous weeds. This vegetation type is therefore highly susceptible to erosion. The other three vegetation types Acock's False Thornveld, Eastern Province Thornveld (Low & Rebelo's Eastern Thorn Bushveld) and Acock's Valley Bushveld (Low & Rebelo's Valley Thicket), exhibit less distinctive patterns in the frequency distribution of erosion.

Perhaps the most noticeable feature of these vegetation types is that the Eastern Province Thornveld soil has the most minimum erosion surface. The invasion of the grassveld by Acacia Karoo in the False Thornveld areas has been linked with overgrazing (Acocks, 1975). According to Trollope and Coetzee (1978), False Thornveld areas are covered mainly by inferior vegetation and are commonly found in the most badly eroded areas of the former-homeland, Ciskei.

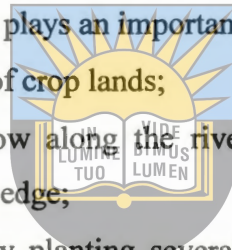
The qualitative effects of vegetation are notably, the well recognized: protection of the soil from raindrop impact, increase in infiltration rates both through improvements in soil structure and utilisation of soil moisture, and increased resistance of the soil surface to erosion (Thornes, 1985). Thompson (1935) also showed that grazing of erosion plots is

thought to be good at maintaining species diversity and also enhances the resilience of the soil and vegetation against degradation (McCabe, 1987).

Best Management Practices (BMPs) for the Management of Erosion

There are several accepted BMPs used for the control of erosion both by wind and water. These following is an account of the different methods as documented by Collins (2001):-

- The use of contour ploughing and wind breaks;
- Leaving unploughed grass strips between ploughed land;
- Making sure that there are always plants growing on the soil, and that the soil is rich in humus (decaying matter and animal remains). Organic matter is regarded as the glue that binds the soil particles together and plays an important part in preventing erosion;
- Avoiding overgrazed and over-use of crop lands;
- Allowing indigenous plants to grow along the river banks instead of ploughing and planting crops right up to the water edge;
- Encouraging biological diversity by planting several different types of plants together (avoiding mono-cultures);



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Economics of erosion

To understand soil erosion, we must be aware of the political and economic factors affecting land users. According to Collins (2001), the previous apartheid system, in South Africa, ensured that 42% of the people lived on the 13% of land (homelands such as the Ciskei). The subsequent overcrowding resulted in severe erosion. As the land became increasingly degraded and thus less productive, subsistent farmers were forced to further overuse the land. The intensive agriculture and overgrazing that followed further caused greater degradation.

Soil erosion can be seen as both a symptom of under-development (i.e. poverty, inequality and exploitation), and cause of underdevelopment (Ramphela, 1991). A reduced ability to produce, invest one's profit and increase productivity, contributes to increasing poverty, and can lead to desertification, drought, floods, and famine.

The above BMPs can be used to remedy the erosion, however, some of the techniques tend to be very expensive and may never pay for themselves entirely unless there is support from the government. Partnerships can be established between communities and Local Government in implementing mechanisms for tackling the problem of erosion



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MATERIALS AND METHODS

Site Selection

Five small catchment areas were selected for study within the Keiskamma River Basin (Fig 4). The criterion for the selection of the catchments was to enable coverage of a wide variety of physical and environmental variables. The rationale behind this was to assume that each stream draining a catchment area reflected in its sediment concentrations, the rate of erosion in the catchment (Davies & Day, 1986). In order to gain accessibility and to be able to properly survey the area, the size of the catchment was taken into consideration.

The first site Saki, was 13.5 km away from the University of Fort Hare (Plate 1). The second site, Ngqele, was about 7 km from the University of Fort Hare (Plate 2). The third and fourth sites are 27 km from the University Fort Hare on the way to Hogsback. The two sites are a distance of 800 m away from each other. Please refer to Plates 4 and 5 for photographs of Hogsback 1 and Hogsback 2 respectively. And lastly, Zingcuka, is approximately 7 km from the Sandile Dam (Plate 5).

Table 2 below gives information on the total extent of each site and the relevant co-ordinates.

Table 2 Site names, co-ordinates and the extent of each site.

Site Name	Location	Area Covered (m ²)
Saki	32°50'20"S & 26°57'45"E	765 676
Ngqele	32°50'21S & 26°57'44"E	171 171
Hogsback 1	32°37'14"S & 26°54'45"E	331 899
Hogsback 2	32°36'53"S & 26°54'25"E	458 251
Zingcuka	23°40'58S & 27°03'54"E	244 550

Keiskamma River Basin

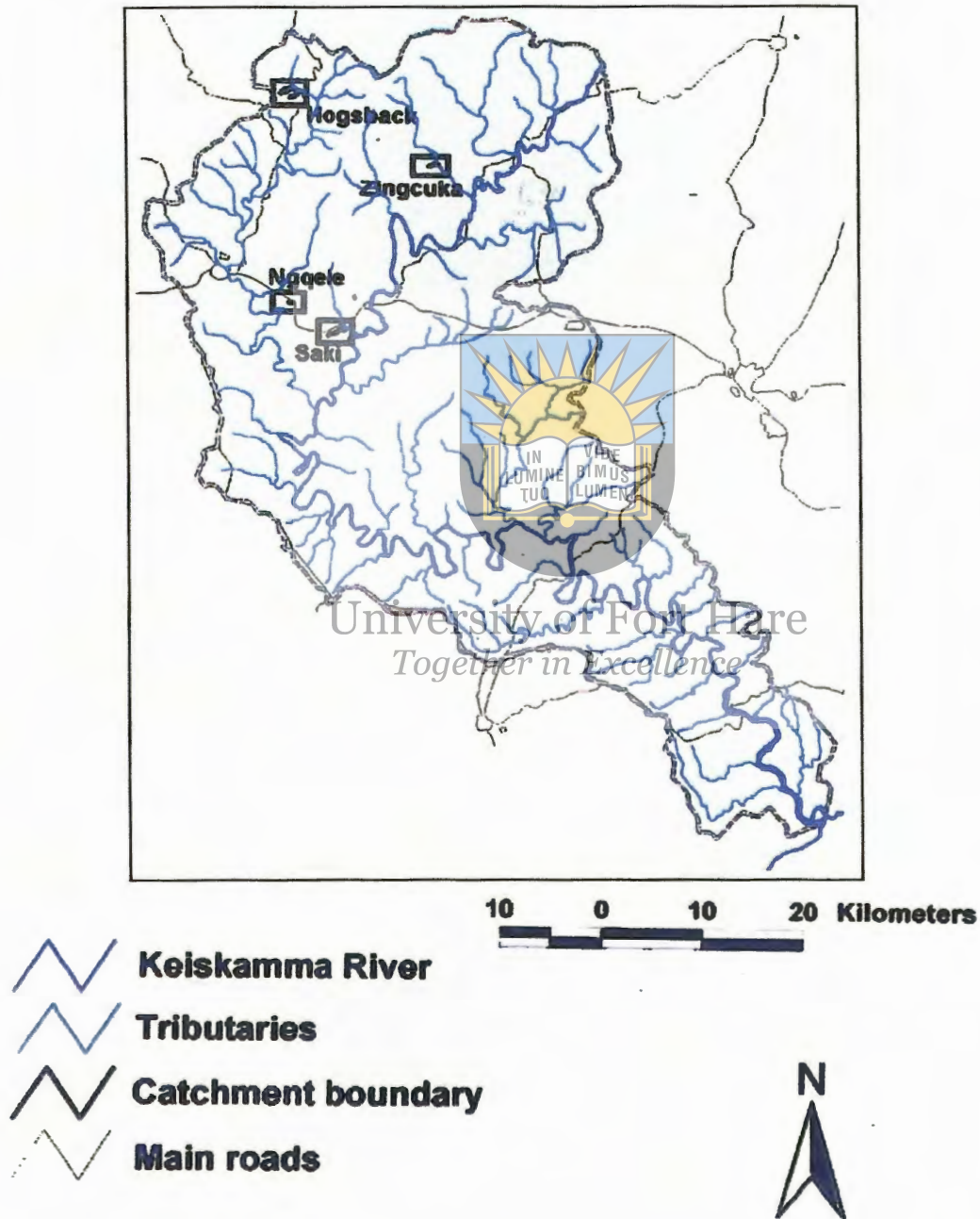


Figure 4

The Keiskamma River Basin with selected catchment areas



Plate 1

Saki Site

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Plate 2

Ngqele Site



Plate 3 **Hogsback 1 Site** University of Fort Hare
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Plate 4 **Hogsback 2 Site**

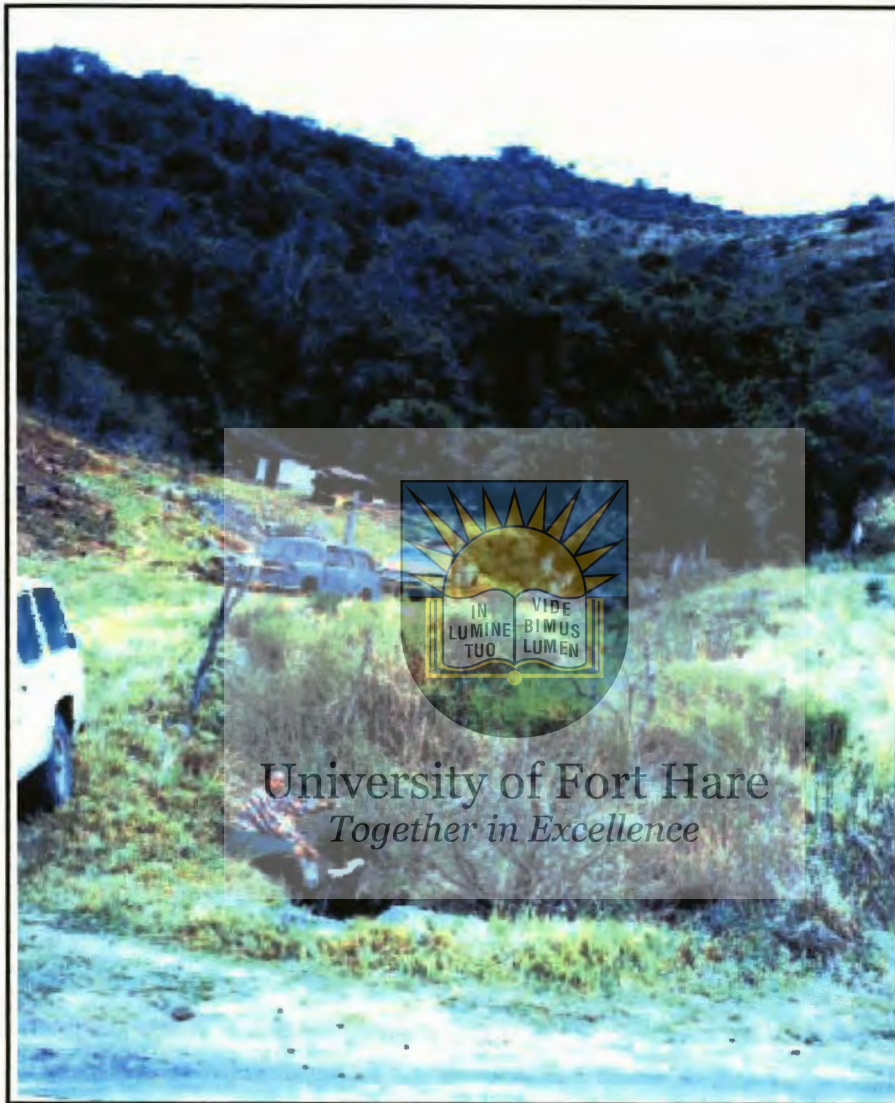


Plate 5 **Zingcuka Site**

Determination Of Sediment Concentrations

Surface water samples were collected from a stream at the base of each small catchment. Sampling was conducted in triplicate for 8 months for two consecutive years. The water collected was used for determining total suspended sediments (TSS). All samples collected were analysed on reaching the laboratory.

A known volume of sample water was filtered under vacuum through a pre-weighed glass-fibre filter (Whatman GF/F) with a pore size of $0.7\mu\text{m}$. The volume of water filtered varied from sample to sample. The more the suspended sediment the less the volume of water filtered and *vice versa*. Filter papers were then dried in an oven set at 105°C for 12 hours (Petts, 1984). On drying, the filter papers were put into a desiccator to cool and then weighed. Total suspended solids were recorded as the increase in weight of the filter paper after drying. Organic matter was burned by ashing the filter papers in a furnace set at 500°C for 5 hours (Tebbut 1992; Dallas, Day & Reynolds 1994; Lesch 1995, Hoffmann 1995). After 5 hours the filter papers were put into a desiccator to cool and subsequently weighed. The values from ashed filter papers allowed for the determination of sediment loads or total suspended sediments (TSS), from which the amount of soil lost from the catchment could be assessed. All tests were performed in triplicate.

Example for the calculation of TSS:-

Weight of dry filter paper	= 0.0375g
Volume of sample filtered	= 320 ml
Weight of filter paper after drying (with filtrate)	= 0.0401g
Weight of filter paper after ashing	= 0.0394g
Total Suspended Sediment (TSS)	= ? mg/l
(Filter with filtrate) - (Weight Dry Filter)	= $0.0401\text{g} - 0.0375\text{g} = 0.0026\text{ g}$
Total Suspended Solids	= $0.0026\text{g} \times 1000\text{ mg}\backslash 1\text{ g} \times$ $1000\text{ml}\backslash 320\text{ ml} \times 1/11$
	= 8 mg/l
(Weight Ashed Filter) x (Weight Dry Filter)	= $0.0394\text{g} \times 0.0375\text{g}$ = 0.0019g
Total Suspended Sediments (TSS)	= $0.019\text{g} \times 1000\text{mg}/1\text{g} \times 1000\text{ml}/320\text{ml} \times 1/11$ = 6 mg/l

Mean TSS values were compared for all the sites and for the main river channel, the Keiskamma River, at Middeldrift.

A regression analysis was performed using a statistical software package called Statistica version 6.0. Scatterplots of TSS against rainfall were produced and these were used to establish if there was a relationship between the amount of rainfall at each site and the amount of sediment produced. Rainfall data used was acquired from the South African Weather Bureau, Pretoria.

Vegetation Survey

Ground Cover

10 x10 m quadrats were selected randomly at each site and these were visually surveyed for ground cover by species (i. e. percentage vegetation cover and percentage bare-ground). Quadrat numbers per site varied between 7 and 12. Sampling of the vegetation was conducted for six months for two consecutive years in all sites. A species area curve was drawn using the Nested Plot Technique (Mueller-Dombois & Ellenberg, 1974). This was done to determine the minimum quadrat size at each site. Percentage ground cover was estimated visually for each plant species falling within the quadrat. To account for 100% of the ground cover, bare patches of land were also estimated and this was termed percentage bare-ground.

The plant samples were pressed and preserved for identification. The plants were then grouped into four categories, namely, grasses, shrubs, trees and herbs and forbs and a species list was compiled (Table 3 and Appendix A). The identification of the plant samples collected was conducted at the Albany herbarium in Grahamstown. The identification was confirmed by comparing the samples with those kept at University of Fort Hare the herbarium located at the Botany Department and those kept at Albany herbarium in Grahamstown.

Grasses generally respond differently to veld management, particularly to grazing by animals. According to Trollope (1986), some grasses will dominate in good veld but decrease with mismanagement. These grasses are called decreasers. Other grasses dominate in poor veld but increase with either overstocking or understocking and this type of grass are termed increasers. Also trees are important channel stabilizers and their removal, especially along

channel banks, can lead to unstable banks. This management system was used to determine management practices at each site. Charts recording the percentage ground cover were produced for each site.

Vegetation Clustering

The multivariate analysis technique was used to summarize the vegetation data. The resultant ordination served to summarize community data by producing a two-dimensional ordination space in which similar samples were close together and dissimilar ones were far apart, i.e. distance = dissimilarity. The basic goal of ordination was to derive ecological space from the data. With standard ordination techniques, this was achieved in a two-step process. Initially ordination was used to summarize community patterns. Secondly, the community patterns were compared with an environmental interpretation of the ordination.

The Detrended Correspondence Analysis (DCA), a CANOCO programme by Ter Braak (1991) was used to describe species distribution and therefore vegetation community patterns at all sites, individually, and at all sites, together. Due to the fact that the study did not consider environmental variables, the DCA became the programme of choice. This was important as the study sites differed greatly with regard to physical and environmental variables.

Land Use Survey

A questionnaire was designed by the researcher to provide answers on the land-use practices at each site (Appendix B). The questionnaire was designed in English, but because the language used by the inhabitants at the sites was Xhosa, the questionnaire was administered in the Xhosa language. To ensure that the content was not misconstrued, questionnaire pamphlets were personally administered by the researcher with the assistance of a Xhosa-speaking science student.

Another advantage of using the translator was that he was familiar with the people's way of life and he knew the best way to approach the people without offending them.

Geographic Information on Land Use Patterns

The Geographic Information System (GIS) ARC/INFO and ARC/PLOT software packages were used to digitize and plot the Keiskamma River Basin with all its major and minor tributaries (Figure 4). The study sites identified were highlighted on this map. Also, detailed maps of each study site were produced (Figures 54-75). Each site had maps showing the stream, contours, vegetation patterns, soil types, erosion patterns, present and recommended land uses in the Keiskamma River Basin during the 1977 Hill Kaplan Scott study. Overlays of erosion patterns and contours; erosion patterns and vegetation types; erosion patterns and soil types; erosion patterns and present land use; and erosion patterns and recommended land use were produced for each of the five study sites.



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RESULTS

Sediment Concentrations

Total suspended sediment (TSS) concentrations varied between and within catchments, dates with no data indicate that samples for TSS had not been taken (Fig 5-9). The values ranged from 1mg/l to 380mg/l. The lowest TSS value (1mg/l) was recorded at the Saki catchment areas during the months of April, May and September and at Hogsback 1 in May. The highest TSS values were recorded at Ngqele and Hogsback 1 in August. Interestingly, it was found that the highest mean TSS values were also recorded at Ngqele and Hogsback 1 (Fig 10). Mean TSS values were compared for all the sites and for a site on the Keiskamma River, at Middledrift, since it was a continuous source throughout the year and is the major tributary within the Keiskamma River Basin. Three sites, Ngqele, Zingcuka and Hogsback 1 recorded TSS values higher than in the Keiskamma River. The other two sites Saki and Hogsback 2 recorded TSS values comparatively lower than that in the Keiskamma River.

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The scatterplots produced did not show any correlation between rainfall and the amount of sediment produced. However, the highest TSS values recorded were mostly during the dry winter months and early spring, for example values recorded in June to August and September were much higher than for other months (Figures 5-10). This is the season of the year where grass cover is poor just before the spring rains.

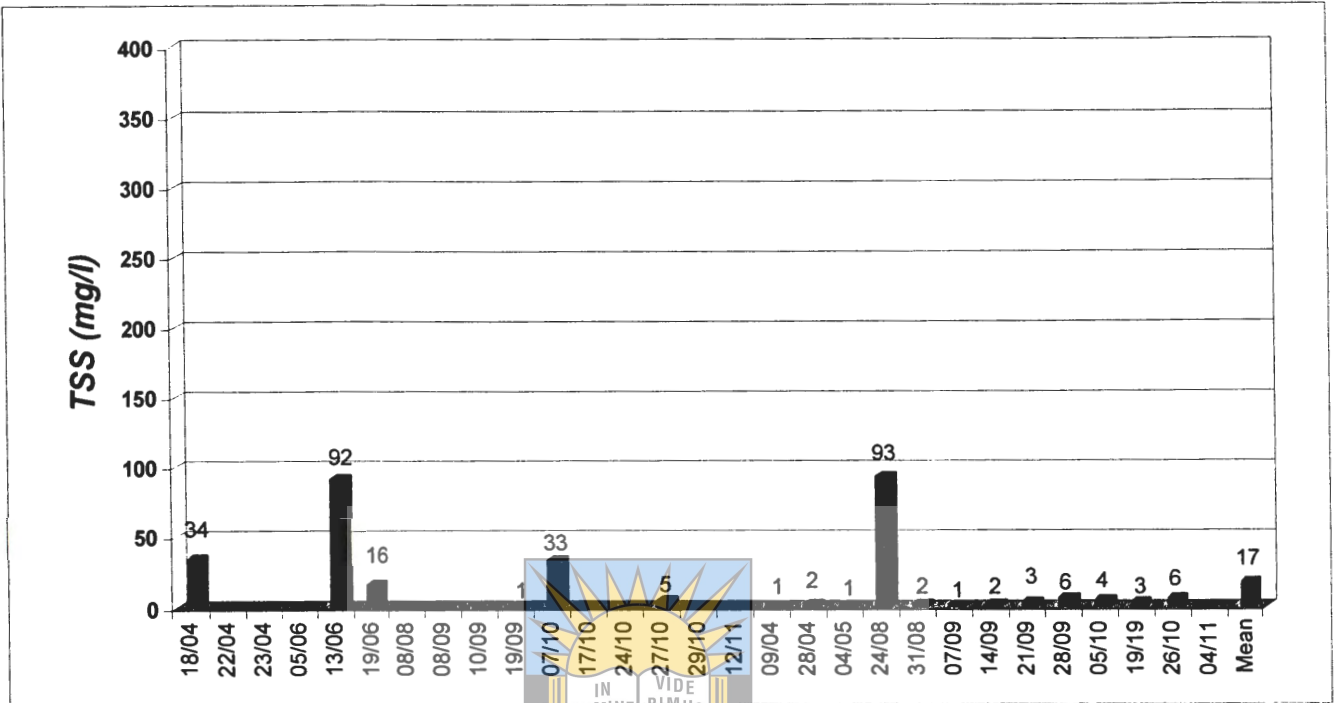


Figure 5

Total Suspended Sediment (TSS) at Saki
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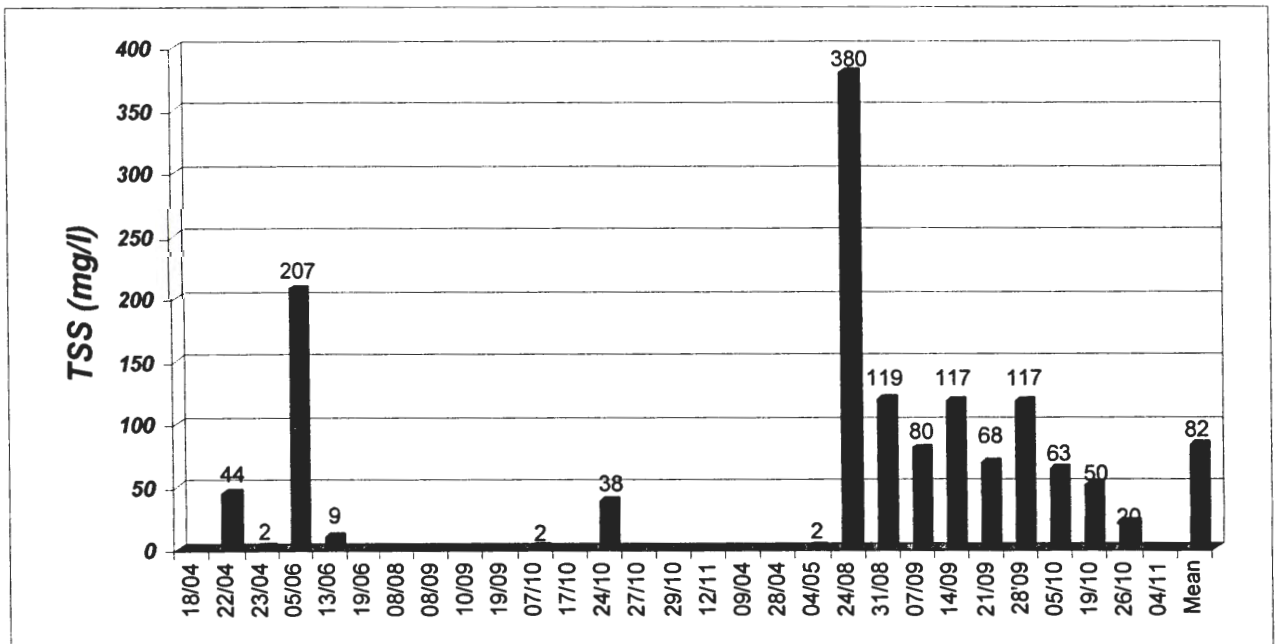


Figure 6

Total Suspended Sediment (TSS) at Ngqele

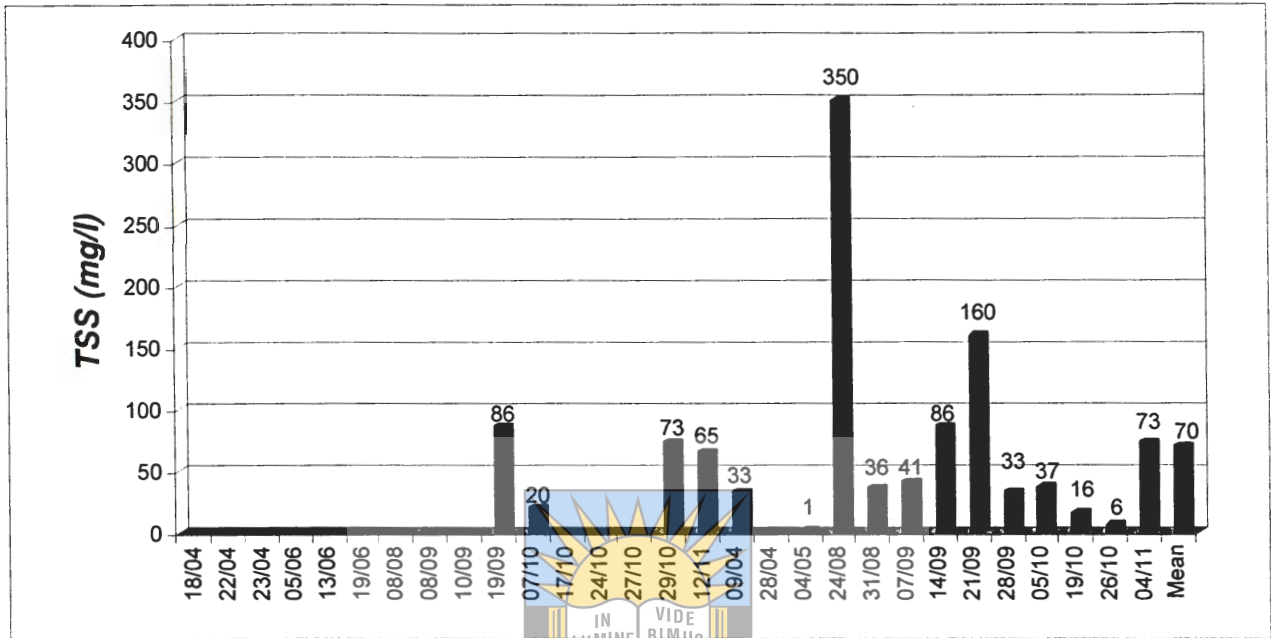


Figure 7 Total Suspended Sediment (TSS) at Hogback 1

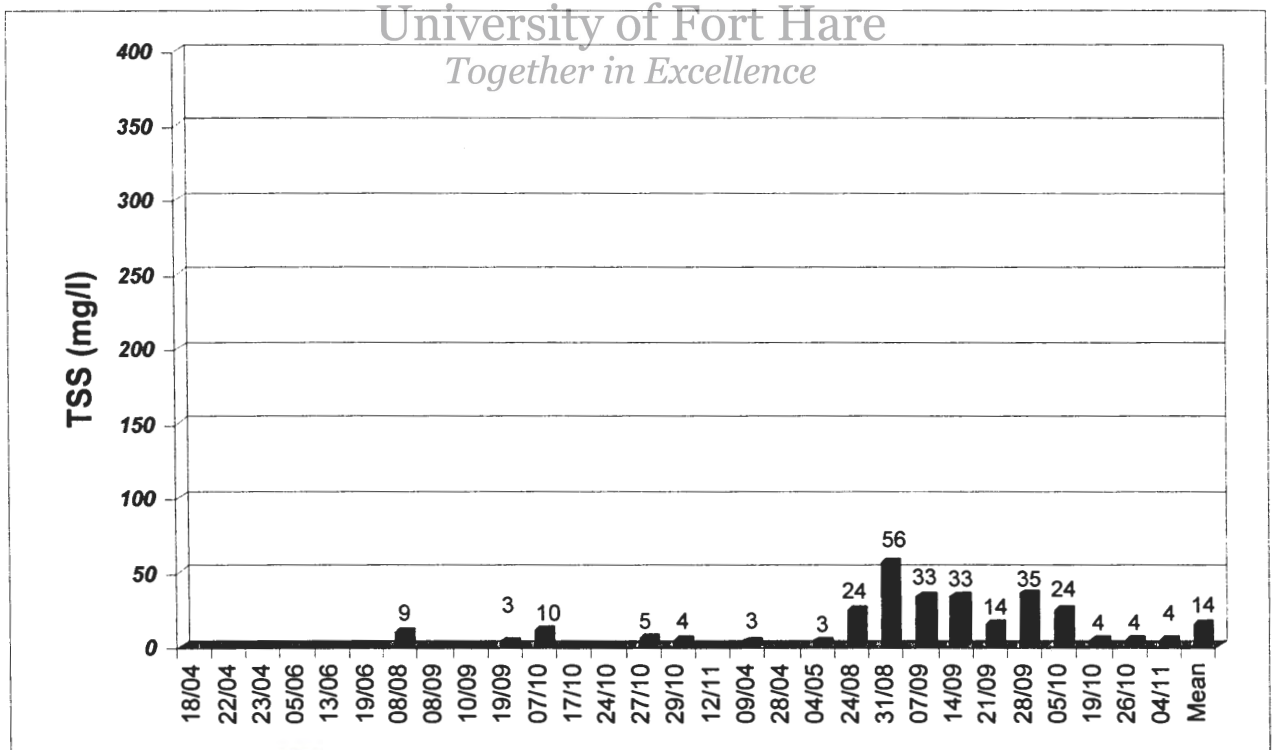


Figure 8 Total Suspended Sediment (TSS) at Hogback 2

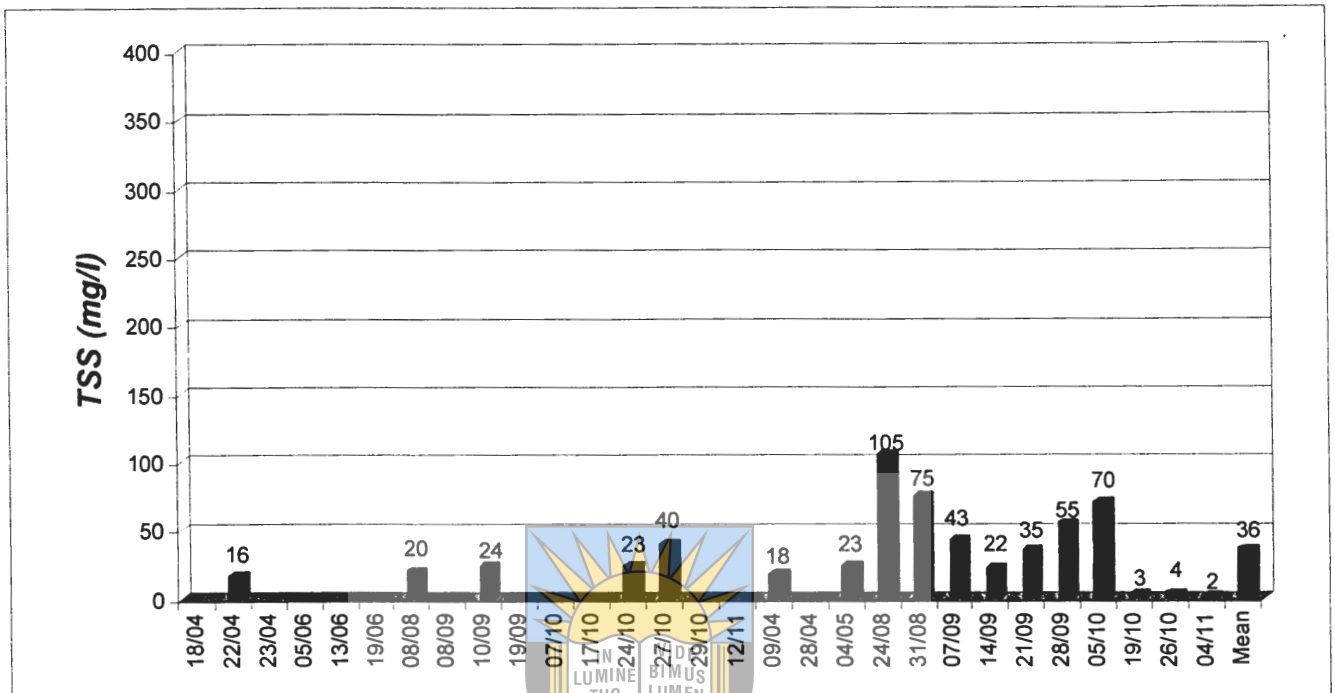


Figure 9 Total Suspended Sediment (TSS) at Zingcuka

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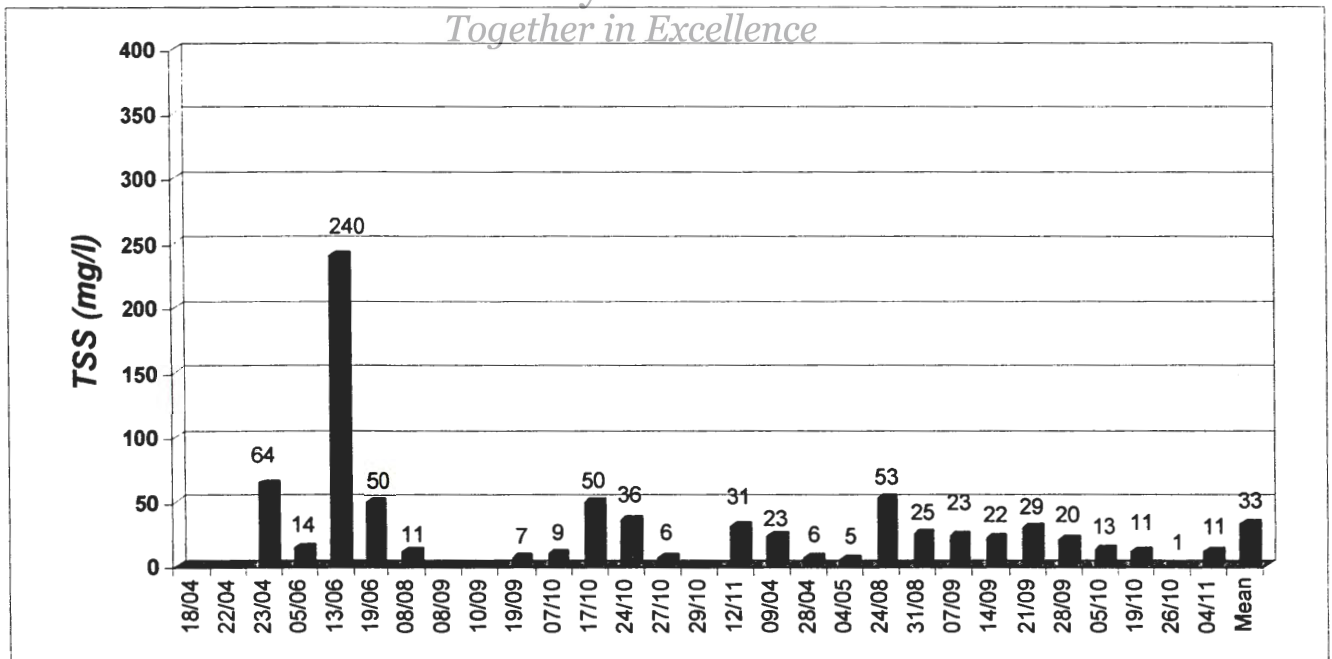


Figure 10 Total Suspended Sediment (TSS) at Keiskamma River in Middeldrift

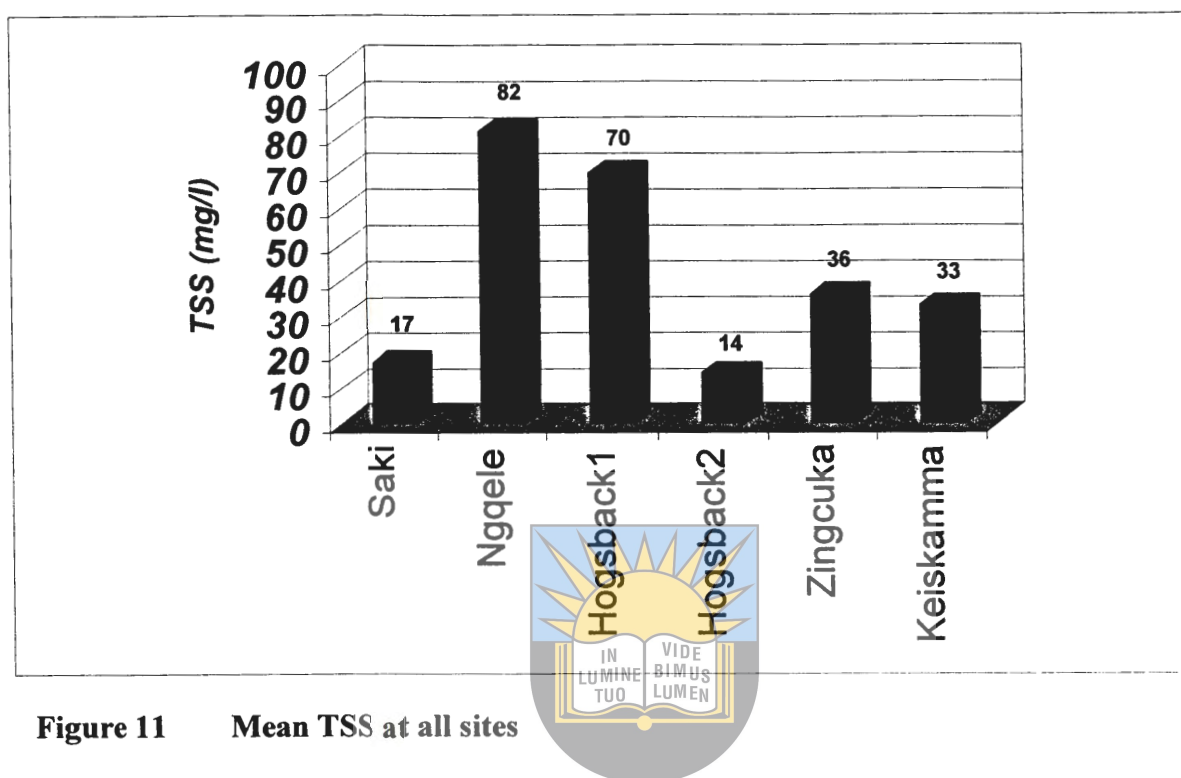


Figure 11 Mean TSS at all sites

Vegetation Analysis

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% Ground Cover

Percentage ground cover and cover type varied from catchment to catchment. The sites with the highest percentage ground cover and consequently the least bareground were Ngqele, Hogsback 2 and Zingcuka (Figures 12-16). These sites also recorded the highest grass cover, at 75%, 35% and 56 % respectively. The highest percentage bareground was recorded at the Saki catchment (Figure 12). The highest percentage cover by tree species was recorded at Hogsback 2 (Figure 15), which had 8% more trees as compared to the other sites.

Grasses at each site were identified and grouped according to their ecological status and each was allocated an average percentage ground cover (Table 3).

Table 3: Ground cover and classification of grass indicator species according to their ecological status

Site	Species Name	% Ground Cover	Ecological Status
Saki	<i>Aristida diffusa</i>	6	Increaser IIc
	<i>Cynodon dactylon</i>	10	Increaser IIb
	<i>Digitaria eriantha</i>	6	Decreaser
	<i>Sporobolus africanus</i>	1	Increaser IIc
Ngqele	<i>Cynodon dactylon</i>	36	Increaser IIb
	<i>Digitaria eriantha</i>	19	Decreaser
	<i>Pennisetum clandestinum</i>	7	Increaser IIb
	<i>Sporobolus fimbriatus</i>	6	Decreaser
Hogsback 1	<i>Aristida bipartita</i>	1	Increaser IIc
	<i>Cynodon dactylon</i>	3	Increaser IIb
	<i>Digitaria eriantha</i>	6	Decreaser
	<i>Eragrostis capensis</i>	2	Increaser IIb, IIc
	<i>Hyparrhenia hirta</i>	3	Increaser I
	<i>Panicum deustum</i>	1	Decreaser
	<i>Pennisetum clandestinum</i>	3	Increaser IIb
	<i>Setaria sphacelata</i>	1	Decreaser
	<i>Sporobolus africanus</i>	6	Increaser IIc
	Hogsback 2	<i>Cynodon dactylon</i>	5
<i>Digitaria eriantha</i>		5	Decreaser
<i>Helictitrichon capensis</i>		1	Decreaser
<i>Hyparrhenia hirta</i>		11	Increaser IIb
<i>Setaria sphacelata</i>		1	Decreaser
<i>Themeda triandra</i>		14	Decreaser
Zingcuka		<i>Bromus catharticus</i>	1
	<i>Cynodon dactylon</i>	51	Increaser IIb
	<i>Digitaria eriantha</i>	3	Decreaser
	<i>Helictotrichon capensis</i>	1	Decreaser
	<i>Panicum deustum</i>	1	Decreaser
	<i>Sporobolus africanus</i>	1	Increaser IIc
	<i>Themeda triandra</i>	4	Decreaser

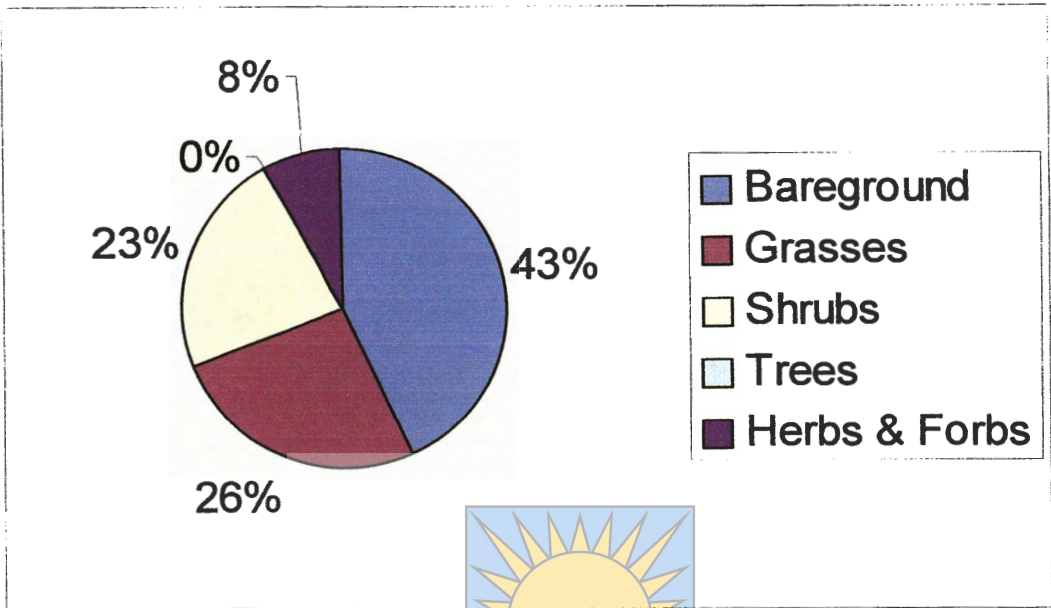


Figure 12 % Ground Cover at Saki

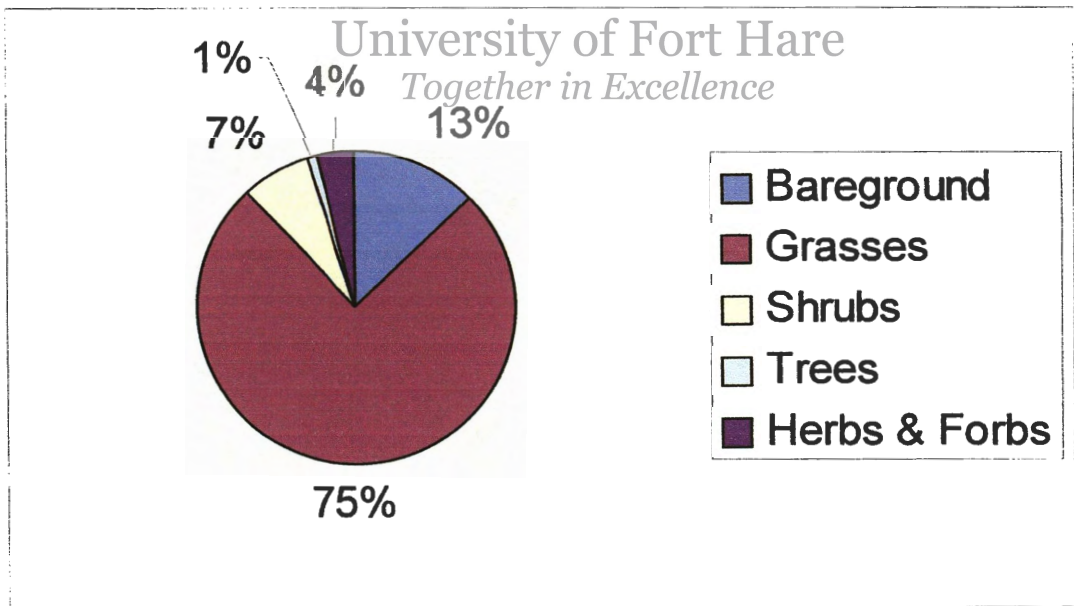


Figure 13 % Ground Cover at Ngqele

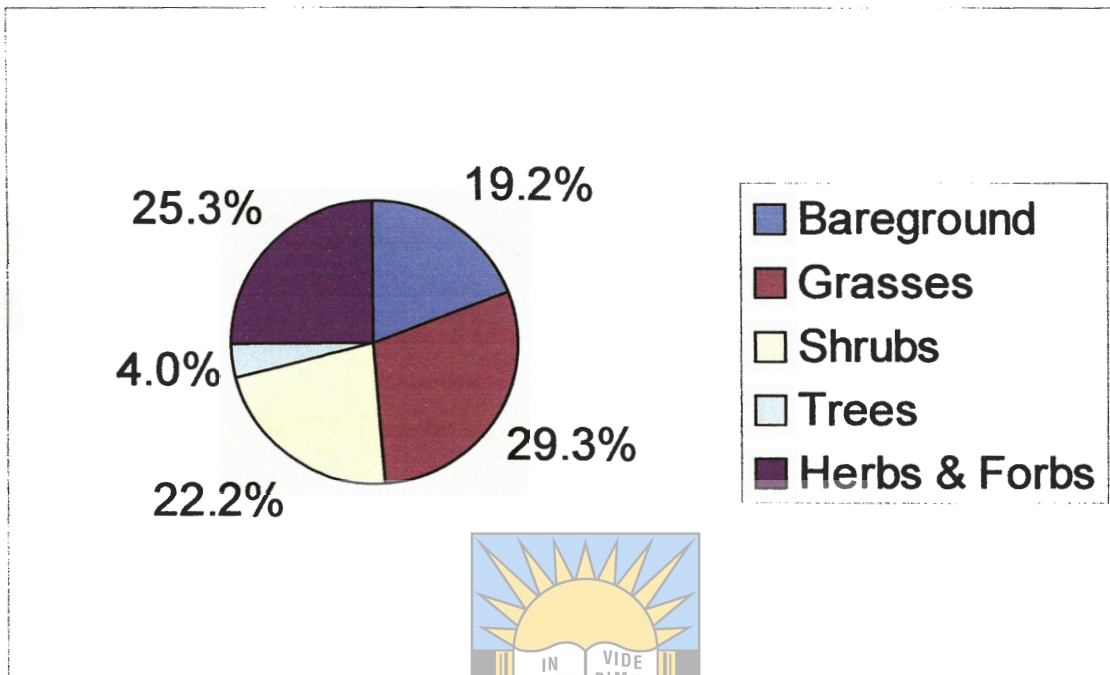


Figure 14 % Ground Cover at Hogsback 1

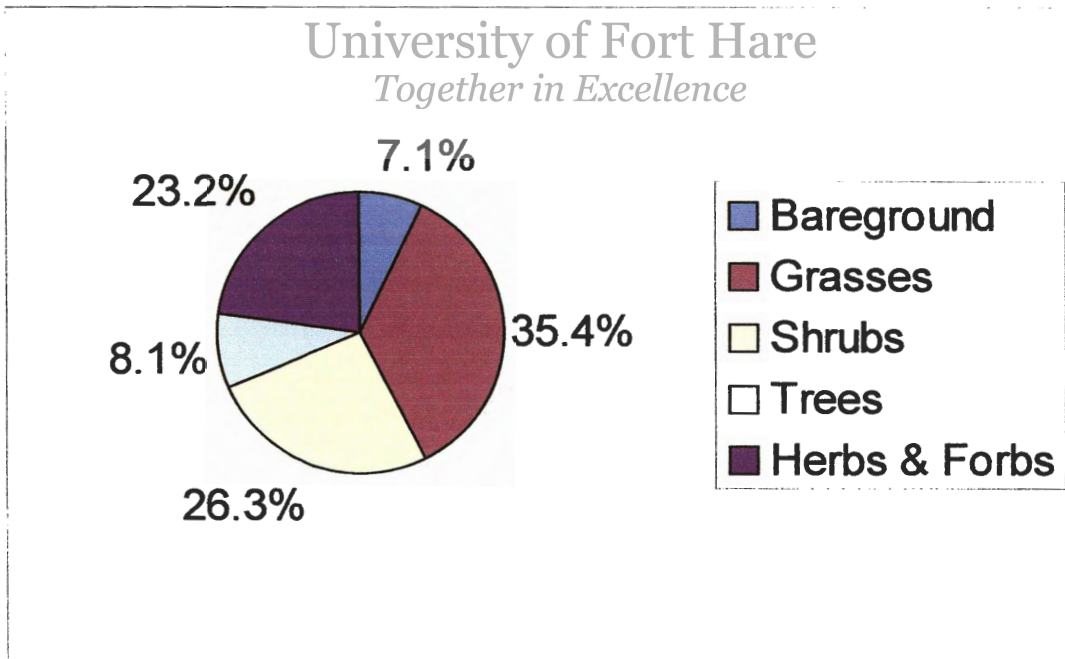


Figure 15 % Ground Cover at Hogsback 2

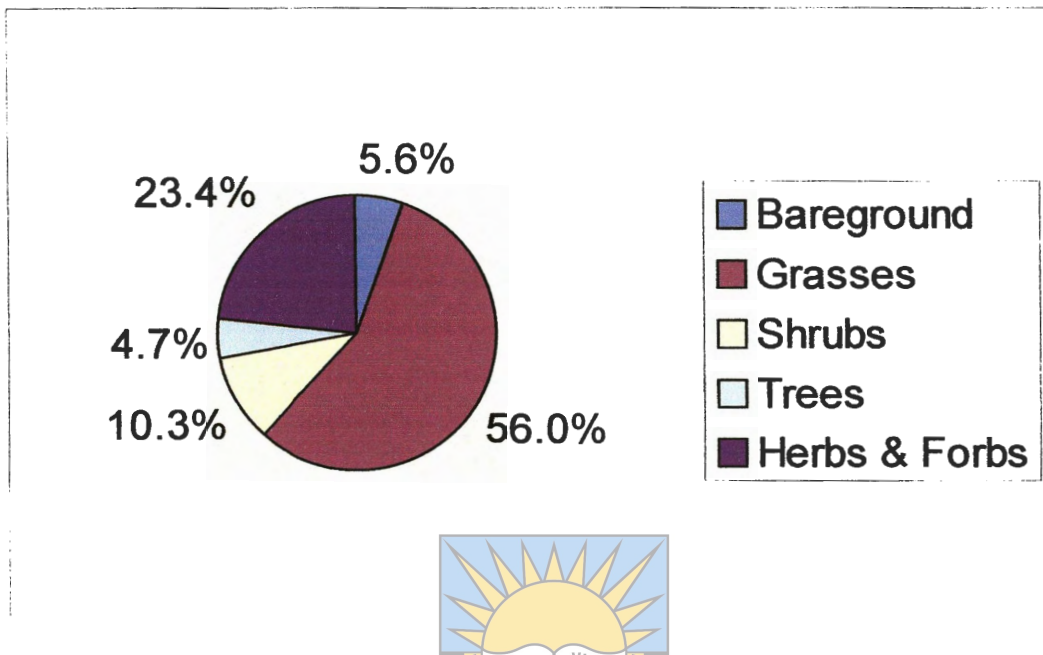


Figure 16 % Ground Cover at Zingcuka



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Vegetation Clustering

Detrended Correspondance Analysis (DCA) is an ordination system that was used to determine species distribution at each site and for all sites together. According to this ordination system, distance means dissimilarity. Therefore the further away a species community the less similar it is to the next community.

Individual sites

Saki site

DCA exhibited a uniform plant specific distribution in all quadrats, the only exception being quadrat 7 (Figure 17). The species composition also appeared to be uniform and was characterized by a high percentage of bareground (43%), and the presence of plant species such as *Chrysocoma cilliata* and grass species such as *Digitaria eriantha* (6%), *Aristida diffusa* (6%), *Cynodon dactylon* (10%) and *Sporobolus africanus* (1%) (Figure 18). This appeared to be an indication of poor veld and might therefore be indicative of poor veld as referred to in Table 3.

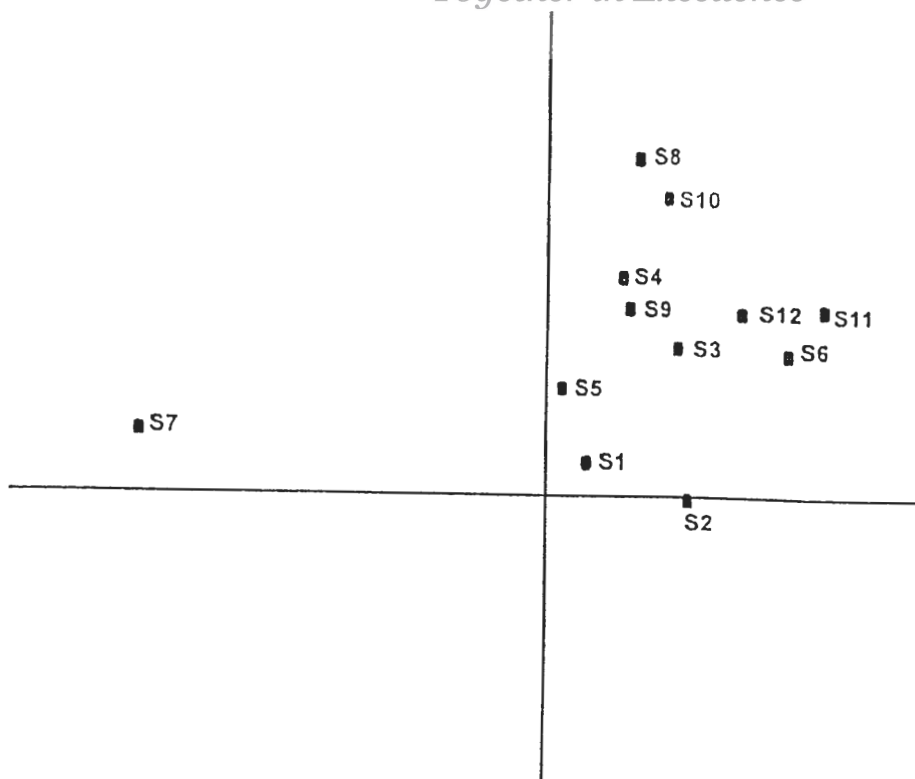


Figure 17 Distribution of quadrats at Saki



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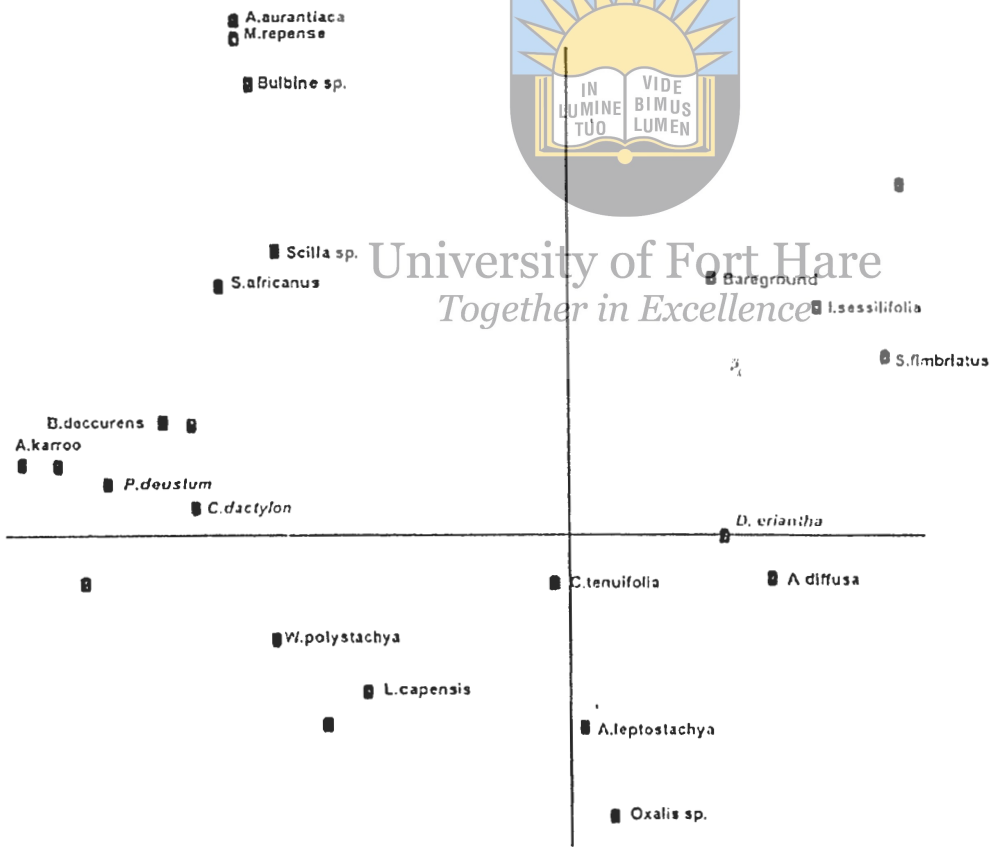


Figure 18 Species distribution at Saki

Ngqele site

DCA at this site also exhibited a uniform distribution of quadrats except for quadrat 6 (Figure 19). The species ordination for this site was characterized by bareground (13%) associated with shrubs such as *Acacia karroo* and *Chrysocoma cilliata* (Figure 20). Grass species at this site were, however, of conflicting ecological status with, for example, *Digitaria eriantha* (19%) and *Sporobolus fimbriatus* (6%) indicative of good veld and others, such as, *Pennisetum clandestinum* (7%) and *Cynodon dactylon* (36%) indicative of poor veld and therefore indicative of bad veld management (refer to Table 3). The high incidence of bareground (13%), shrub species *Chrysocoma cilliata* and *Acacia karroo*, and grass species such as *Pennisetum clandestinum* and *Cynodon dactylon* are indicative of an either degrading or degraded site (Table 3).



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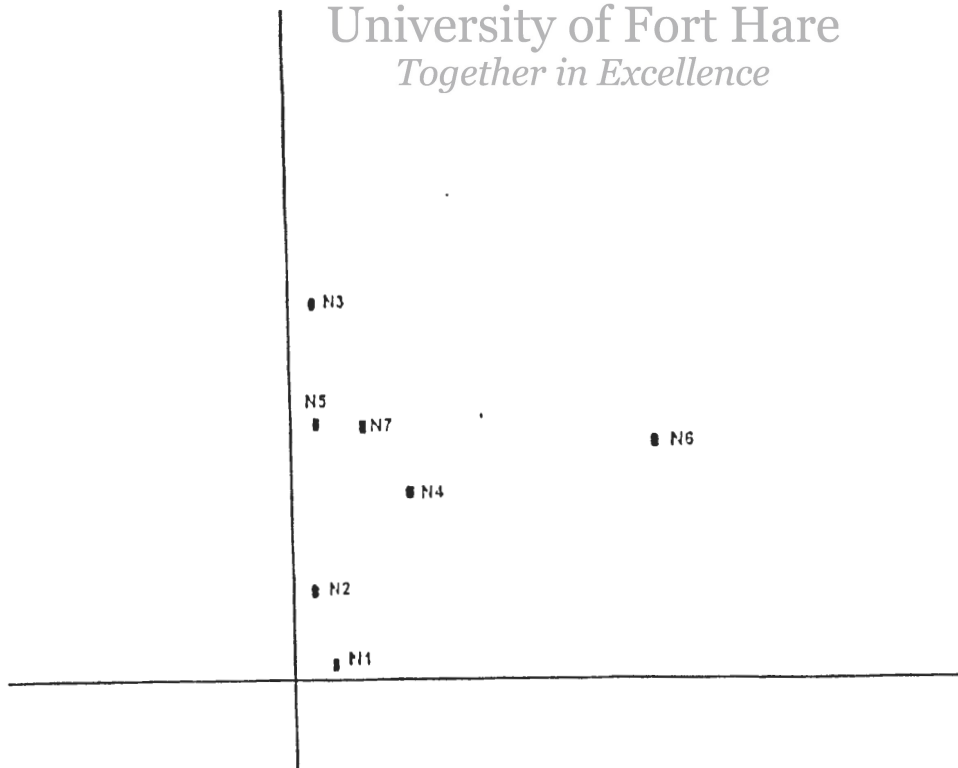
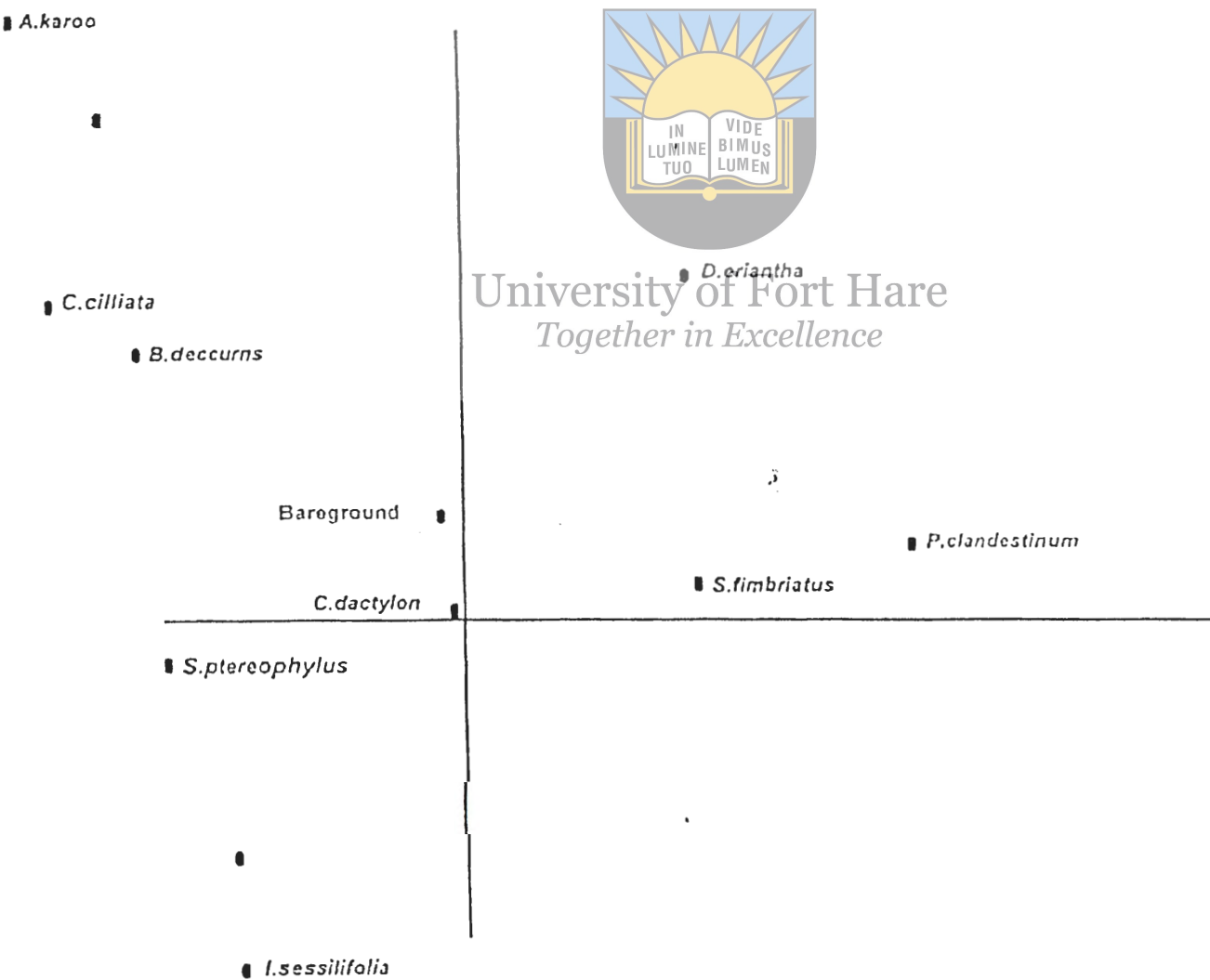


Figure 19 **Distribution of quadrat at Ngqele**



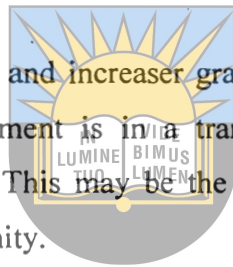
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Figure 20 Species distribution at Ngqele

Hogsback 1 site

DCA exhibited some uniformity in both the quadrat ordination (Figure 21) and the species ordination diagrams (Figure 22). All vegetation classifications were represented at this site. Tree and shrub species found were, for example, *Ptaeroxylon obliquum*, *Calpurnia aurens*, *Scutia myrtina*, *Maytenus heterophylla* and a variety of *Helichrysum* and *Senecio* species. Grass species found were, for example, *Eragrostis capensis* (2%), *Sporobolus africanus* (6%), *Aristida bipartita* (1%), *Cynodon dactylon* (3%) and *Hyparrhenia hirta* (3%) which are increaser grass species, indicative of poor veld. There was also a low occurrence of decreaser grass species such as *Panicum deustum* (1%) and *Digitaria eriantha* (6%), which are indicative of good veld (refer to Table 3).

The occurrence of a mixture of decreaser and increaser grass species and a relatively high bareground, may indicate that the catchment is in a transitional state from good veld condition to a more degraded condition. This may be the result of over-grazing or over-cultivation of the land by the local community.



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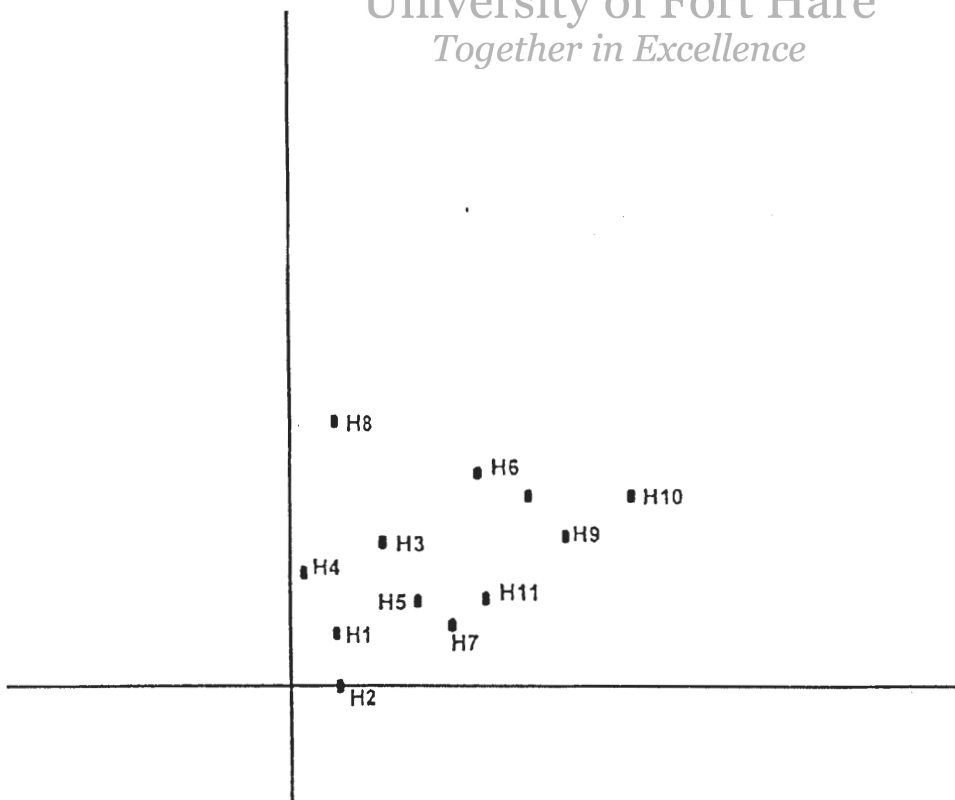


Figure 21 **Distribution of quadrats at Hogsback1**

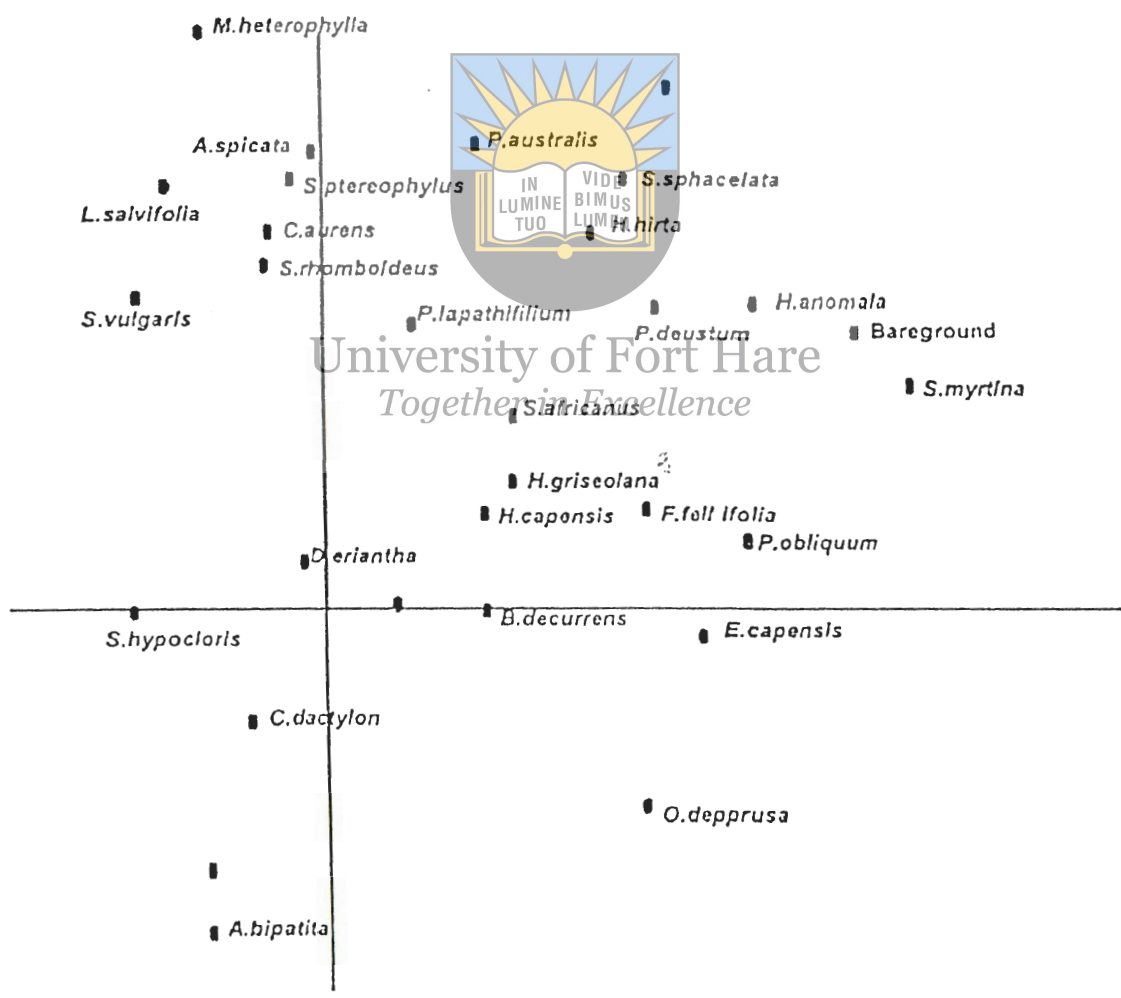


Figure 22 Species distribution at Hogsback1

Hogsback 2 site

DCA for this site exhibited a uniform distribution of both quadrats and species ordination (Figures 23 and 24). The species ordination was characterized by a number of trees and shrubs. These were namely, *Scutia myrtina*, *Rhamnus prinoides*, *Maytenus heterophylla*, *Felicia felifolia*, *Walafrida polystachya*, *Calpurnia aurens*, *Helichrysum* and *Senecio* species. Table 3 shows the grass species found within this community and these were mostly dominated by decreaser grass species such as *Digitaria eriantha* (5%), *Helictotrichon capensis* (1%), *Setaria sphacelata* (1%) and *Themeda triandra* (14%). The type of vegetation found at this site has a good complement of trees and shrubs and the presence of decreaser grass species, which are indicative of a site with veld, which is well-managed.



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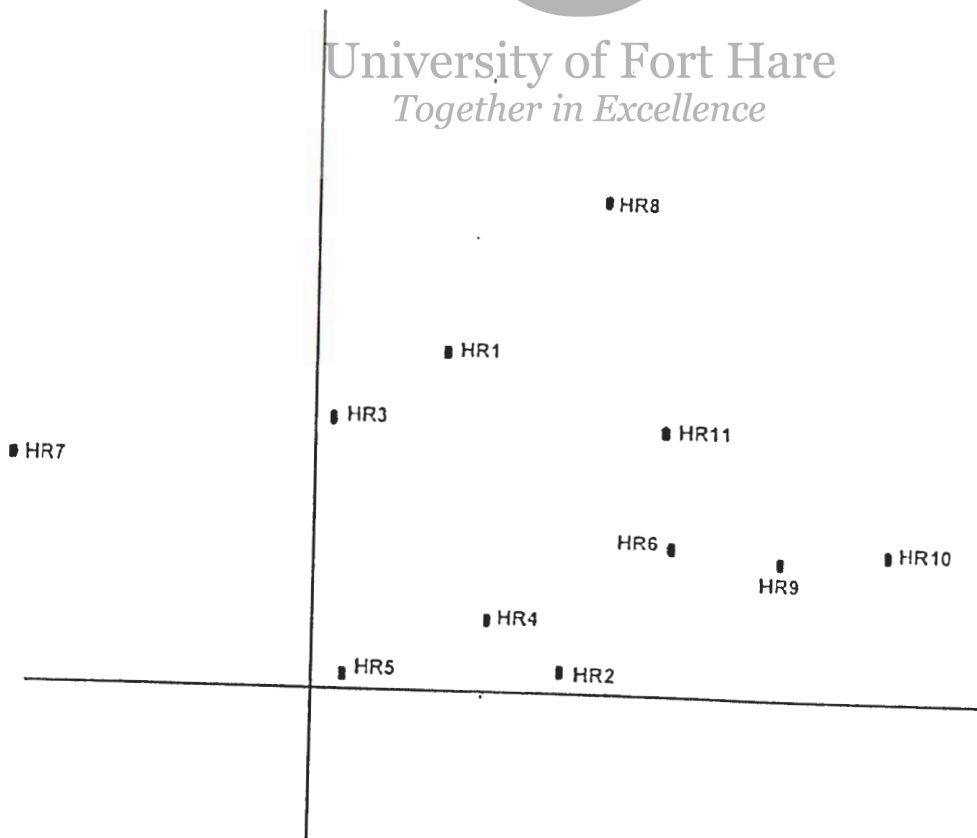


Figure 23 **Distribution of quadrats at Hogsback2**

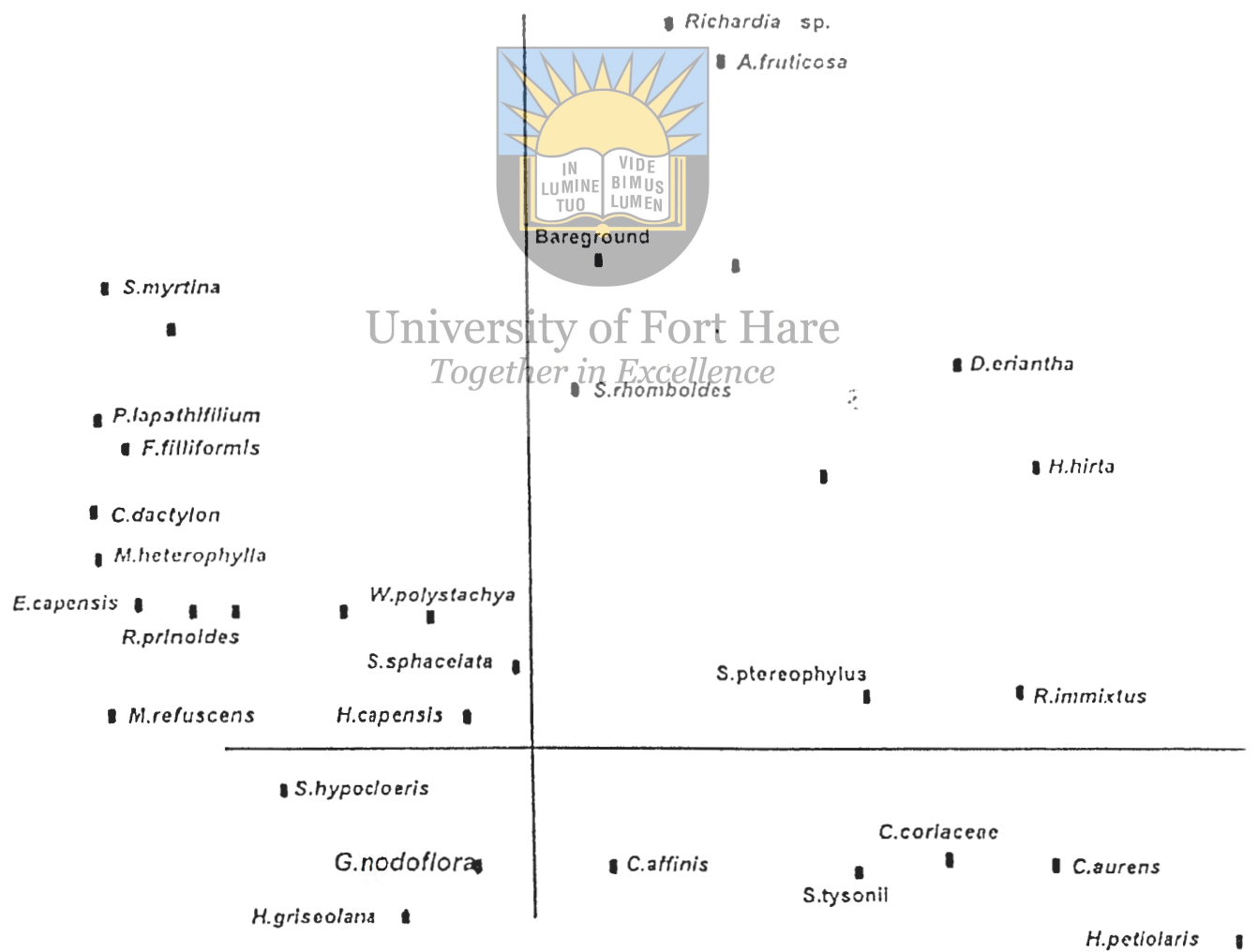
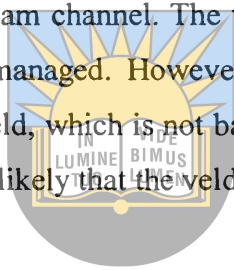


Figure 24 Species distribution at Hogback2

Zingcuka site

DCA exhibited uniform quadrat and species distribution (Figures 25 and 26). The vegetation community at this site was composed of trees and shrubs, some grass species and some herbs and forbs. Trees and shrubs found were, *Calpurnia aurens*, *Ziziphus mucronata*, *Canthium aethiopicum*, *Maytenus heterophylla*, *Hippobromus aethiopicum* and *Chrysocoma ciliata*. Grass species found were mainly *Sporobolus africanus* (1%), *Panicum deustum* (1%), *Cynodon dactylon* (51%), *Digitaria eriantha* (3%), *Bromus catharticus* (1%) and *Themeda triandra* (4%). The grass sward at this site was dominated by increaser species, namely *Cynodon dactylon* and *Sporobolus africanus*. These grasses are important indicators of badly managed veld. The site was also characterized by *Phragmites australis*, a good stream stabilizer found lining the banks of the stream channel. The vegetation at this site indicated bad veld type, which has not been well-managed. However the low bareground (i.e. the lowest of all the sites) is an indication of veld, which is not badly managed and consequently has less exposed bareground. It is therefore likely that the veld at this site is in transition from a very good veld to a degrading one.



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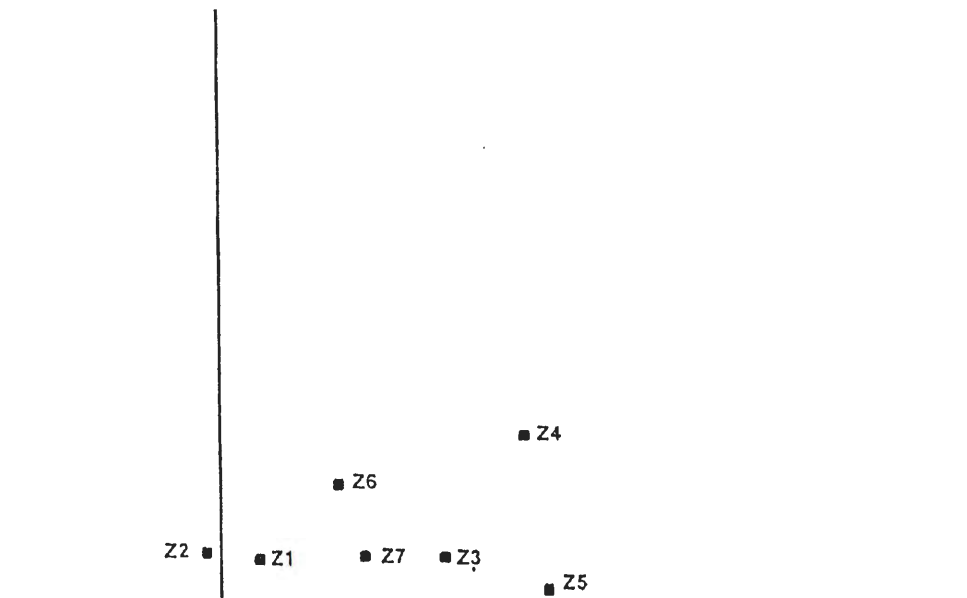


Figure 25 Distribution of quadrats at Zingcuka

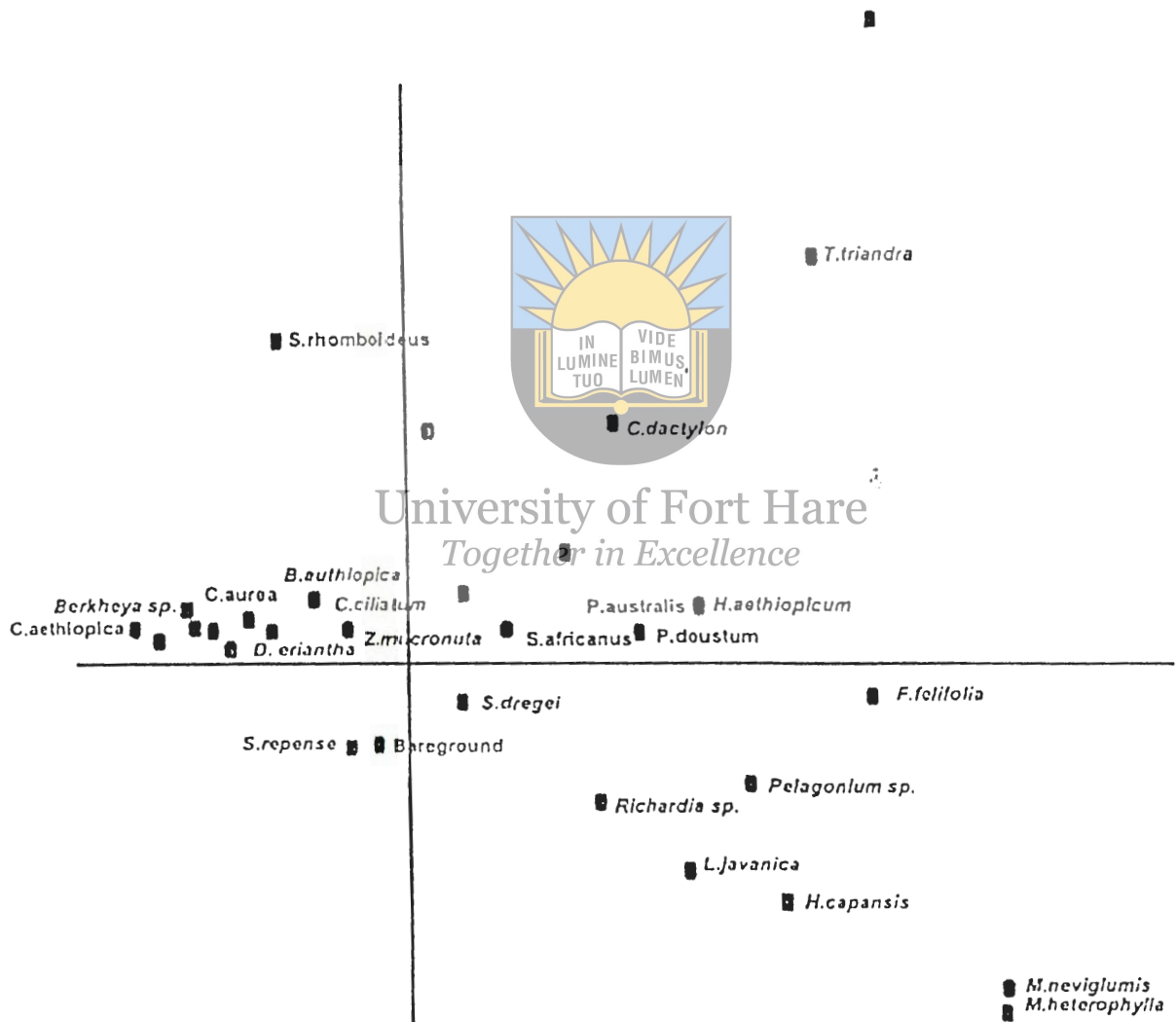


Figure 26 Species distribution at Zingcuka

All sites

The DCA for quadrats at all sites exhibited three separate groupings (Figure 27). Group "A" is composed of quadrats from the Saki site, Group "B" is Ngqele and Zingcuka and the last group "C" is composed of the two Hogsback sites.

The DCA for species ordination for all sites depicted grouping of the vegetation into three different plant communities (Figure 28). The plant communities ranged from the most degraded "A", through to "B" which was transitional, to the least degraded "C". The "A" community was characterized by a plant species community with the lowest occurrence of trees and shrubs, however there was a high incidence of *Acacia karroo* and *Chrysocoma ciliata*. *Acacia karroo* and *Chrysocoma ciliata* are shrub species, which were indicative of degraded veld. Grass species found under this group were mostly increaser grass species such as *Aristida diffusa*, and *Pennisetum clandestinum*. Plant species characterizing this community were mostly found to be dominant at the Ngqele and Saki catchments. These were also the sites with the highest recorded percentage bareground of all the sites selected for study.

The community "B" was found to be in transition with very low occurrences of the woody type of vegetation (Figure 28). Trees and shrubs found within this plant community included species such as *Ziziphus mucronata*, *Canthium ciliatum* and *Hippobromus pauciflorus*. Grasses were composed of a mixture of increaser and decreaser grass species. These were namely, *Melinis repense* and *Cynodon dactylon* respectively. A mixture of trees, shrubs and a high percentage of *Cynodon dactylon* at the two sites, appeared to be an indication that the group represented sites, which were in transition from very good veld which was characterized by a good tree cover and degraded or degrading catchment sites with high percentage bareground and a grass cover dominated by *C dactylon*. Species found within this community were mostly found growing at the Ngqele and the Zingcuka catchments (Figures 27, 28 and Table 3).

Community "C" was identified as the least degraded community. This community was characterised by a good tree cover and no occurrence of *Acacia karroo* and *Chrysocoma*

cilliata. Tree species found within this community were, for example, *Scutia myrtina*, *Ptaeroxylon obliquum*, *Calpurnia aurens*, *Rhamnus prinoides*, *Maesa refuscenus* and *Canthium aethiopica*. *Phragmitis australis* was found to be a common stream stabilizer in this plant community. Grasses found were *Sporobolus africanus*, *Panicum deustum*, *Eragrostis capensis*, *Aristida bipartita* and *Digitaria eriantha*. The most dominant grasses within this group were *Digitaria eriantha* and *Panicum deustum*. These were considered to be decreaser grass species and were assumed to be indicative of good veld. The plant species found occurring within this community were mostly found to be growing at the Hogsback catchments. Plant species found to be dominant on the lower part of the ordination curve closer to the x-axis were mostly those found to be growing at the Hogsback 2 catchment site. The remaining species within the community "C" were those found to be growing at the Hogsback 1 catchment.

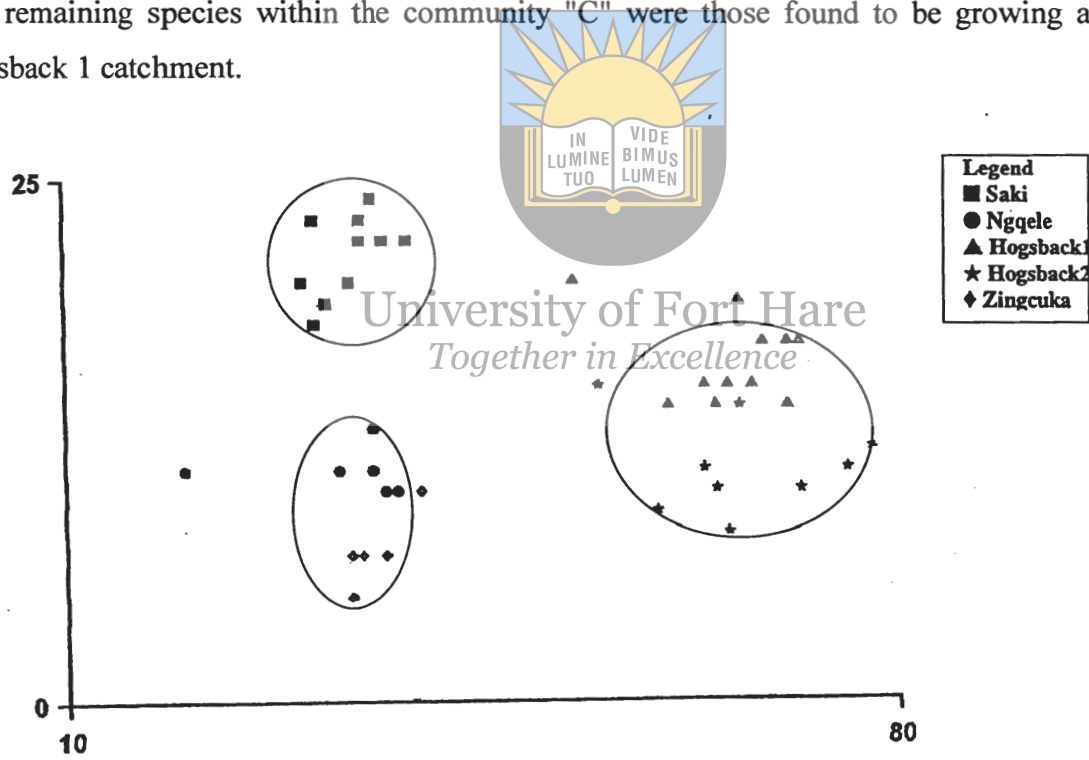


Figure 27 Distribution of quadrats against species names at all sites

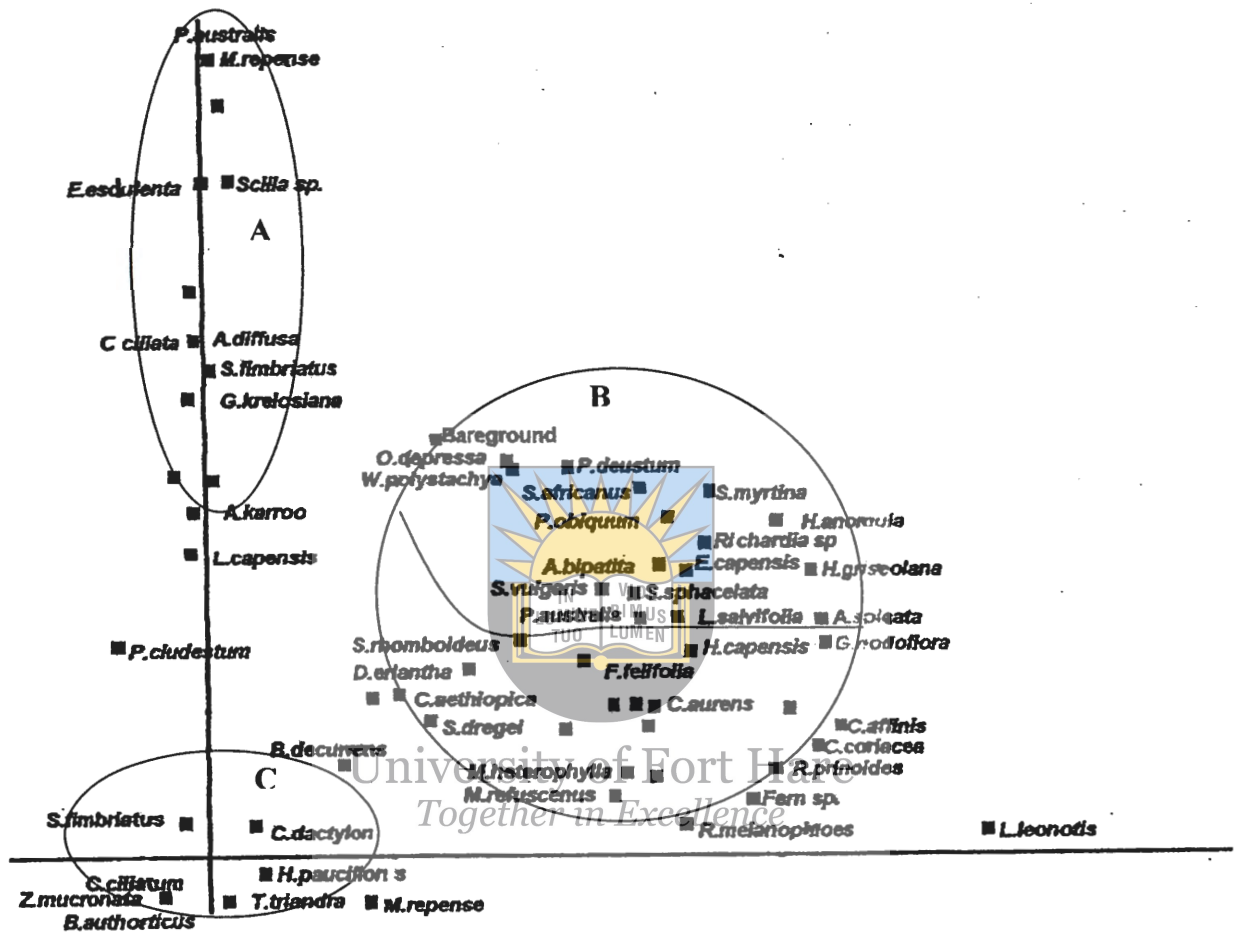


Figure 28 Distribution of species names against quadrat number at all sites

Land Use

A questionnaire was administered in all selected research sites, namely, the Hogsback sites, Ngqele and Saki. The Hogsback sites were combined since the two village homes were at close proximity to one another and to the catchment areas. The sampling procedures were persistent at Saki and Ngqele village homes, the only exception being at Zingcuka where the survey was conducted only in the only house found within the catchment radius. At Saki and Ngqele, the village homes were situated within the catchment itself. Information acquired at Zingcuka was from the only house that fell within the radius of the catchment area. Twenty questionnaires were administered at all sites.

The questionnaire used to address the following issues:

Gender And Marital Status Of Respondents

The majority of the respondents at all sites were females (Figure 29). There was on average only about 20% male respondents in all the study sites. Only about 36% of the respondents were married and the rest were either single or widowed (Figure30). The highest percentage of widowed people were reported at Saki and Hogsback whilst the highest percentage of single people was reported at Ngqele and Hogsback (Figure 30).

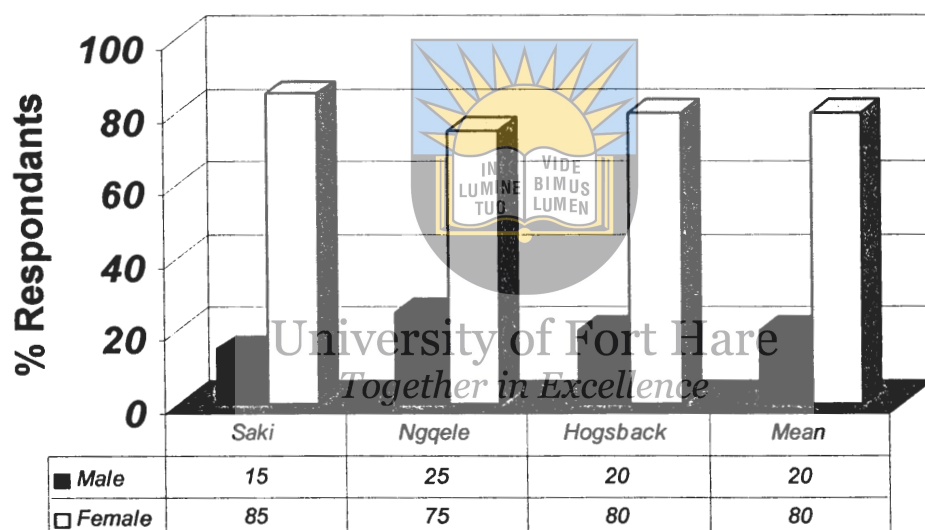


Figure 29 Gender of Respondents at all Sites

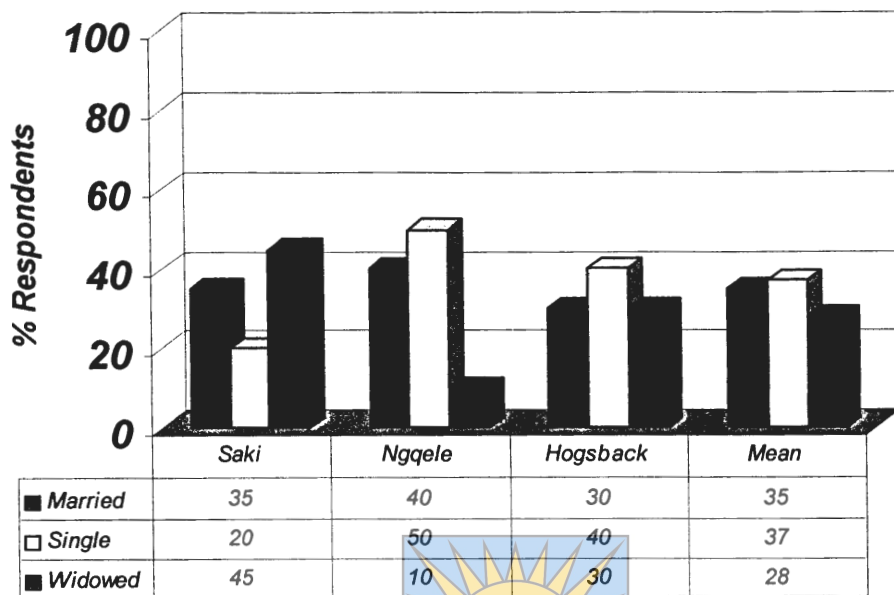


Figure 30 Marital Status of Respondents

Number Of People Per Household and Their Water Usage

There was on average six people per household within all the research sites (Figure 31). The source of water at all the sites was either river water or tap water. The source of water at Ngqele and Saki was tap water and at Hogsback and Zingcuka water was attained from nearby streams, namely the Tyume and Wolf rivers respectively. The average volume of water used per person per day in all the sites was 18 litres (Figure 32). The lowest volume of water used per person per day (12 litres) was reported at Zingcuka. This amount of water was below the present Reconstruction Development Programme's provision of 25 litres per person per day as stated in the 1997 White Paper on water policy and now included in the National Water Act (Act 36 of 1998) as the basic human needs reserve.

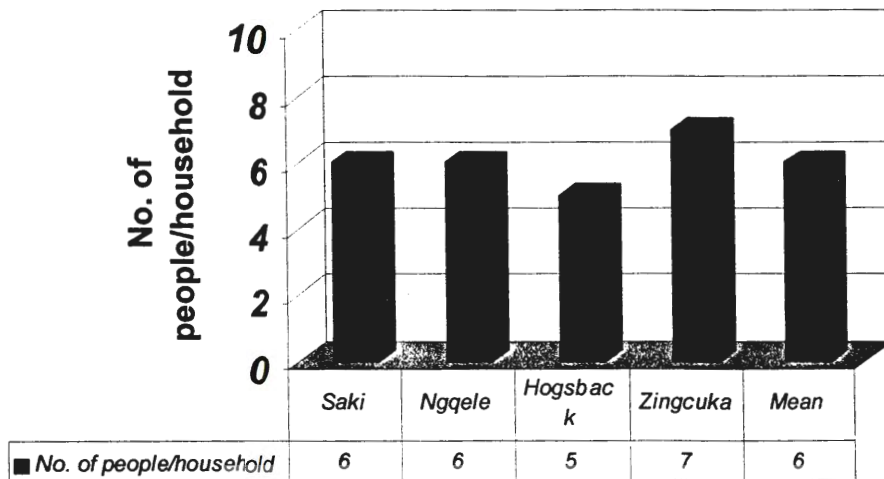


Figure 31 Average number of people per household per site

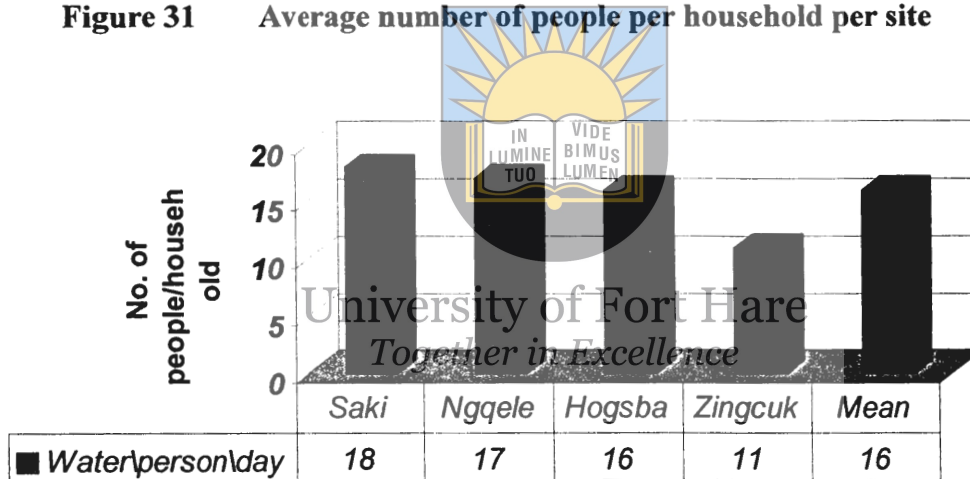


Figure 32 Average volume of water per person per day

Water quality impressions at all sites were good and satisfactory, except for impressions given by respondents at the Zingcuka site (Figure 33). The source of water for this site was from the Wolf River. This figure also shows that the water quality at Hogsback (Tyume river) was of good quality and excellent for consumption. Approximately, 40% of the respondents from Ngqele had a good impression of the water they used with the remaining 60 % complaining mostly about the hardness of the water. This consequently led to other complaints such as bad taste and poor results when using the water for washing clothes. A further 20% of respondents from Ngqele also complained about health problems such as stomachaches and diarrhoea subsequent to consumption of the water.

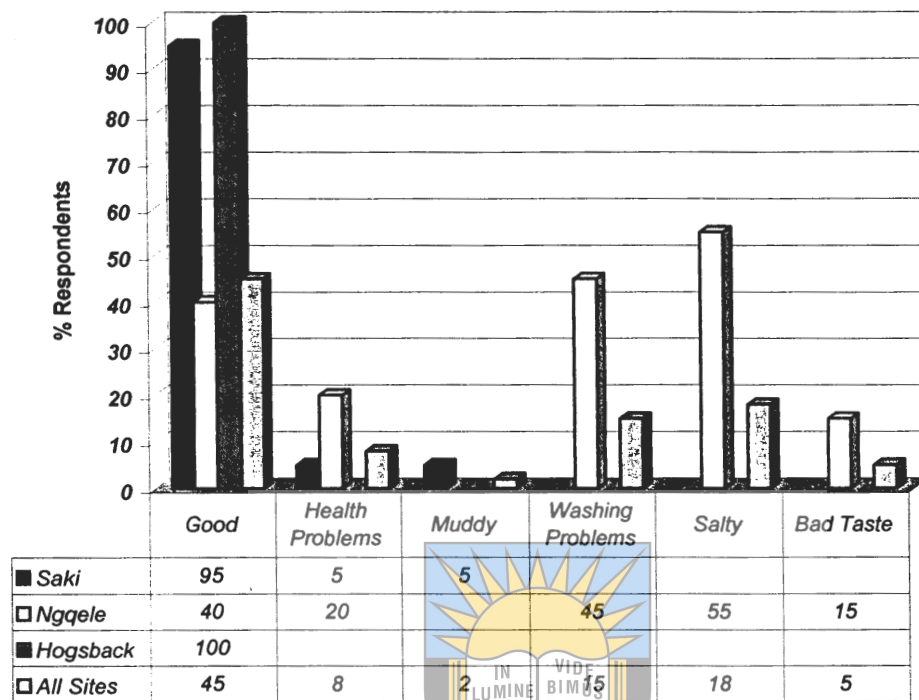


Figure 33 Water quality evaluation by respondents

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Approximately, 90% of the respondents from Saki were happy with the quality of water they obtained from their taps (Figure 33). Another 10% of the respondents complained about muddiness of the water and illness after using the water for drinking and cooking.

Respondents with access to land

The average size plot owned by those respondents with access to cultivated fields was 2 morgen (Figure 34). There was on average approximately 43% of respondents with access to cultivated lands in all the sites (Figure 35). None of the people interviewed at Zingcuka had access to land. The highest percentage of people who had access to land for cultivation and cultivated their fields were at Saki and Ngqele. Approximately 10% of the respondents from Hogsback had access to fields, but none of them actually cultivated their fields. This, according to Bembrigde *et al.* (1982), presents a considerable loss of production potential. The majority of those respondents who cultivated their lands were subsistence farmers (Figure 36). There was about 10% of crop farmers from Saki who actually sold their crop.

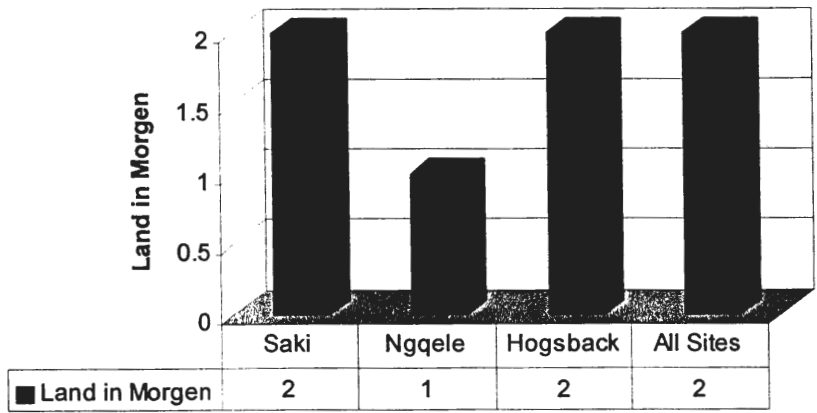


Figure 34 Average area of land (morgen) per site owned by respondents with access to cultivated land

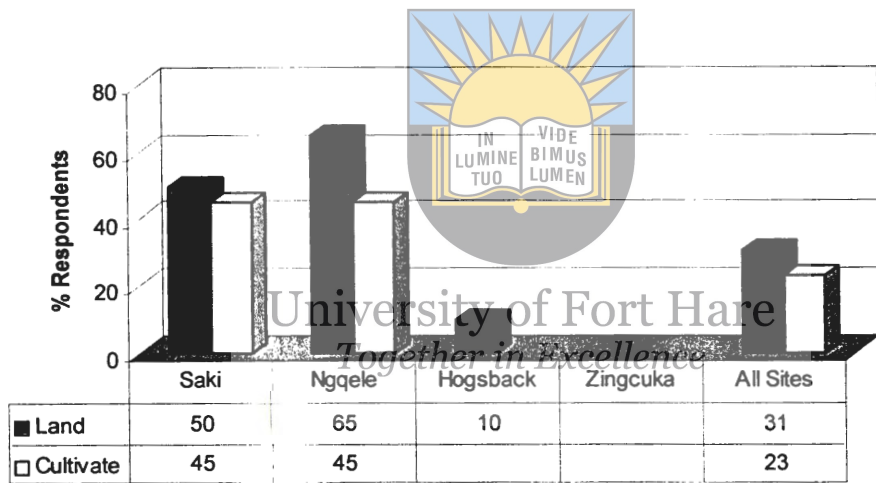


Figure 35 Average percentage of respondents with access to land and are currently cultivating

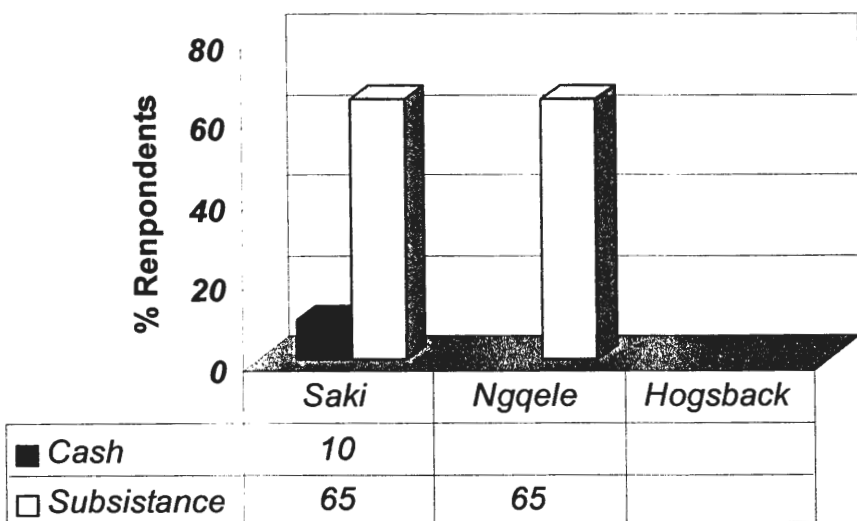


Figure 36 Average percentage use of cultivated land by those with access to cultivated lands

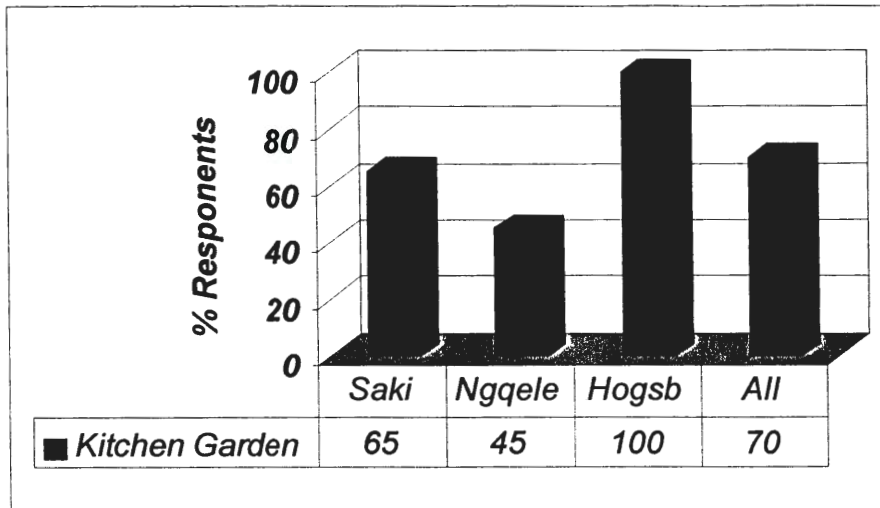


Figure 37 Average percentage of respondents with kitchen gardens

There was also a high incidence of kitchen gardens within the study areas (Figure 37). All the respondents from Hogsback cultivated kitchen gardens. The lowest occurrence of cultivated gardens was recorded at Ngqele. The respondents at Zingcuka also cultivated kitchen gardens. The most dominant crop grown in all sites was maize which was grown both in the fields and in kitchen gardens mostly by those who did not have access to cultivated land (Figure 38 - 40). The highest incidence (100%) of maize cultivation by respondents occurred in Hogsback (Figure 39). The lowest percentage (42%) of the respondents who cultivated maize were from Saki (Figure 40). Other types of crops grown included vegetables such as beans, spinach, cabbage and fruit such as peaches, melons and peanuts.

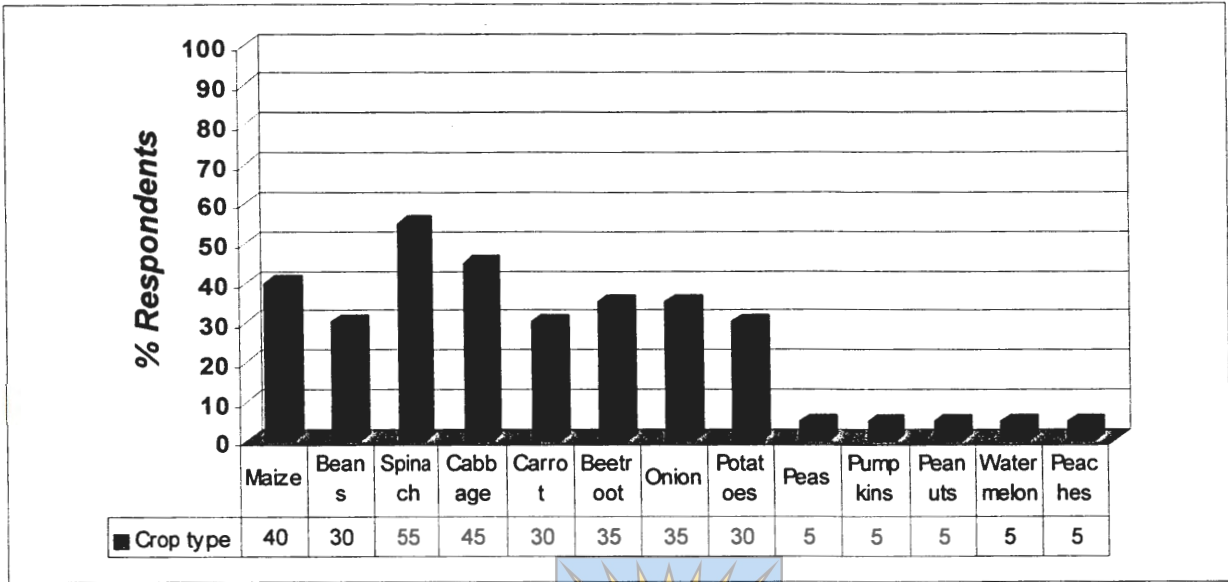


Figure 38 Crop types grown by respondents at Saki

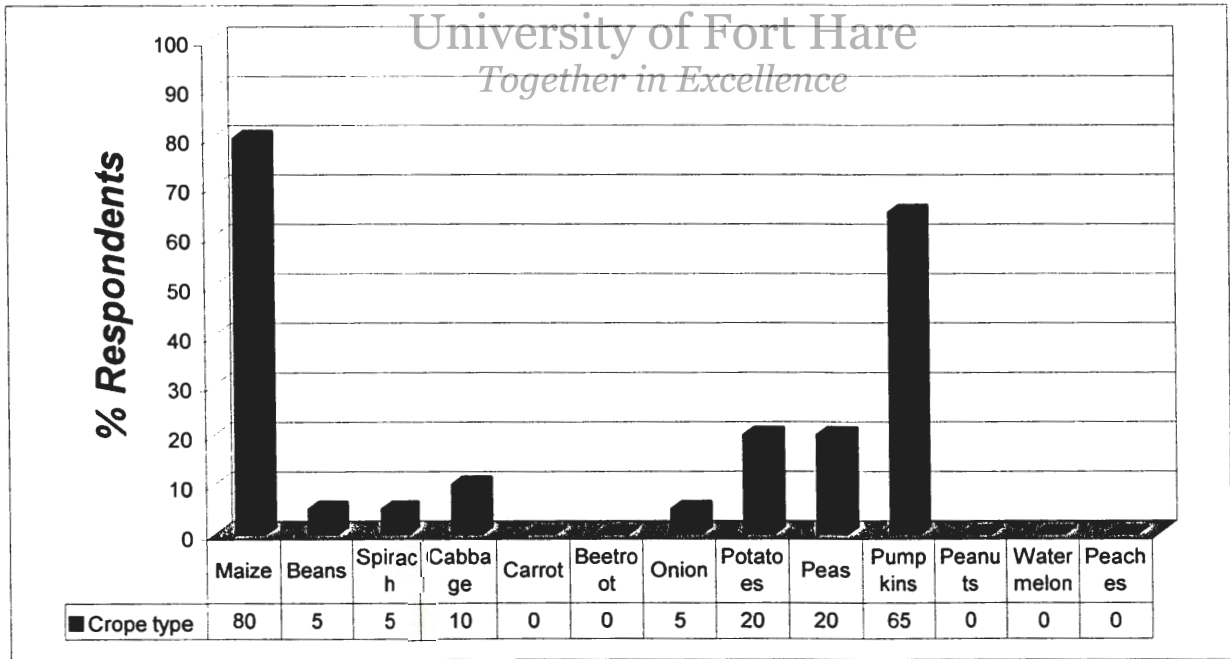


Figure 39 Crop types grown by respondents at Ngqele

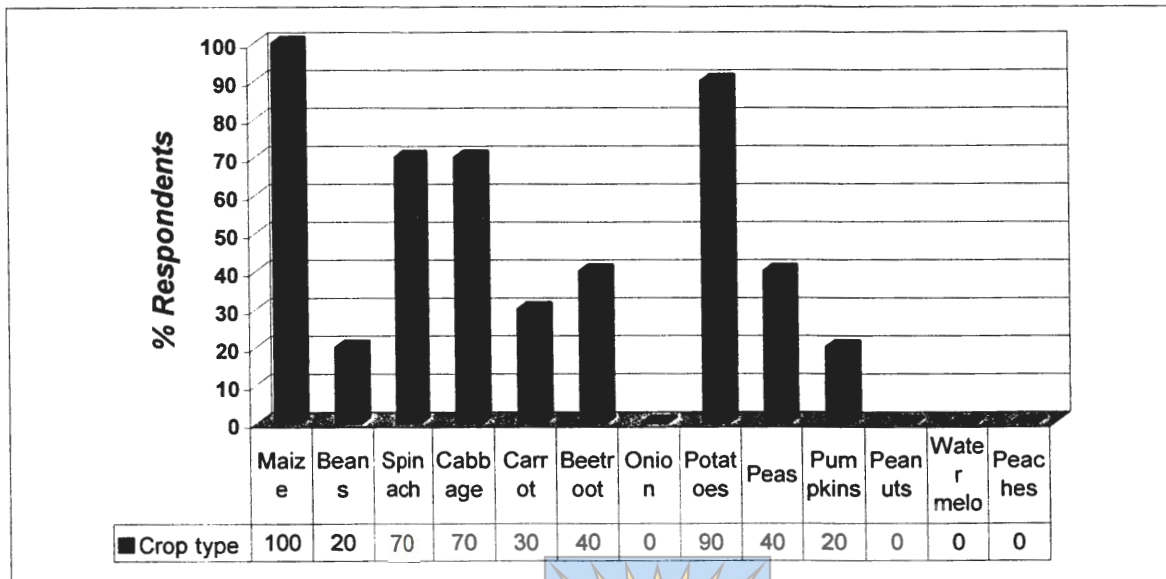


Figure 40 Crop types grown by respondents at Hogsback sites

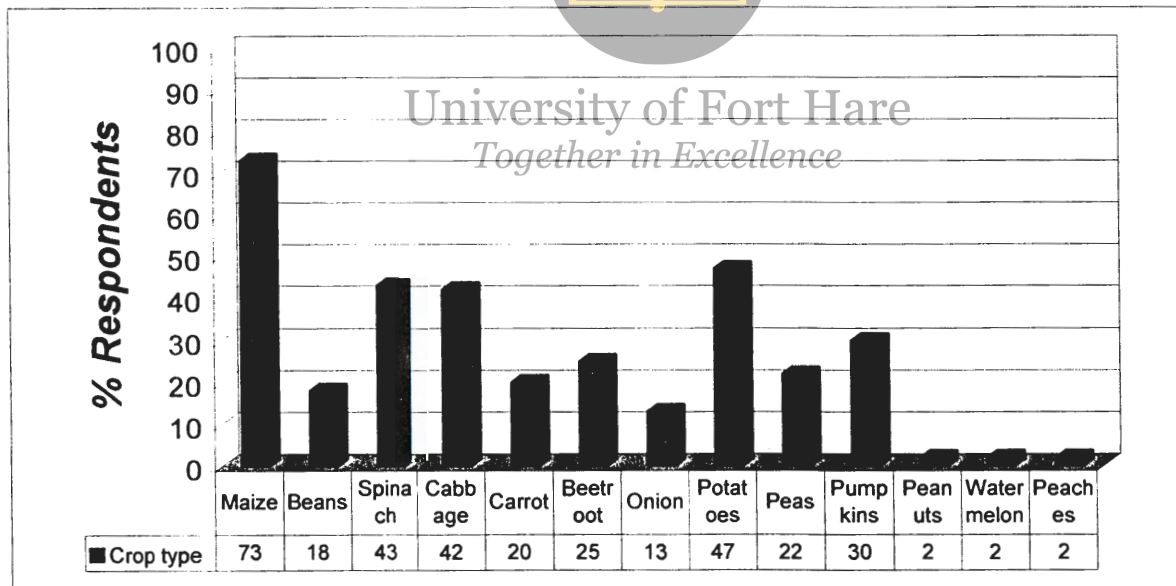
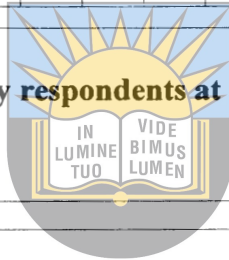


Figure 41 Crop types by respondents at all sites

Stock farmers

The highest percentage (100%) of stock farmers were recorded at Saki and a lower percentage (60%) was recorded at Hogsback and Ngqele (Figure 42). These stock farmers had varied proportions of stock numbers and stock types. The highest numbers of stock per household were recorded at Ngqele (Figure 43). The next highest numbers of cattle, sheep and chickens were recorded at Hogsback with the lowest at Saki and Zingcuka.

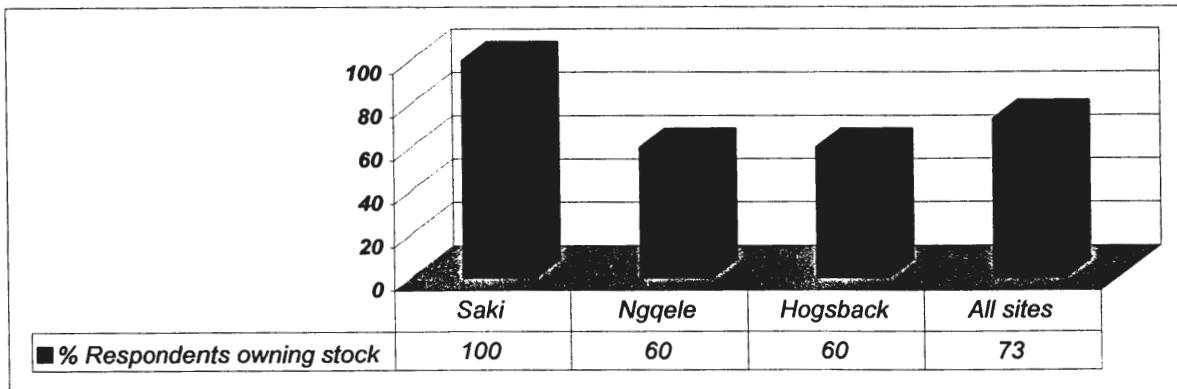


Figure 42 Average percentage stock per site

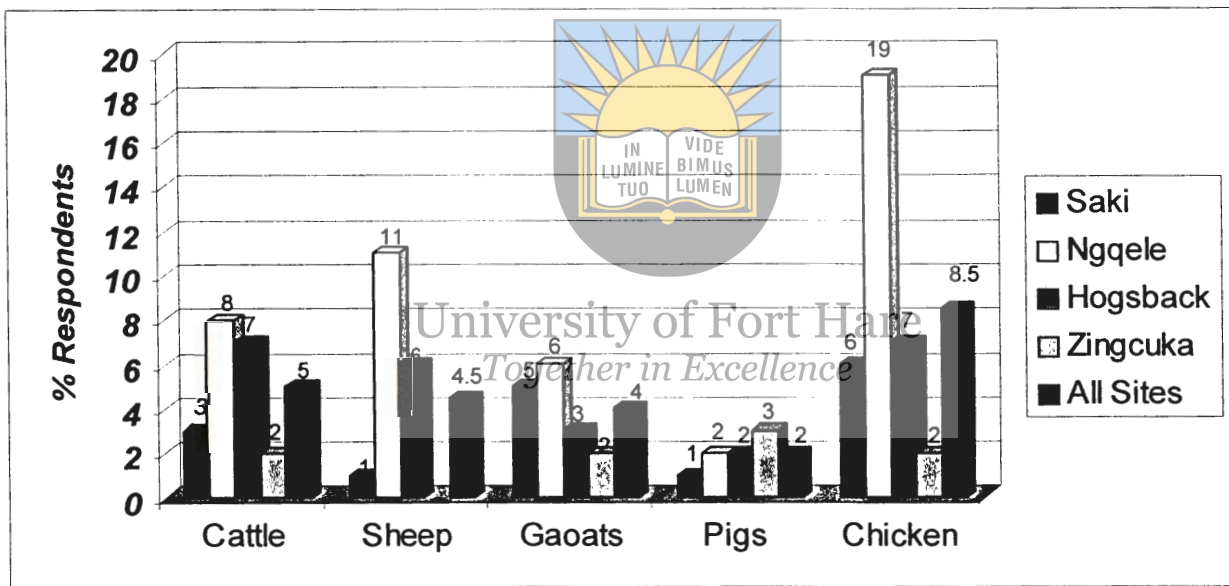


Figure 43 Average numbers of stock owned per household at each site

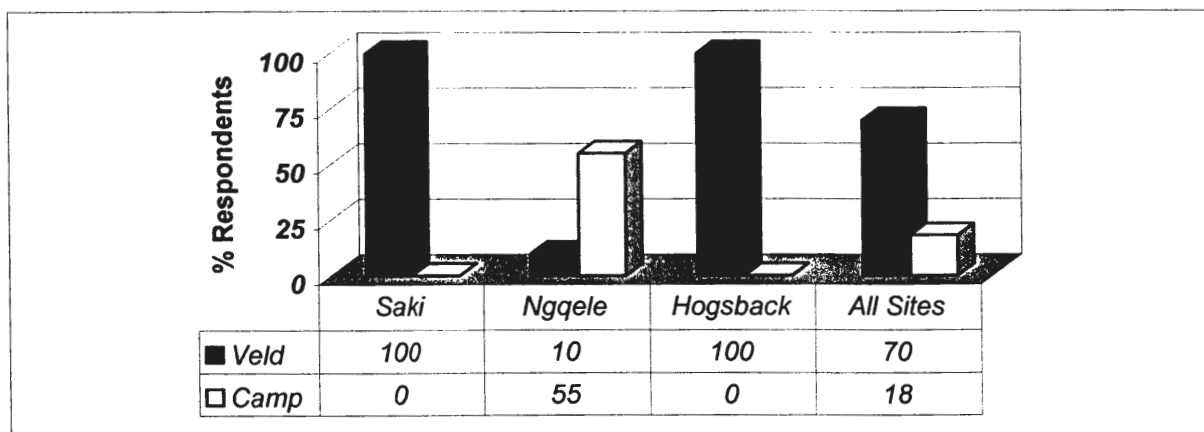


Figure 44 Preferred grazing sites

Stock essentially grazed in the veld in all sites, except for the Ngqele site where rotational grazing camps were used (Figure 44), especially for cattle. Stock not included in camps, essentially grazed on the grass growing within the settlement area.

Source of fuel

The most commonly used sources of fuel in all the sites was wood and cowdung (Figure 45-47). Of the tree species used, the most commonly used species was *Acacia karroo*. At the Hogsback sites, a greater variety of tree species were used with no occurrence of *Acacia karroo* (Figure 47). The Zingcuka respondents on the other hand used *Schotia affra*, *Acacia caffra* and *Rhus dentata* as fuel wood species.

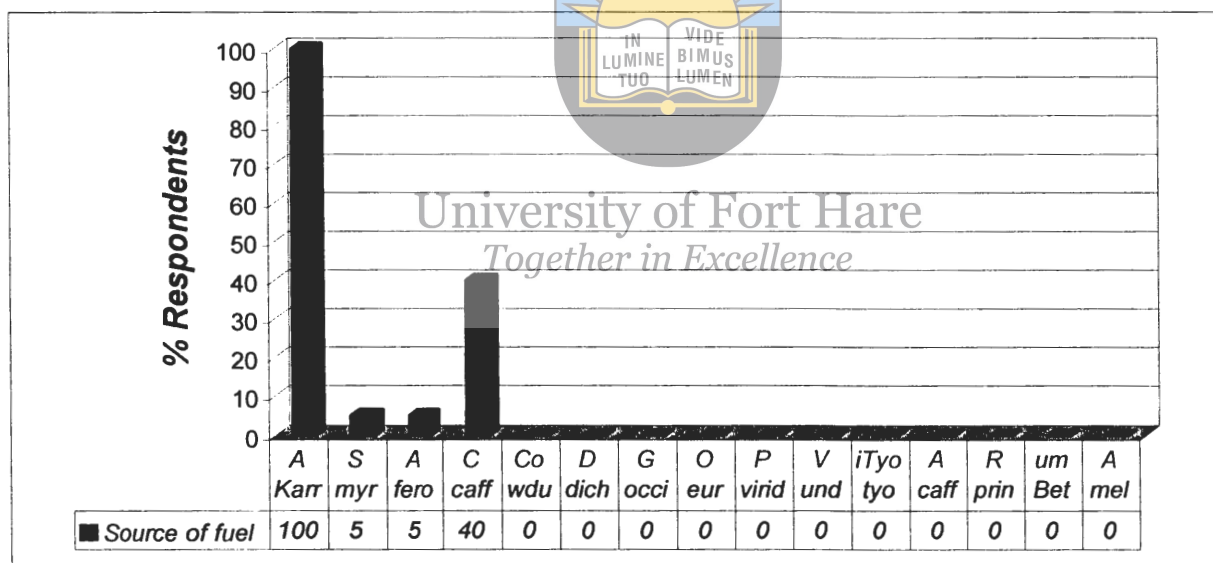


Figure 45 Average percentage source of fuel used by the respondents at Saki

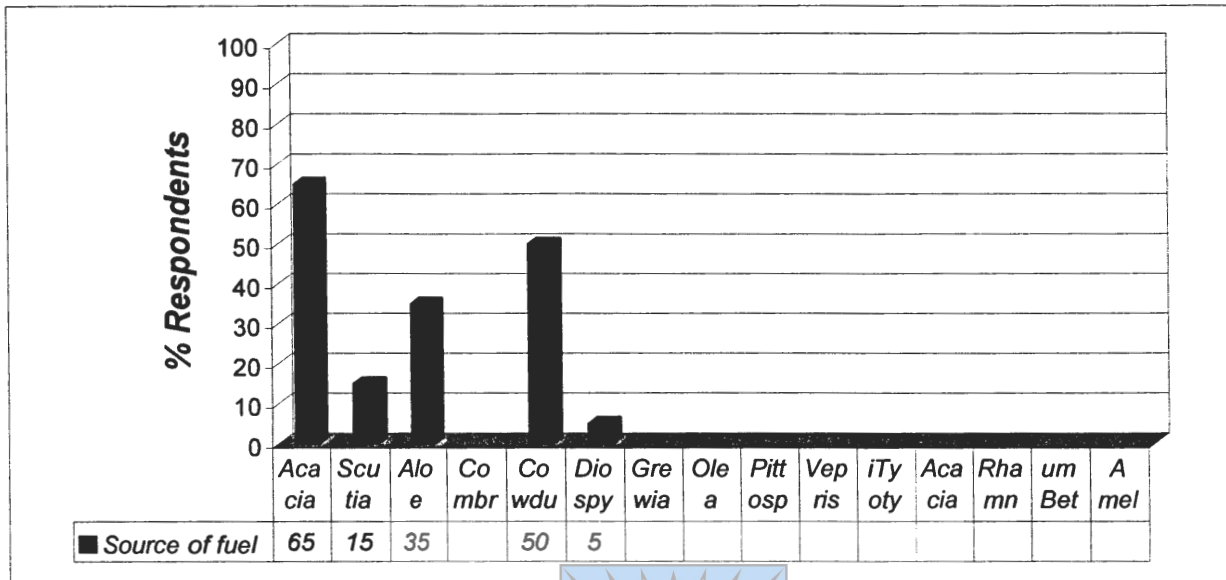
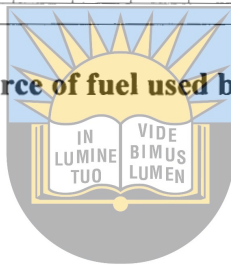


Figure 46 Average percentage source of fuel used by the respondents at Ngqele



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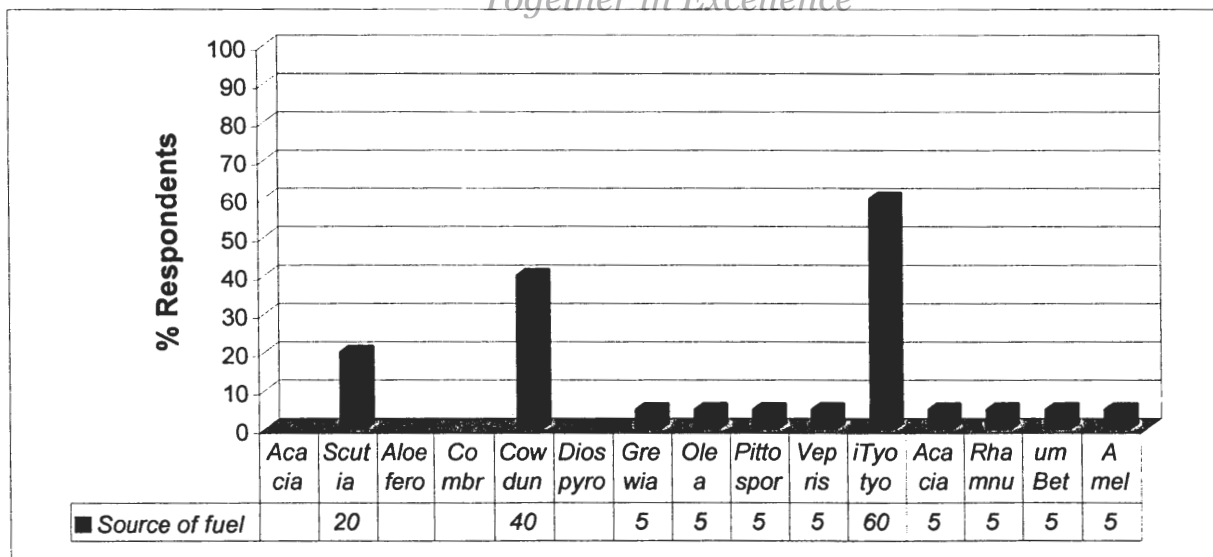


Figure 47 Average percentage source of fuel by respondents at both Hogsback sites

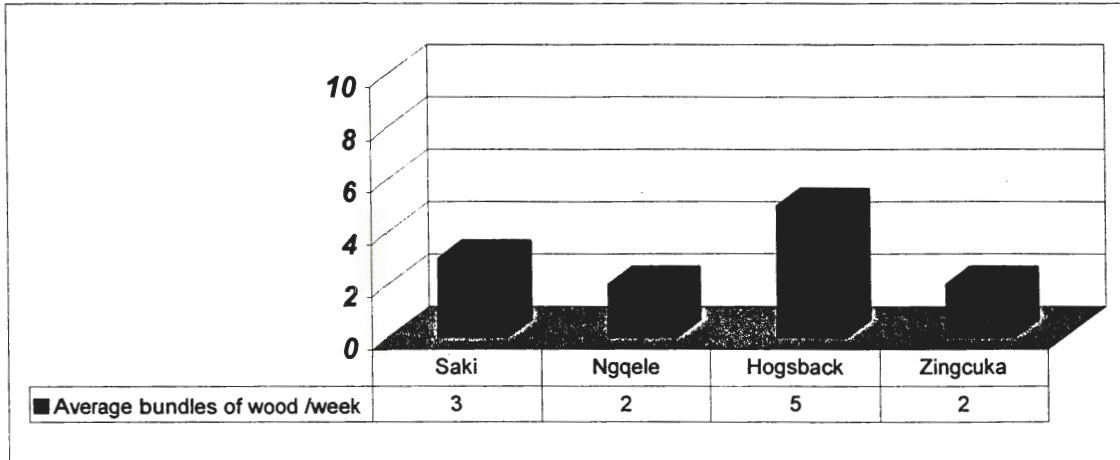


Figure 48 Average amount of wood collected per week

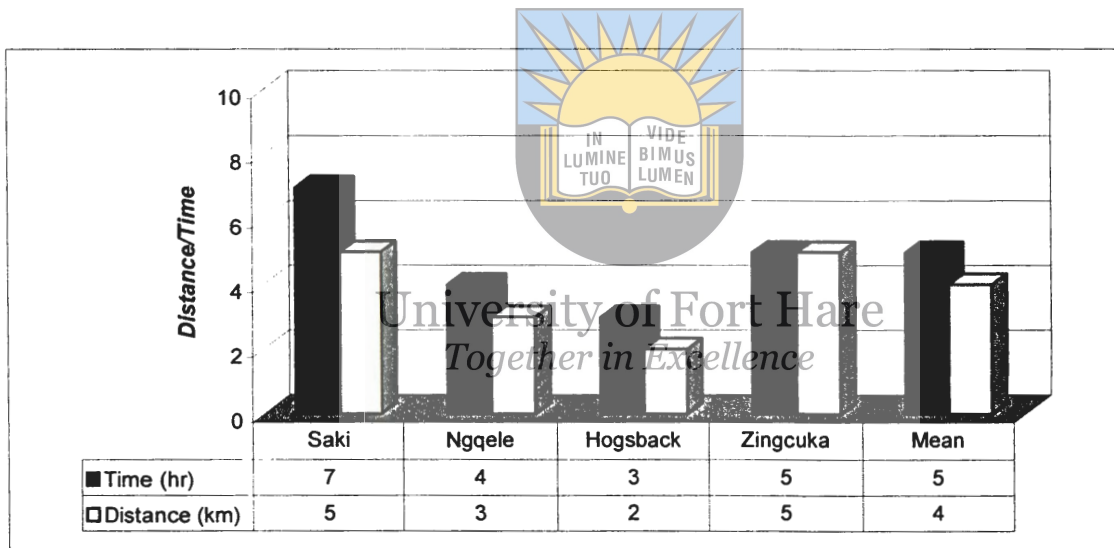


Figure 49 Average time spent and distance walked by respondents for collecting wood per day

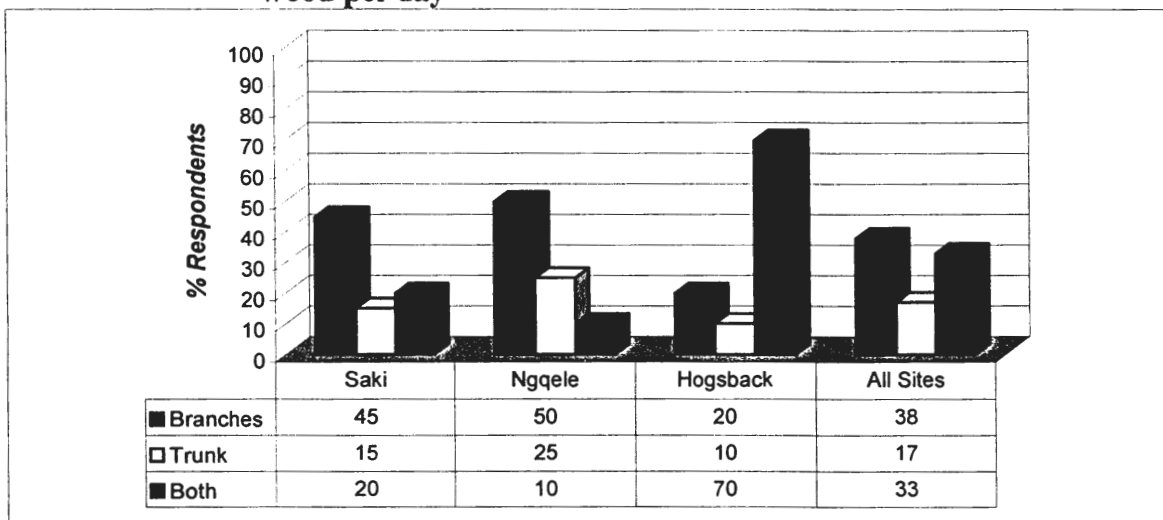


Figure 50 Parts of trees used for wood by respondents at all sites

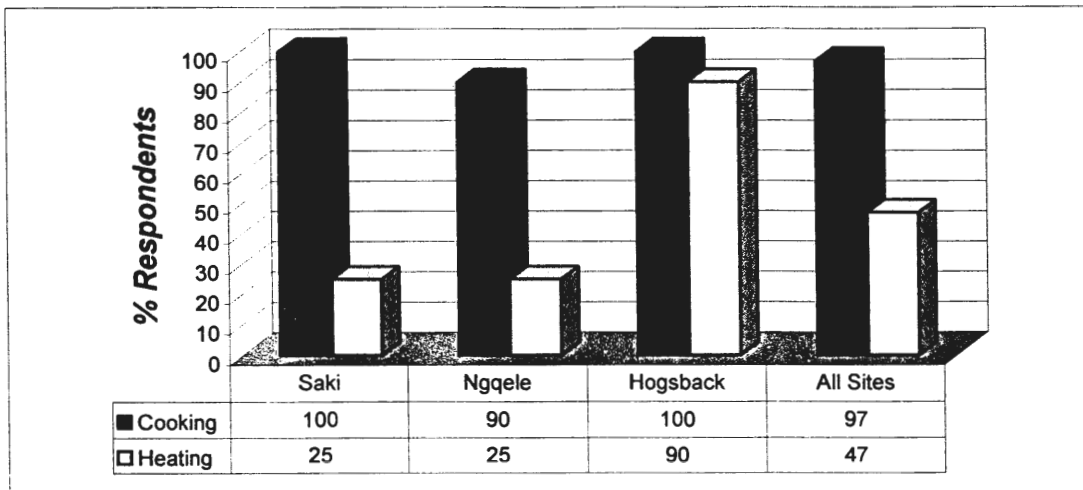


Figure 51 Use of wood by respondents at all sites

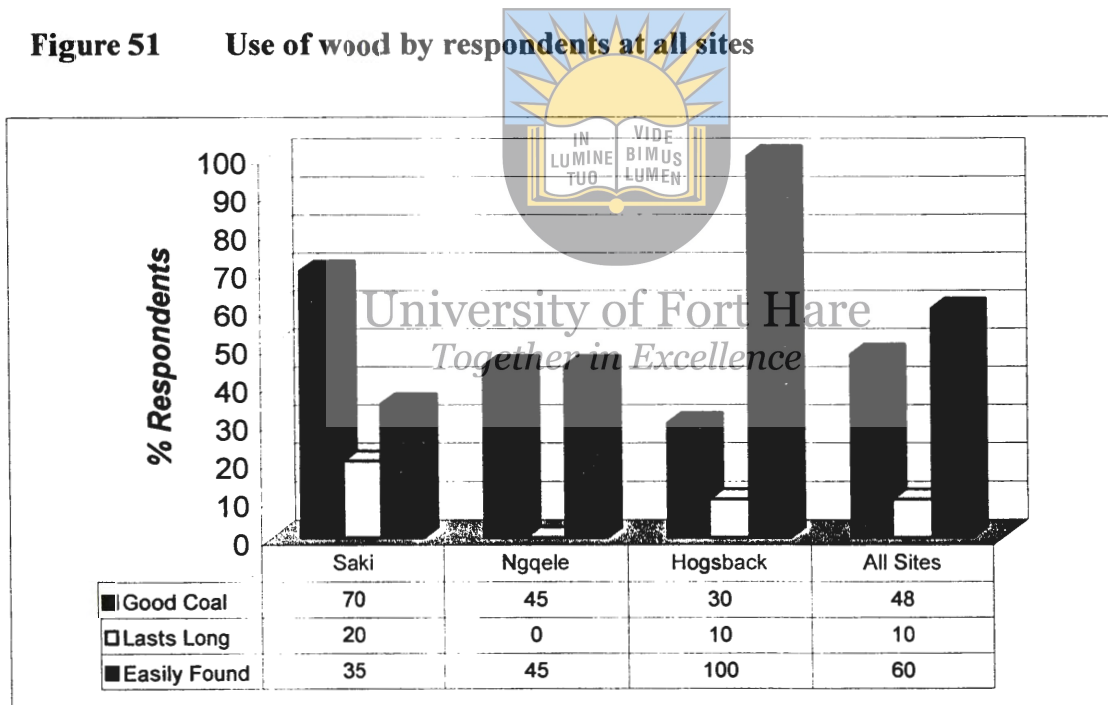


Figure 52 Reasons for choice of wood by percent respondents at all sites

The reason for choice of wood varied from site to site, due to the floristic nature of the wood (Figure 52). Hundred percent of the respondents from Hogsback reported that they used their selection of fuel source (wood) because it was readily available. Approximately 30% of the respondents from this site used their choice of wood because they derived good coal from this. Approximately 70% of the respondents from Saki reported to be using their type of wood because it gave good coal. This was the site with the lowest occurrences of easily found wood (Figure 52).

Erosion Awareness

Most of the respondents at all sites understood and knew the meaning of erosion and what the probable causes and its consequences were. An average of 60% of the people were aware of the erosion status at all sites (Figure 53). The highest percentage (70%) of people aware of erosion was reported at the Ngqele site and the lowest (60%) Hogsback. Those respondents who were aware of erosion reported that they mostly witnessed erosion taking place when it had rained or during windy days or seasons of the year. They also reported that they have avoided cultivation on sloppy areas and should cultivation take place on such sloppy areas, then they would practice contour ploughing and make furrows so that the water could flow without washing away soil, especially when it rains. To rehabilitate streams the inhabitants of Saki reported that they have aligned tyres along the banks of the stream to alleviate stream bank erosion.

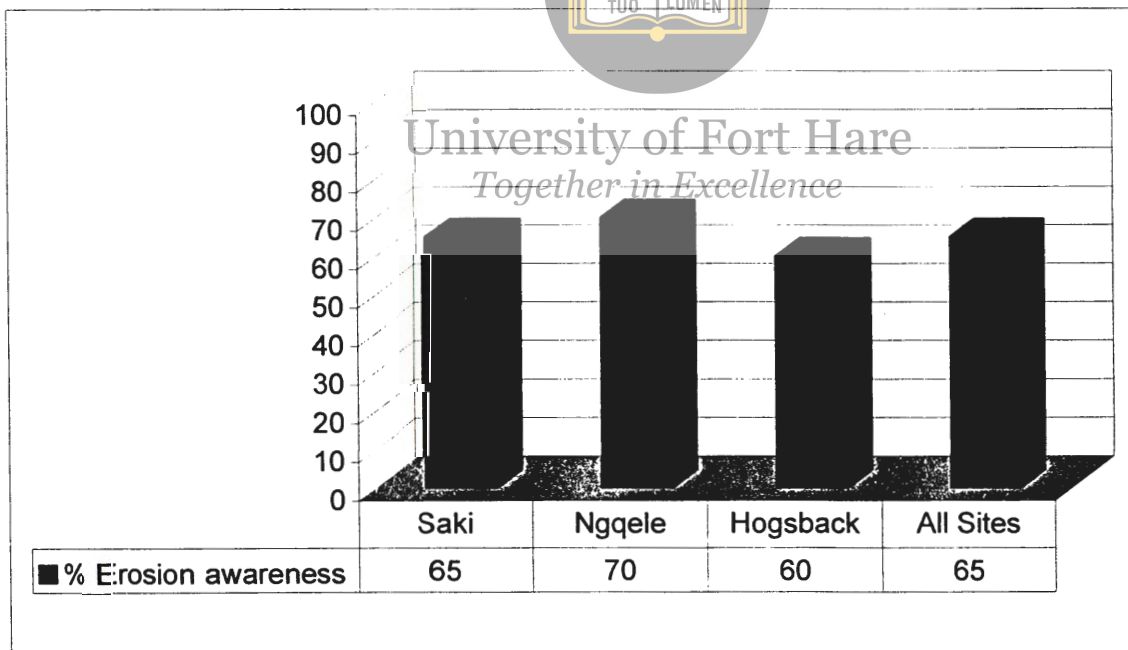


Figure 53 Average percentage of respondents who are aware of erosion

Geographic Information on Land Use Patterns

Saki Catchment (767676 m²)

Catchment Characteristics: 1977

Soils

The soil characteristics of this catchment area were graphically depicted and found to be characterized by Beaufort sediments. According to HKS (1977), soil types found included Valsrivier (psuedo duplex), Lindley (psuedo duplex) and Mispah (Figure 54). This figure shows that Mispah covered the greater extent of the catchment area (88%) with the Valsrivier (2%) and Lindley (10%) only confined to the base of the catchment area. Valsrivier and Lindley also appeared to be confined to the area of the catchment, which was dominated by gully erosion. This was because both soil types (Valsrivier and Lindley) were characterised by relatively slowly permeable, sodic clays concentrated near the surface, which according to HKS (1977), made the soils very sensitive to mismanagement. Mispah on the other hand was found to be concentrated on the part of the catchment area characterized by sheet erosion. This according to HKS (1977) was because the erodibility of Mispah is assumed to be highly dependent on the slope gradient. The slope characterizing this catchment area appeared to be gentle (12 degrees) (Figure 55). The catchment was already eroded by 100% in 1977 (Figure 54). Approximately 15% of the catchment was characterized by gully erosion with the remaining 75% by sheet erosion.

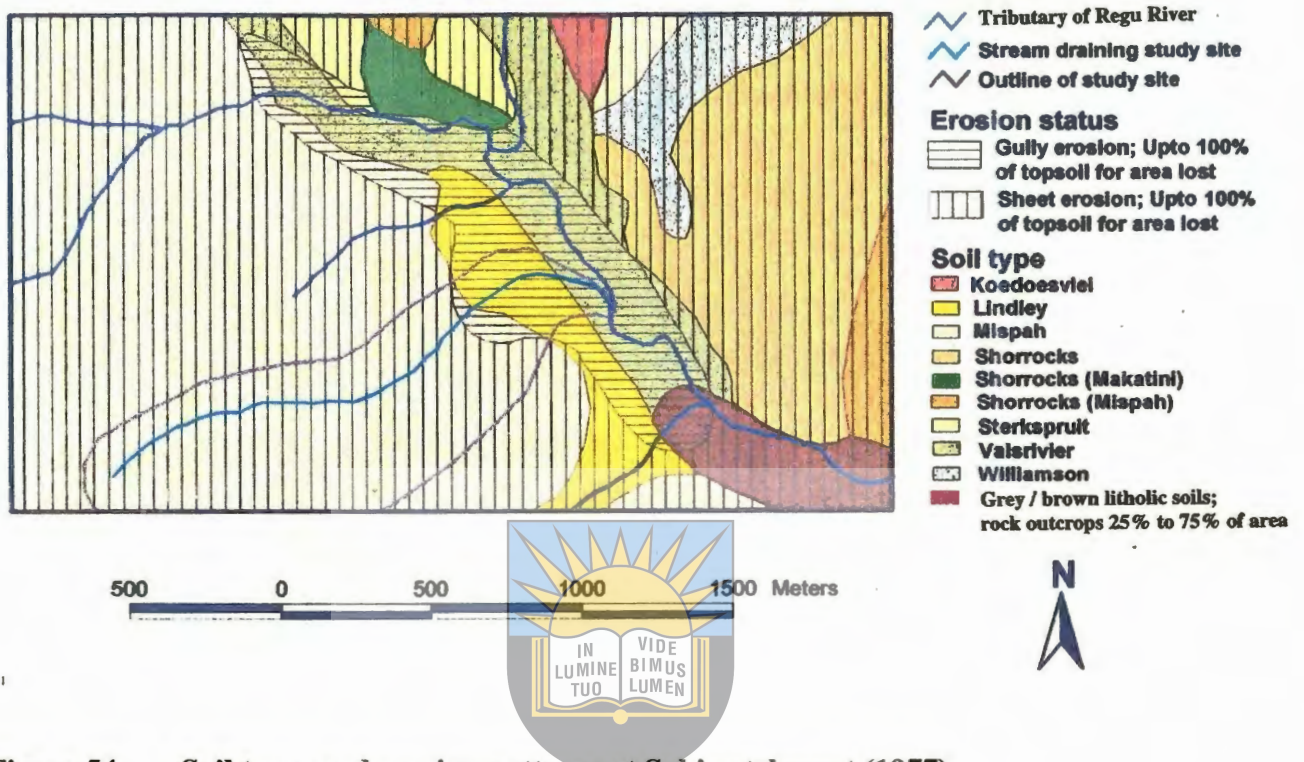


Figure 54 Soil types and erosion patterns at Saki catchment (1977)

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Vegetation

The Saki catchment's vegetation characterization based on HKS (1977), is depicted by Figure 55. This catchment was characterized by Acock's False thornveld of the Eastern Cape, which has been classified as the Eastern thorn bushveld by Low and Rebelo (1996). This veld type was characterized by grasslands invaded by thicket type vegetation. The dominating savanna tree is *Acacia karroo*. Dominant grasses comprise *Cynodon dactylon*, *Digitaria eriantha*, and *Sporobolus fimbriatus*. This veld type is highly prone to erosion especially due to overgrazing HKS (1977).

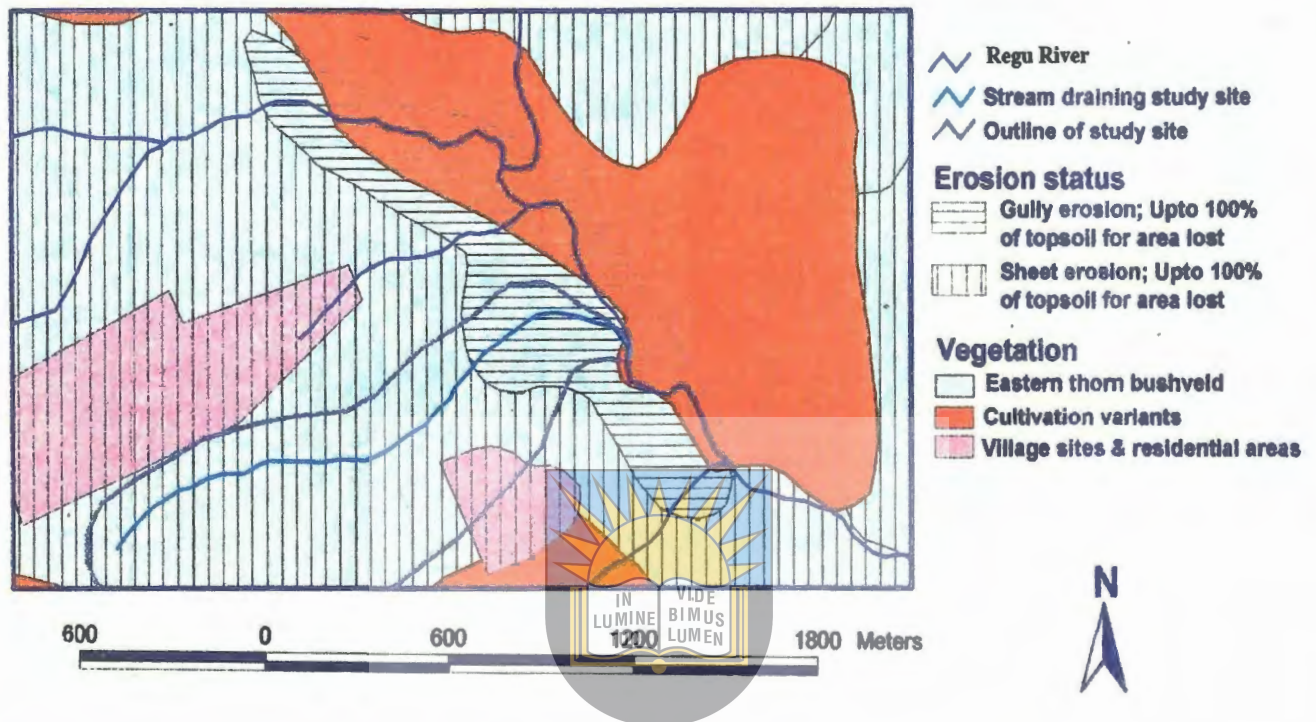


Figure 55 Vegetation and erosion patterns at the Saki catchment (1977)

Status of land use as surveyed by GIS

It was found that approximately 4% of the catchment area was used as a settlement area and the remaining 96% used for grazing stock (Figure 56). This figure also depicts that this land use practice might not have been the best land use practice, as 100% of the catchment area was eroded. This finding prompted HKS (1977) to justify his recommendations of promoting different land use practices, in an effort to alleviate the problem of erosion (Figure 57).

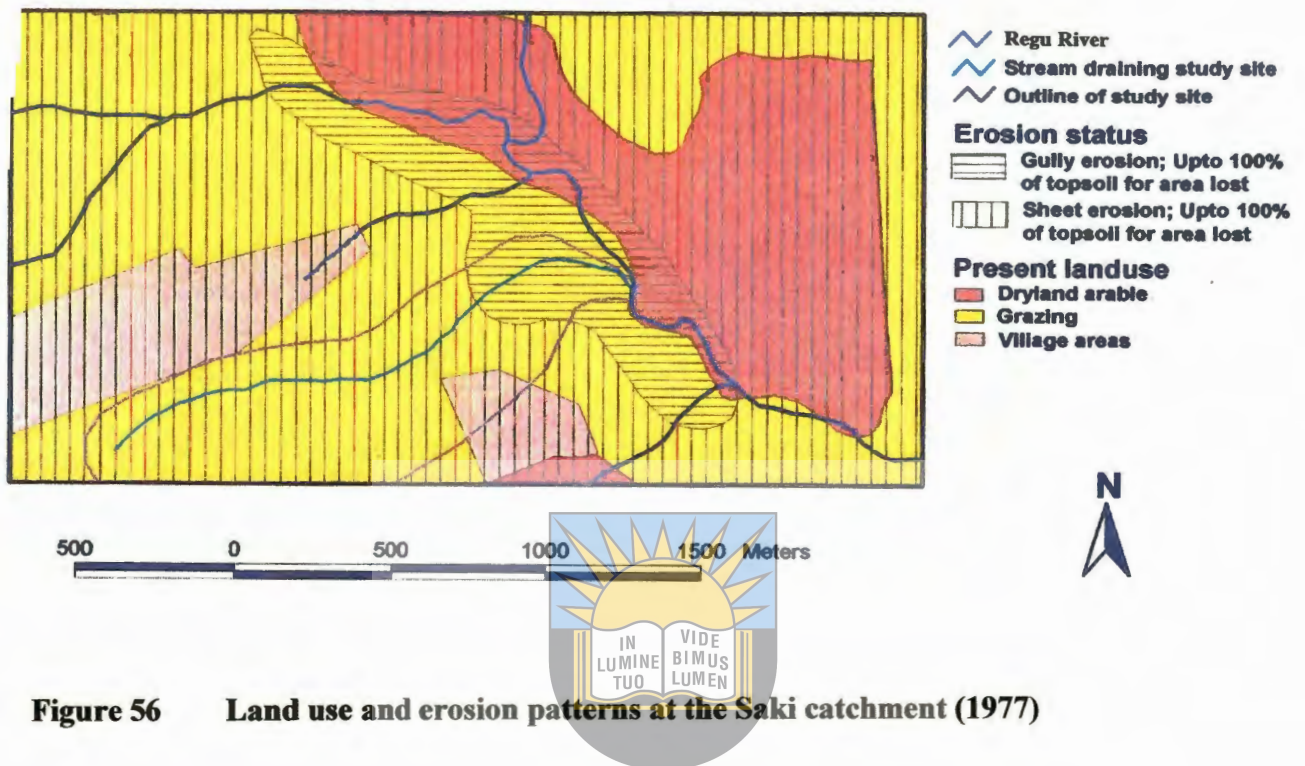


Figure 56 Land use and erosion patterns at the Saki catchment (1977)

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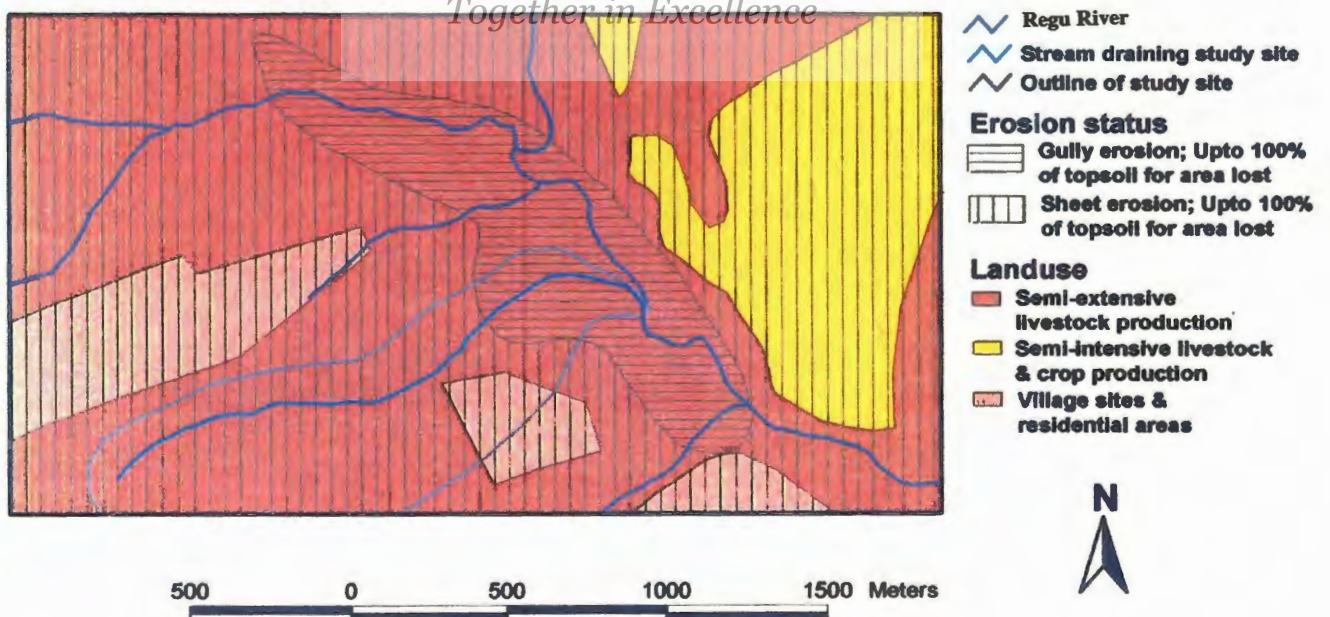


Figure 57 Recommended land use and erosion patterns at the Saki

Catchment Characteristics at Saki during the 1998 Survey

Figure 58 depicts the catchment characteristics at Saki, in October 1998. The vegetation type, Eastern thorn bushveld, covered approximately 82% of the catchment area, with an additional 4% of the area used for cultivated cycol variants. Approximately 4% of the catchment was still used for settlement purpose and another 2% used as cultivating fields. The entire catchment area was also used for grazing. This contradicted with the recommended land use as suggested by the 1977 study by HKS. This contradiction in land use practice has consequently resulted in an increase in gully erosion (Figures 57 and 58). At the time of the study, 18% of the catchment was covered by gully erosion compared to 15% in 1977. Sheet erosion has consequently decreased from 85% in 1977 to 82% in 1998 (Figures 57 and 58).

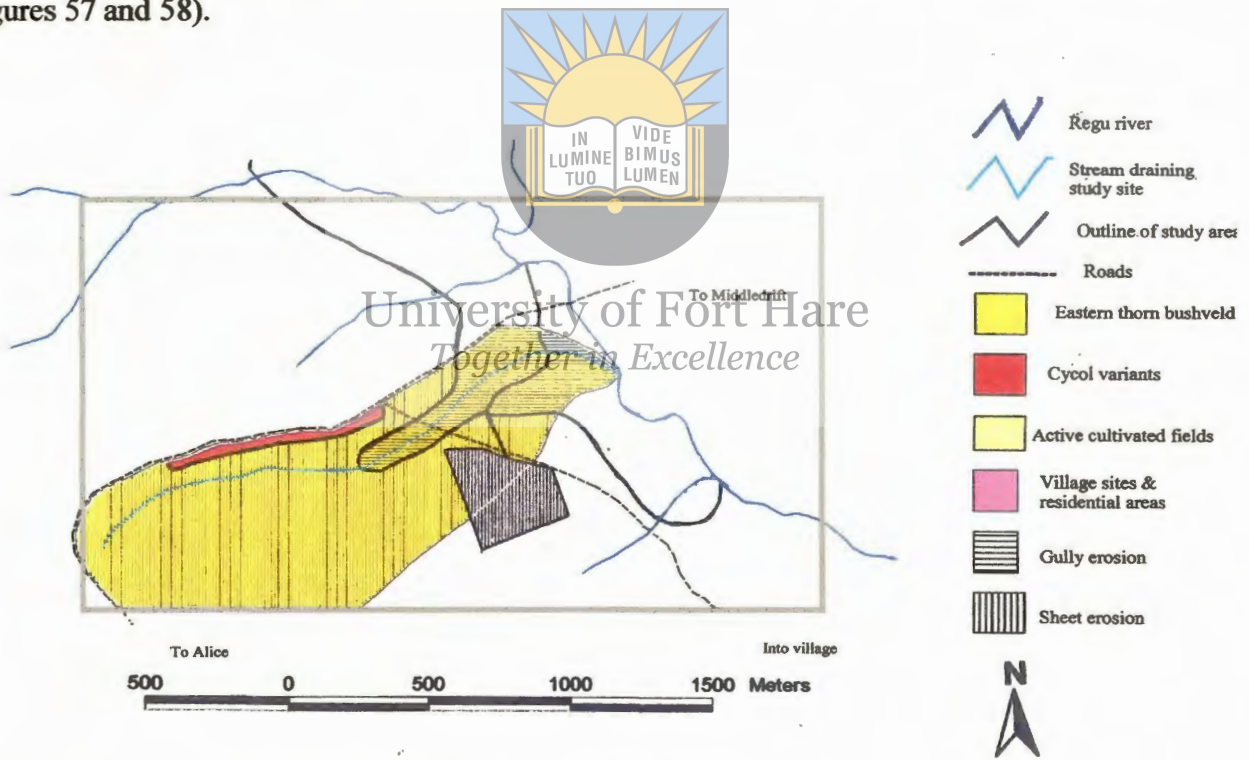


Figure 58 Catchment characteristics at Saki (1998)

Ngqele Catchment (171171 m²)

Catchment Characteristics: 1977

Soils

The soils that characterised the site are graphically depicted in Figure 59. Sharrocks with rock outcrops were the dominant soil covering the site. These soils are Beaufort sediments with a minor influence of dolerite (Hill Kaplan and Scott, 1977). Dark reddish brown or brown fine sandy loam overlying an apedal, dark red or yellowish red, sandy clay loam is characteristic

of this soil type. The slope gradient at this site was at an angle of 14 degrees, which was a relatively gentle slope (Figure 60). Erosion seemed to be independent of the slope and the soil type. Only approximately 28% of the catchment showed signs of erosion.

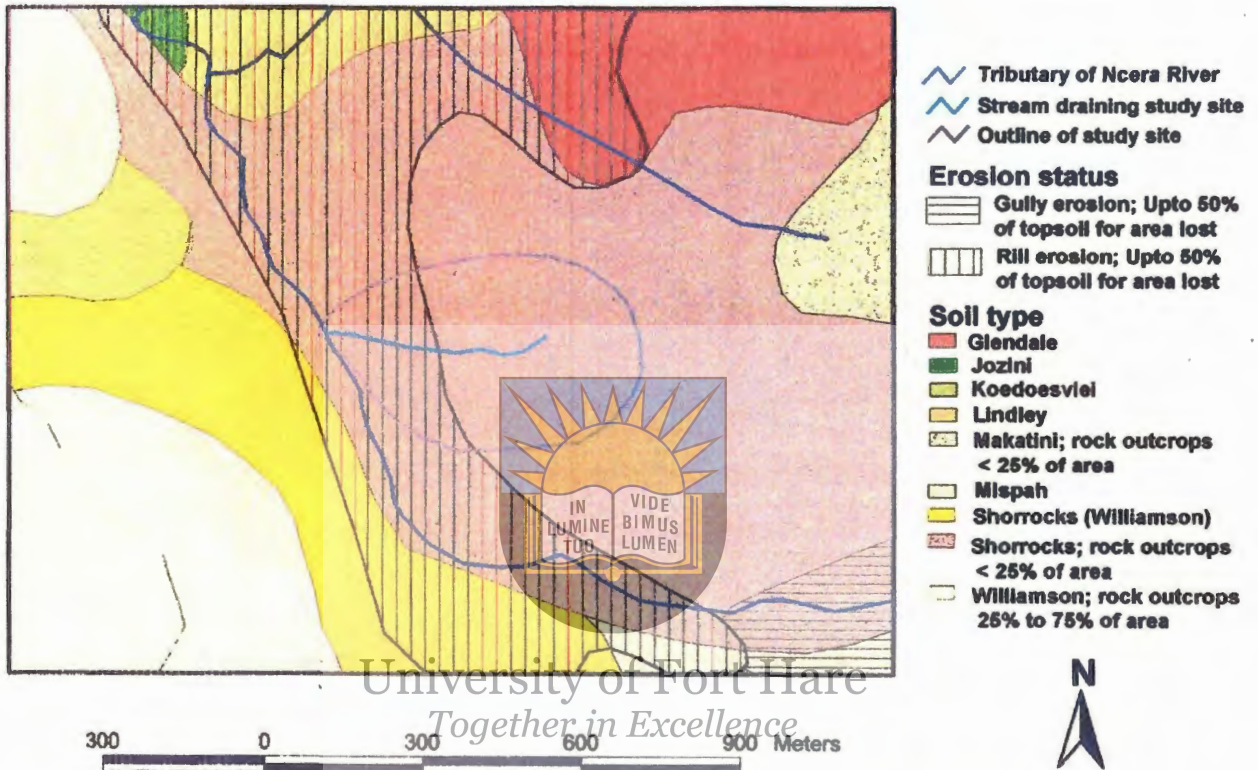


Figure 59 Soil types and erosion patterns at the Ngqele catchment (1977)

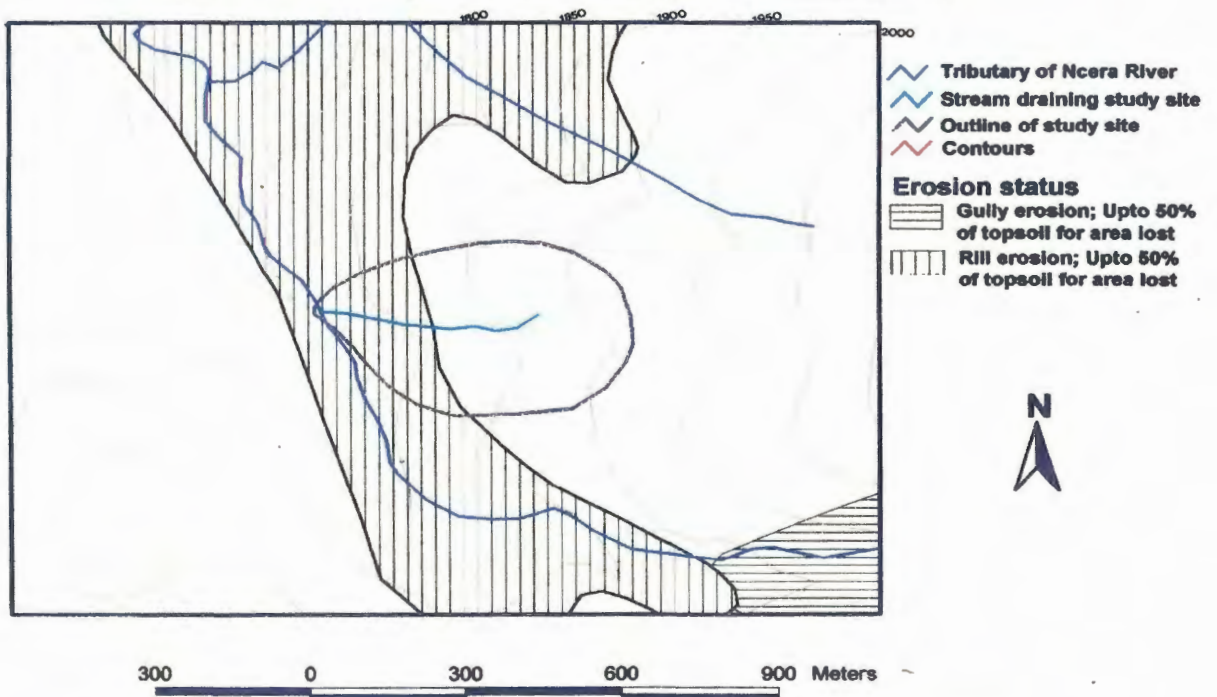


Figure 60 Contours and erosion patterns at the Ngqele catchment (1977)

Vegetation

There was no specific vegetation type characteristic of the catchment area during the 1977 HKS study (Figure 61). Cultivation variants covered 20% of the eroded area. These cultivation variants were mainly associated with grasses, herbs and forbs. Shrubs found were basically of karroid nature. These were namely *Chrysocoma ciliata*, *Walafrida sp* and *Indigofera sp*. Grass species found were dominated by *Cynodon dactylon* and *Digitaria eriantha*.

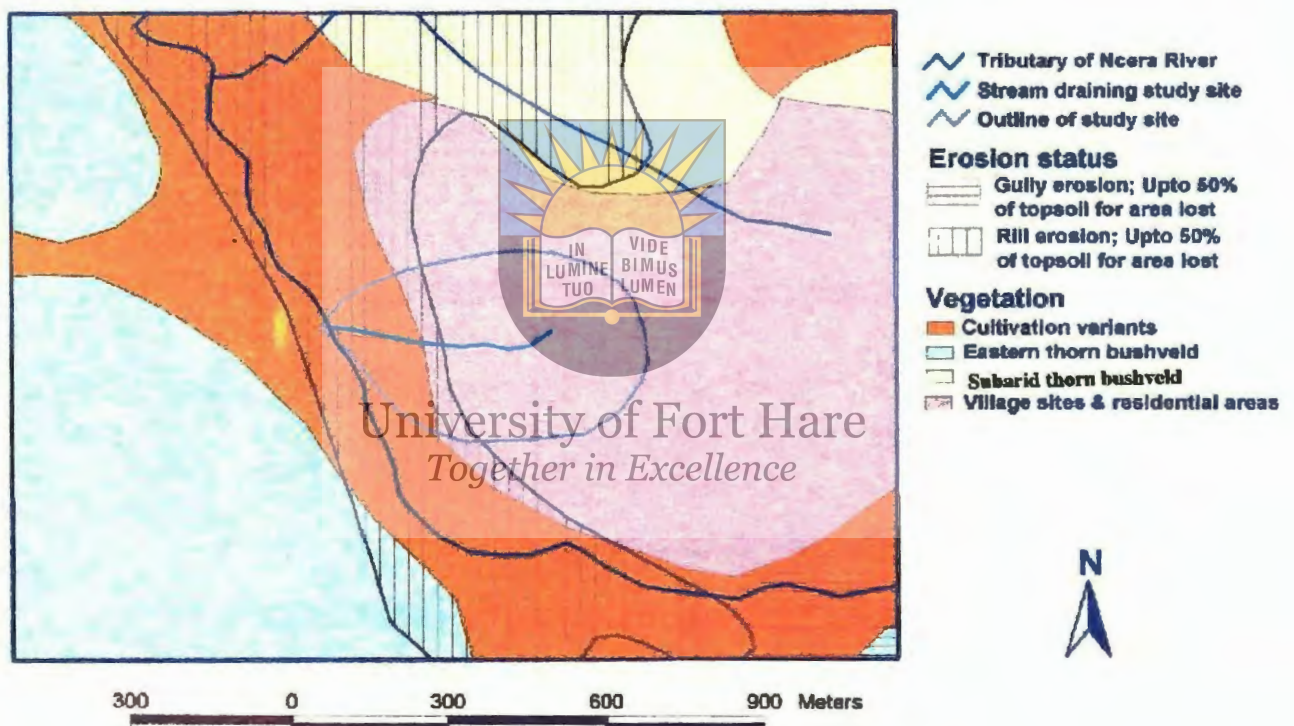


Figure 61 Vegetation and erosion patterns at the Ngqele catchment (1977)

Status of land use surveyed by GIS

It was found that 80% of the catchment area was used as a settlement area and the remaining 20% for dryland arable farming (Figure 62). Consequently, the entire area that was used for dryland arable farming and was also characterised by rill erosion.

Based on this information, HKS (1977) came up with recommended land use practices to be followed in order to alleviate erosion in the catchment area (Figure 63). According to these

recommendations, the entire area, which was previously used for dryland arable farming, was to be used for semi-extensive livestock production. This type of land use was thought to have less impact on the environment and on the incidence of erosion.

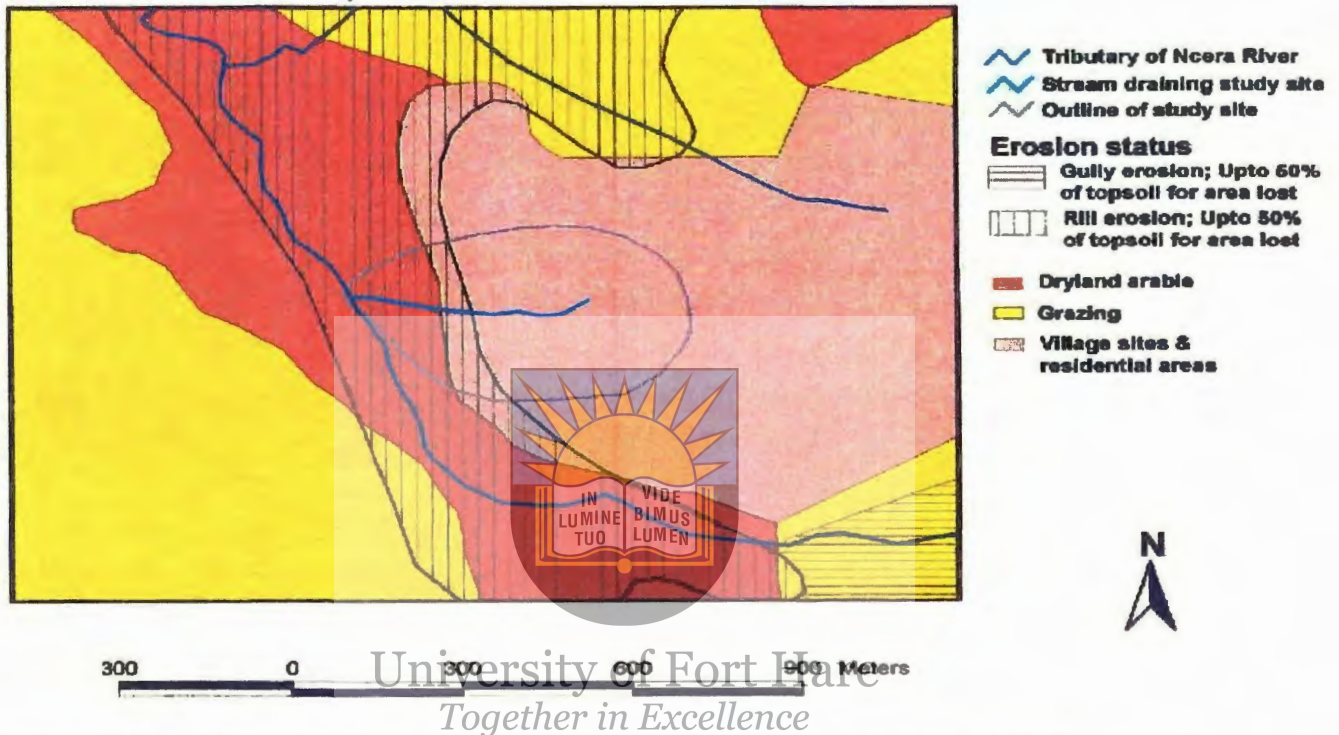


Figure 62 Land use and erosion patterns at the Ngqele catchment (1977)

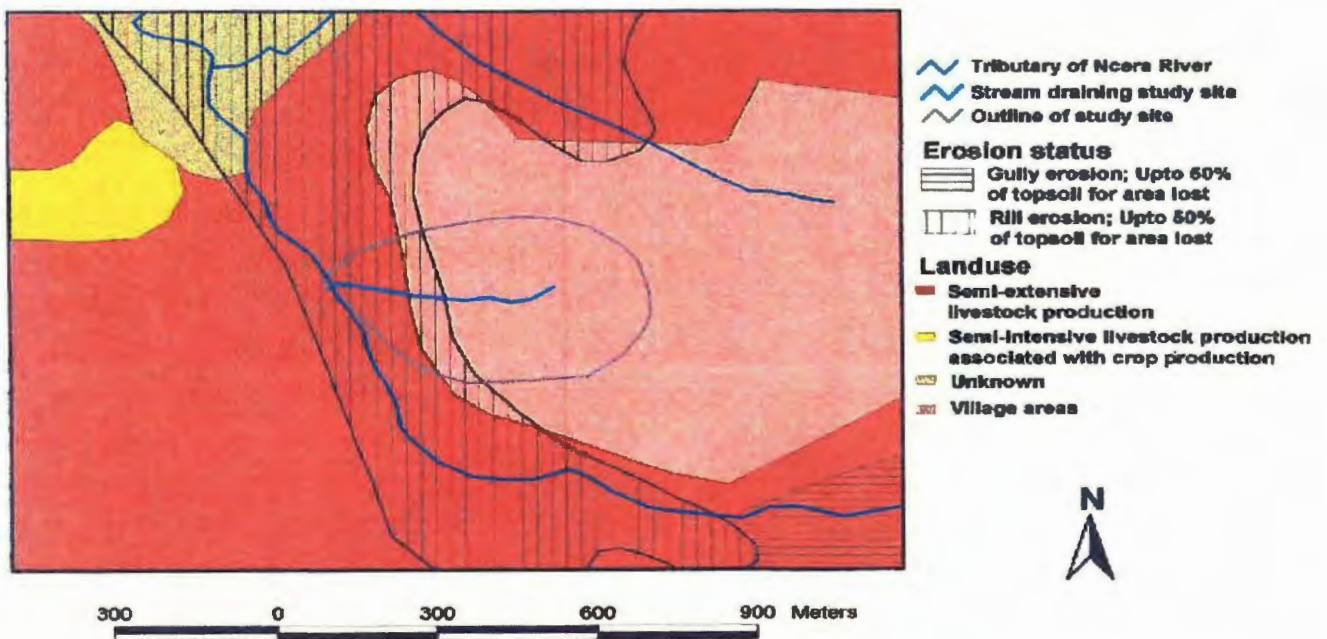


Figure 63 Recommended land use and erosion patterns at the Ngqele catchment (1977)

Catchment Characteristics at Ngqele during the 1998 Survey

The catchment characteristics at Ngqele are depicted by Figure 64. The figure also indicates that approximately 73% of the Ngqele catchment area was used as a settlement area. This percentage was similar to the original 80% proposed by HKS (1977). The area of the catchment covered by cultivation variants had decreased from 20 to 8% of the area (Figures 61 and 64). Of the 8% cultivation variants, only 2% were used as active cultivated field as the remaining 6% was left fallow. The catchment area was characterized by Eastern thorn bushveld dominated by grasses, herbs and forbs. Rill erosion which was mainly confined to the area along the stream banks had developed into deeply incised gullies. These gullies accounted for approximately 8% of the total catchment area.

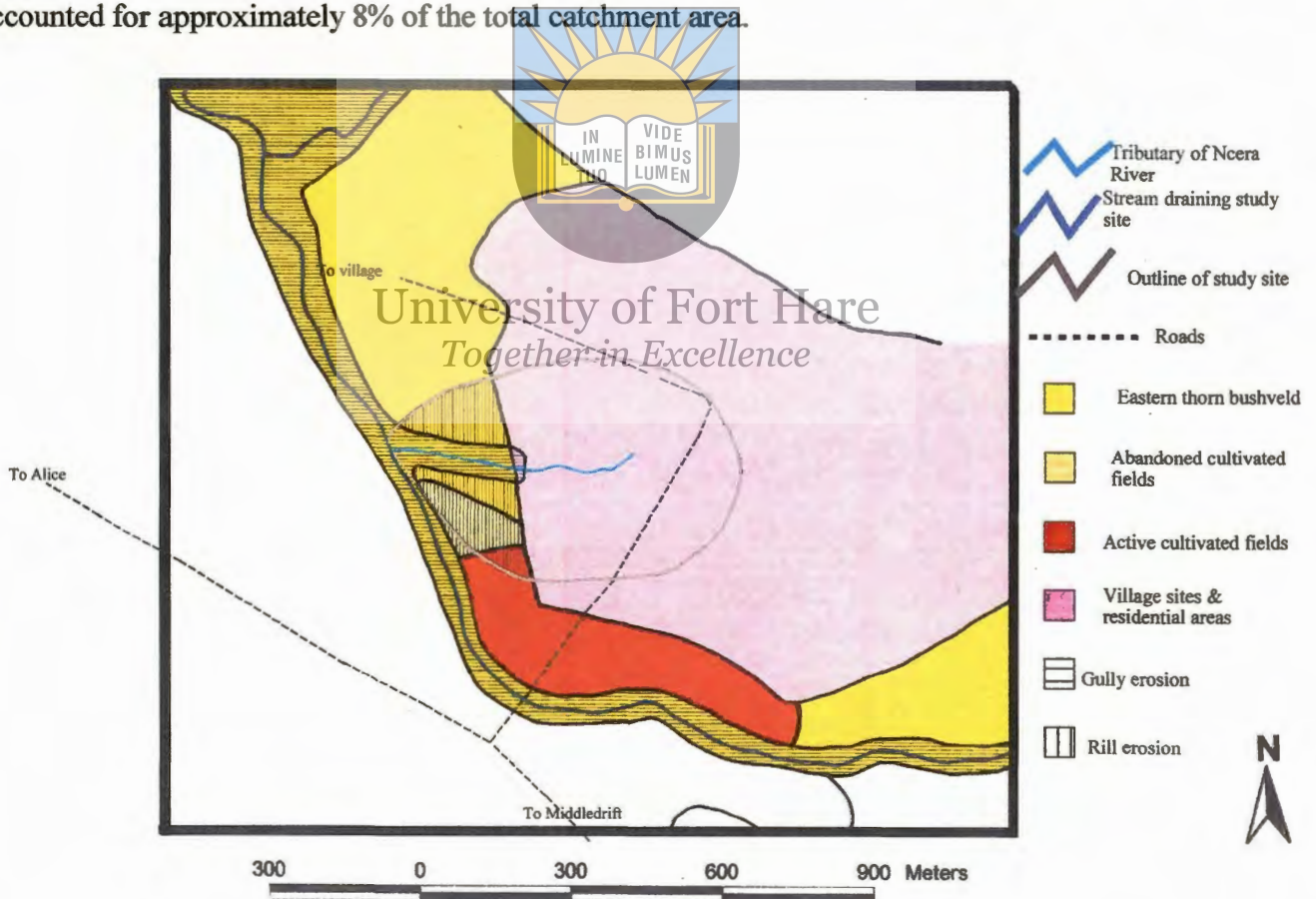


Figure 64 Catchment characteristics at the Ngqele catchment (1998)

Hogsback 1 Catchment (331899 m²)

Soils

The soils on this site were characterized by Williamson soils with slope gradients ranging from 15 to 65 percent. This soil type is characterised by brown and greyish brown colour soil and is very shallow in nature. According to HKS (1977), these soils have a very high erosion hazard.

Figure 64 shows that the only soil type prone to erosion was the Williamson soils with slope gradients varying from between 15 and 30 percent. This soil type was also found concentrated towards the base of the catchment area. Erosion at this site was of class 2E, where up to 50% of the top soil was lost to gully erosion (HKS, 1977). The gradient at this catchment site was a moderately steep slope at an angle of 31 degrees (Figure 66). This slope gradient seemed not to have any effect on the erodibility of the soil.

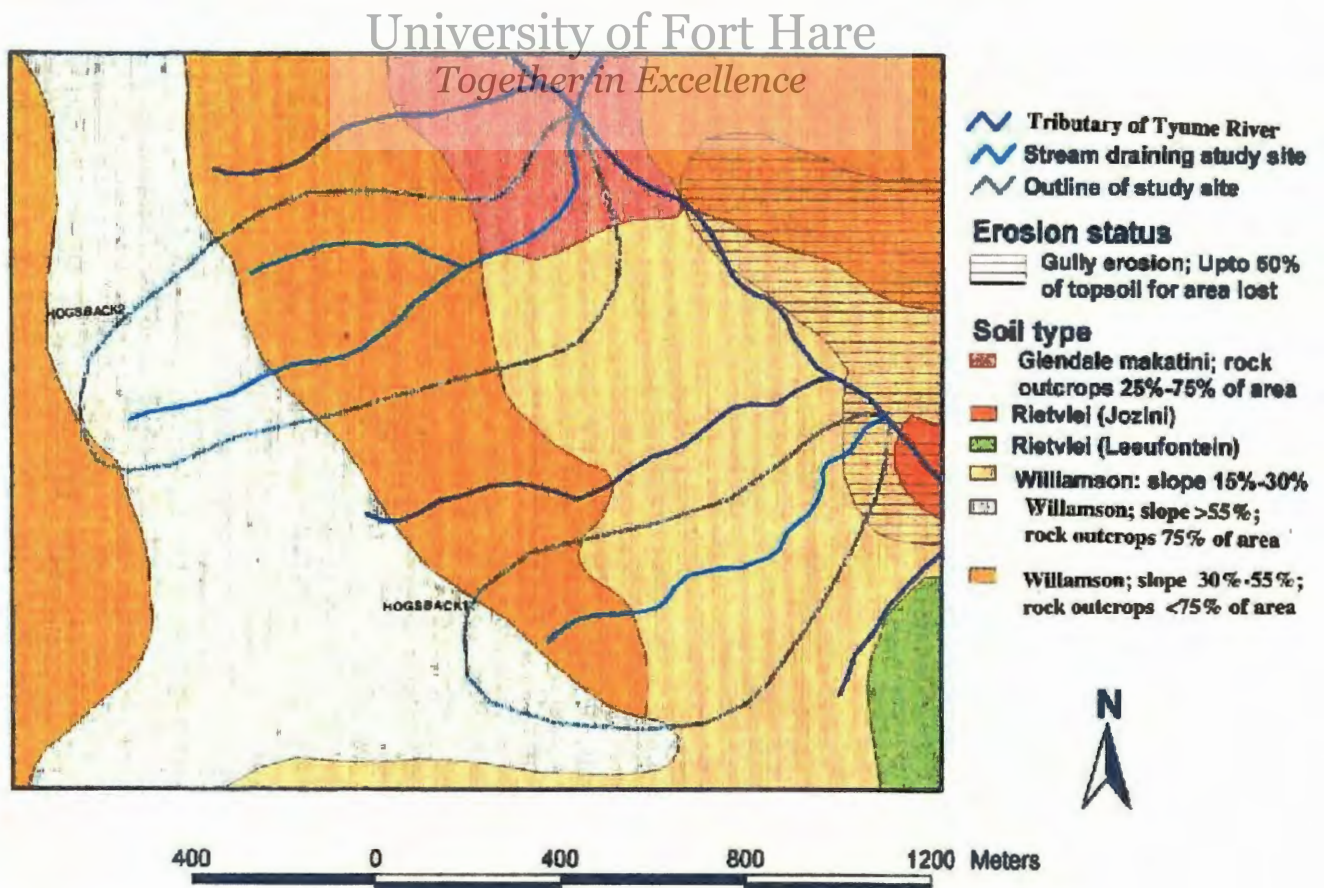


Figure 65 Soil types and erosion patterns at the Hogsback catchments (1977)

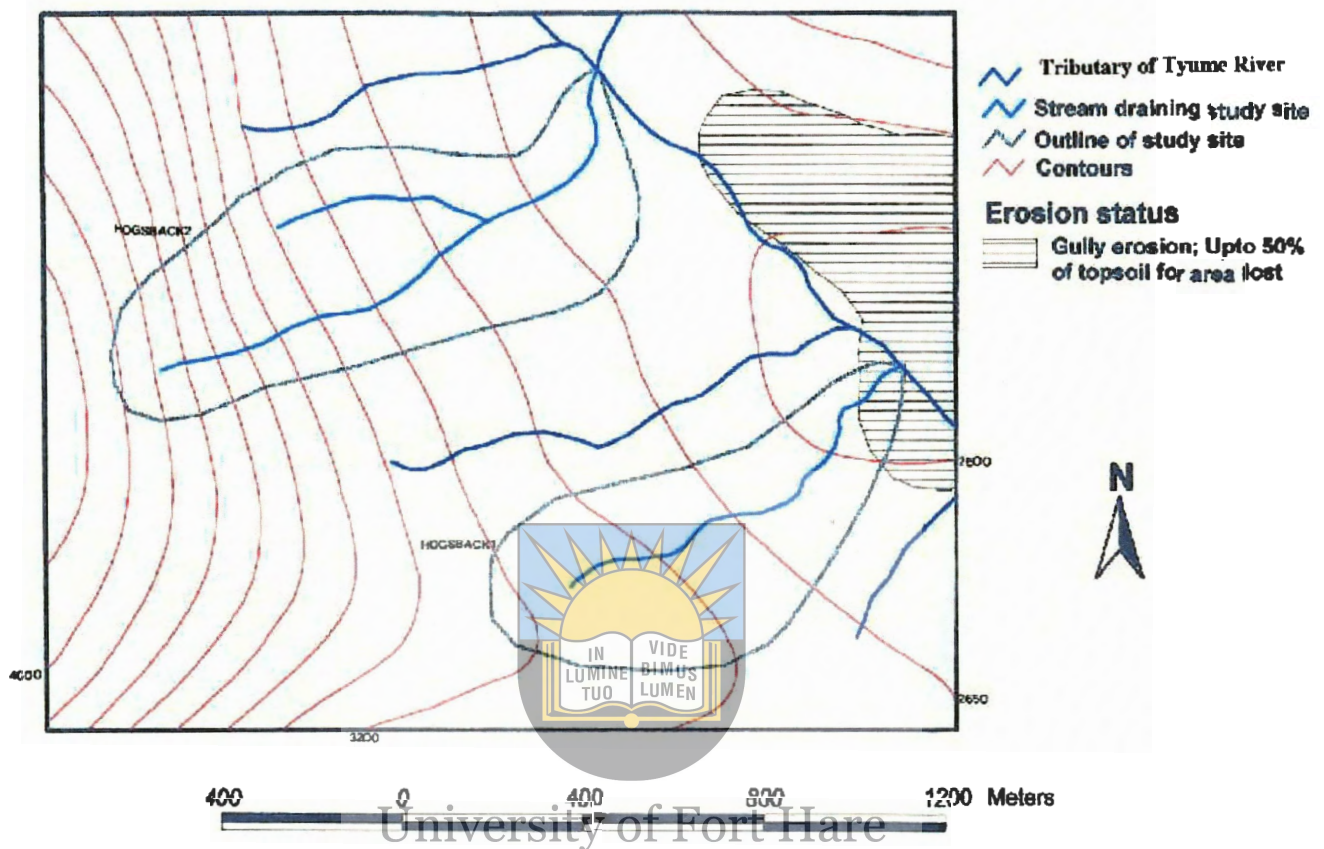


Figure 66 Contours and erosion patterns at the Hogsback sites

Vegetation

Approximately 65% of the catchment area was characterized by the Subarid thorn bushveld (Acock's Submontane grasslands) and the remaining 35% characterised by Afromontane forests (Acock's Dohne Sourveld) (Figure 67). Subarid thorn bushveld was characterized by sweet thorn *Acacia karroo* bush clumps or individuals and an intact grass layer except where it was severely overgrazed. Dominant grass species found included *Digitaria eriantha* and *Sporobolus fimbriatus*. Shrubs such as *Maytenus heterophylla*, *Scutia myrtina* and *Canthium ciliatum* and small trees such as *Rapanea melanophloes* dominated the Afromontane forests. Approximately 5% of the Subarid thorn bush veld was found growing in gullied areas.

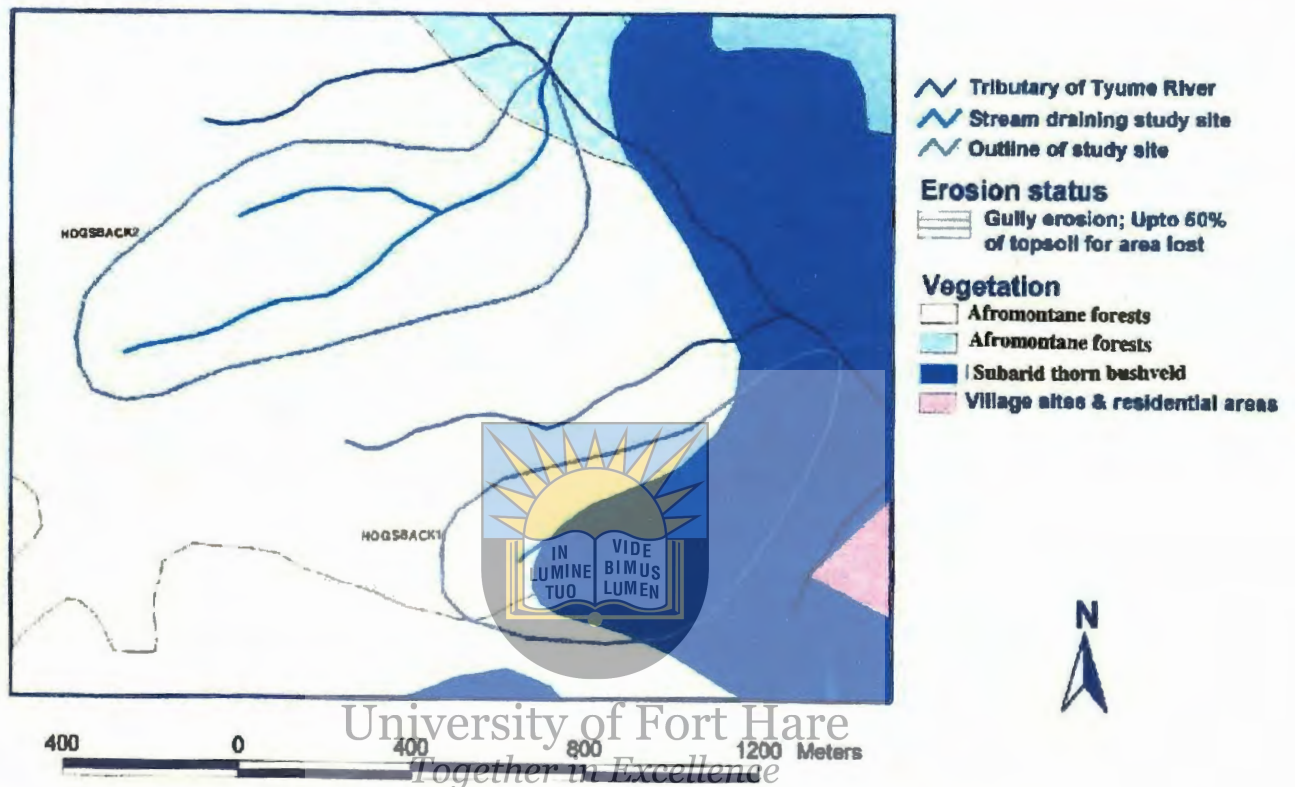


Figure 67 Vegetation and erosion patterns at the Hoggsback catchments (1977)

Status of land use surveyed by GIS

According to HKS (1977), the entire catchment area was used for grazing stock (Figure 68). This could have led to the development of gullies within the catchment area. The recommended land use as per the findings from the HKS study conducted in 1977, suggested that the catchment be used for three different land uses (Figure 69). According to these recommendations, 65% of the catchment area was to be used for semi-intensive livestock production, 23% for semi-extensive livestock production and 12% for semi-intensive livestock and crop production. Figure 69 also shows that, semi-intensive livestock production around the area covered with gullies will be the land use of choice to curb the erosion in the catchment area.

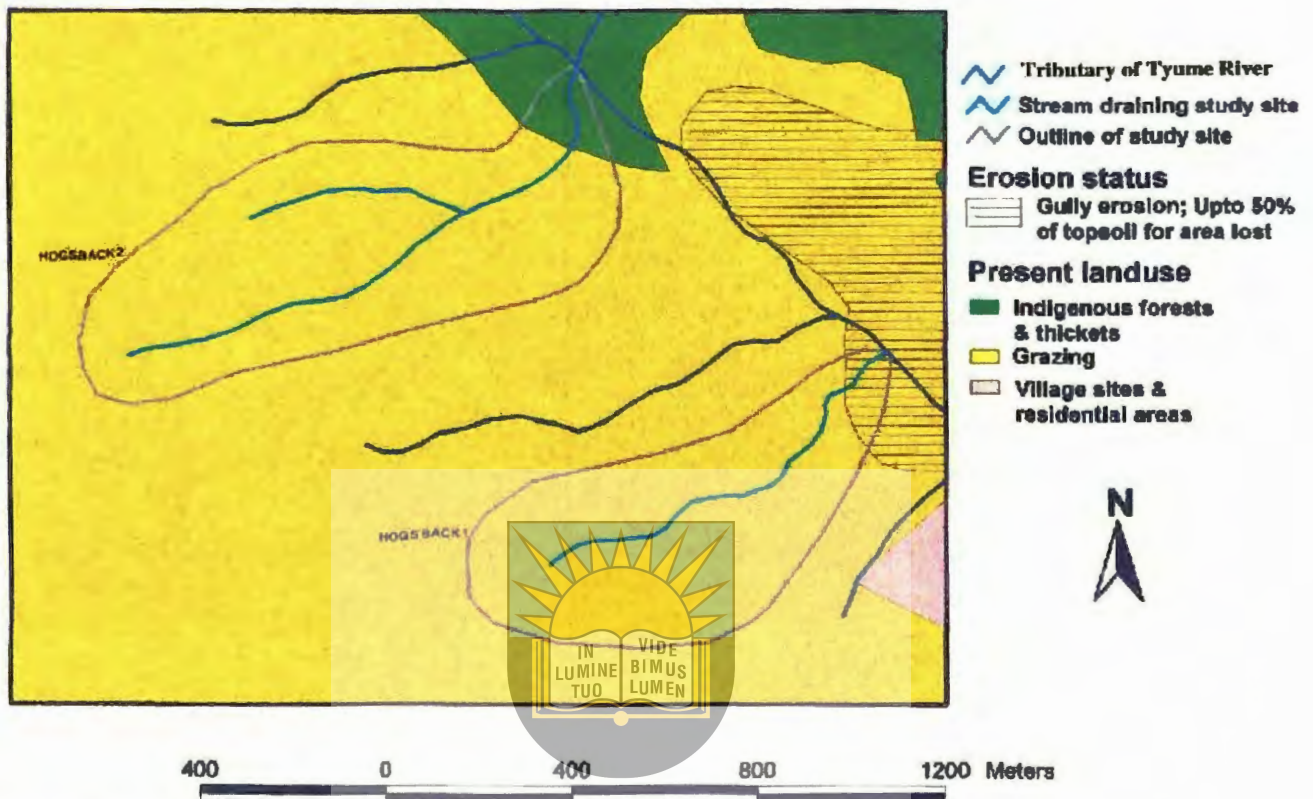


Figure 68 Land use and erosion patterns at the Hogsback catchments (1977)

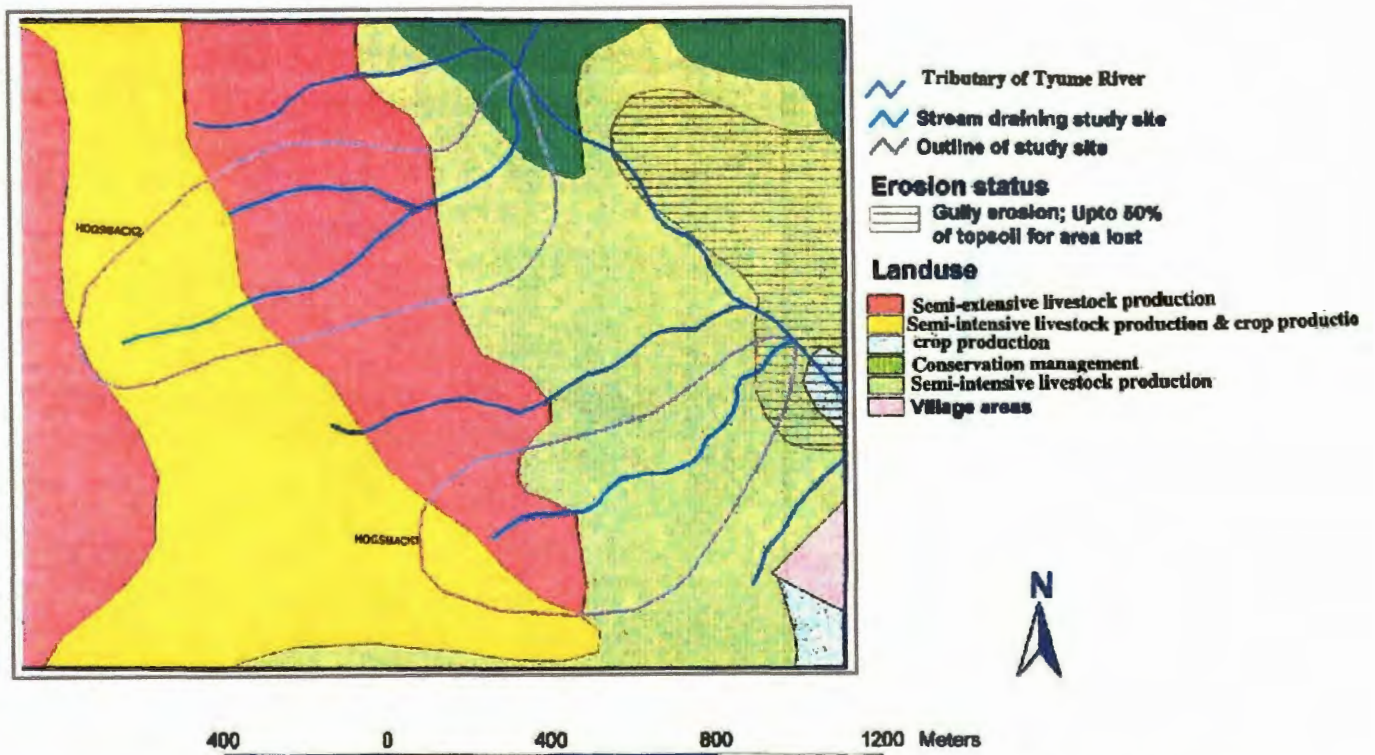


Figure 69 Recommended land use and erosion patterns at the Hogsback catchments (1977)

Catchment Characteristics at the Hogsback 1 during the 1998 Survey

Figure 70 depicts the catchment characteristics of the two Hogsback catchments as per the results of the investigations conducted in October 1998. The Hogsback 1 catchment in this figure illustrates that over 70% of the catchment area is covered with Subarid thorn bushveld, and that is consequently the area prone to mostly gully erosion and to a less extent sheet erosion. The bushy type of Afromontane forests dominated the remaining 30% of the area. This figure also depicts that the area is still not managed according to the recommended land use practices as suggested by the 1977, HKS study. Erosion has since progressed from 5% gully erosion, which was mainly confined to the base of the catchment, to 18%. There was also evidence of rill erosion covering 6% of the catchment area. The entire catchment area was used for grazing stock.

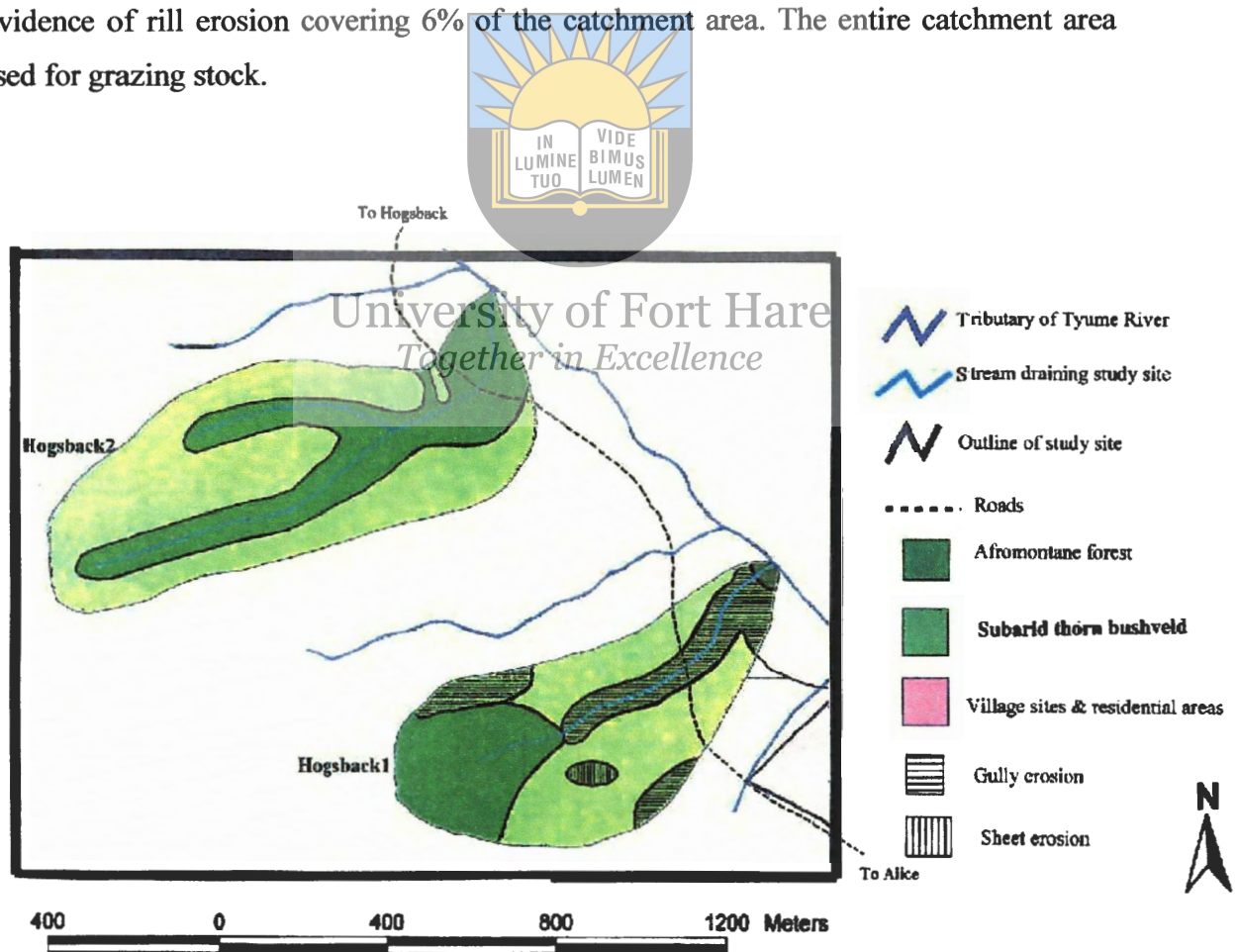


Figure 70 Catchment characteristics at the Hogsback catchments (1998)

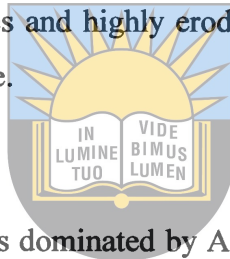
Hogsback 2 Catchment (458251 m²)

Catchment Characteristics: 1977

Soils

The Hogsback 2 catchment area was characterised by two soil types (HKS, 1977). These were, namely the Glendale makantini and the Williamson soil series (Figure 65). Glendale makantini soil series that are characterized by red, strongly or weakly structured clay and are mostly found on steep slopes. The Williamson series are brown and grayish brown in colour and very shallow in nature. Both soil types are of a very high erosion hazard (HKS, 1977).

The contours at Hogsback 2 revealed a very steep slope, with a slope gradient of 48 degrees (Figure 66). Despite the very steep slopes and highly erodible soils, the catchment area did not show any signs of erosion taking place.



Vegetation

The vegetation at this catchment area was dominated by Afromontane forest, that is Acock's Dohne Sourveld vegetation type (Figure 67). This veld type is characterized by a bushy type of vegetation comprising species such as *Scutia myrtina*, *Canthium ciliatum*, *Maytenus heterophylla* and *Rapanea melanophloes* as the most dominant tree species found on site. Herb species found include a species *Centella*.

Status of land use surveyed by GIS

Over 95% of the catchment area was used for grazing and the remaining 5% mainly used for the conservation of indigenous forests and thickets (Figure 68). The recommended land use practices as suggested by HKS (1977) were as follows. Approximately 4% of the catchment area was to continue being used as a conservation management site for forests and thickets and 45% of the area in the middle of the catchment used for semi-extensive livestock production. An additional 51% was to be used for semi-intensive livestock production of which 31% of it used for crop production.

Catchment Characteristics at Hogsback 2 during the 1998 Survey

The catchment characteristics of the Hogsback 2 catchment is depicted by Figure 70. This figure depicts a change in the vegetation character of the area. Approximately 40% of the

catchment area was at the time of the study covered by bushy types of Afromontane forests, which were mainly concentrated along the stream. The whole catchment area was used for grazing, mostly by cattle. There was, however, no evidence of erosion occurring at this site.

Zingcuka Catchment (24455 m²)

Catchment Characteristics: 1977

Soils

Soil types found at this catchment were characterised by Lindley and Williamson soils (Figure 71). These soils were dominated by gray or brown litholic Beaufort sediments which are highly prone to erosion, especially on steeper slopes (HKS, 1977). Rock outcrops covered approximately 25% of the area.

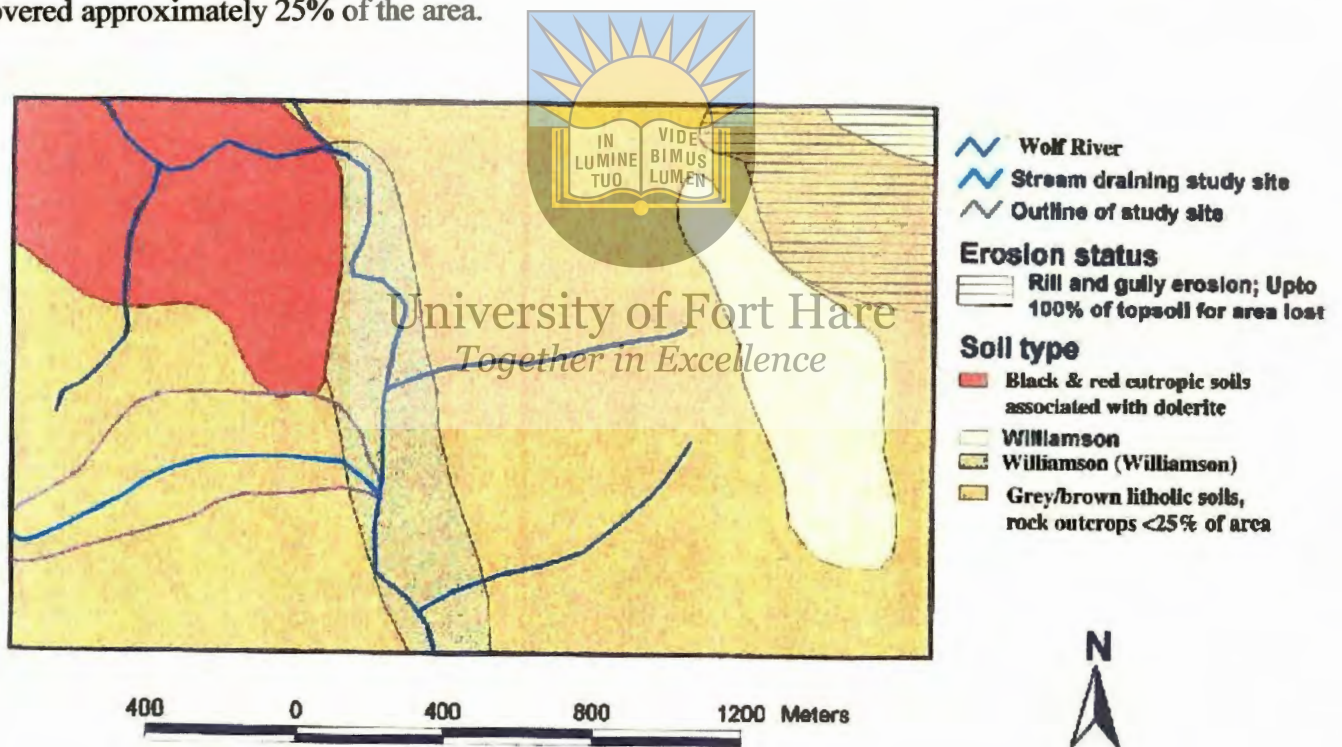


Figure 71 Soils and erosion patterns at the Zingcuka catchment (1977)

The catchment area was also characterized by very steep slopes of slope gradients in the region of 47 degrees (Figure 72). There was no sign of erosion taking place within the catchment area, despite the characteristic steep slopes and highly erodible soils.

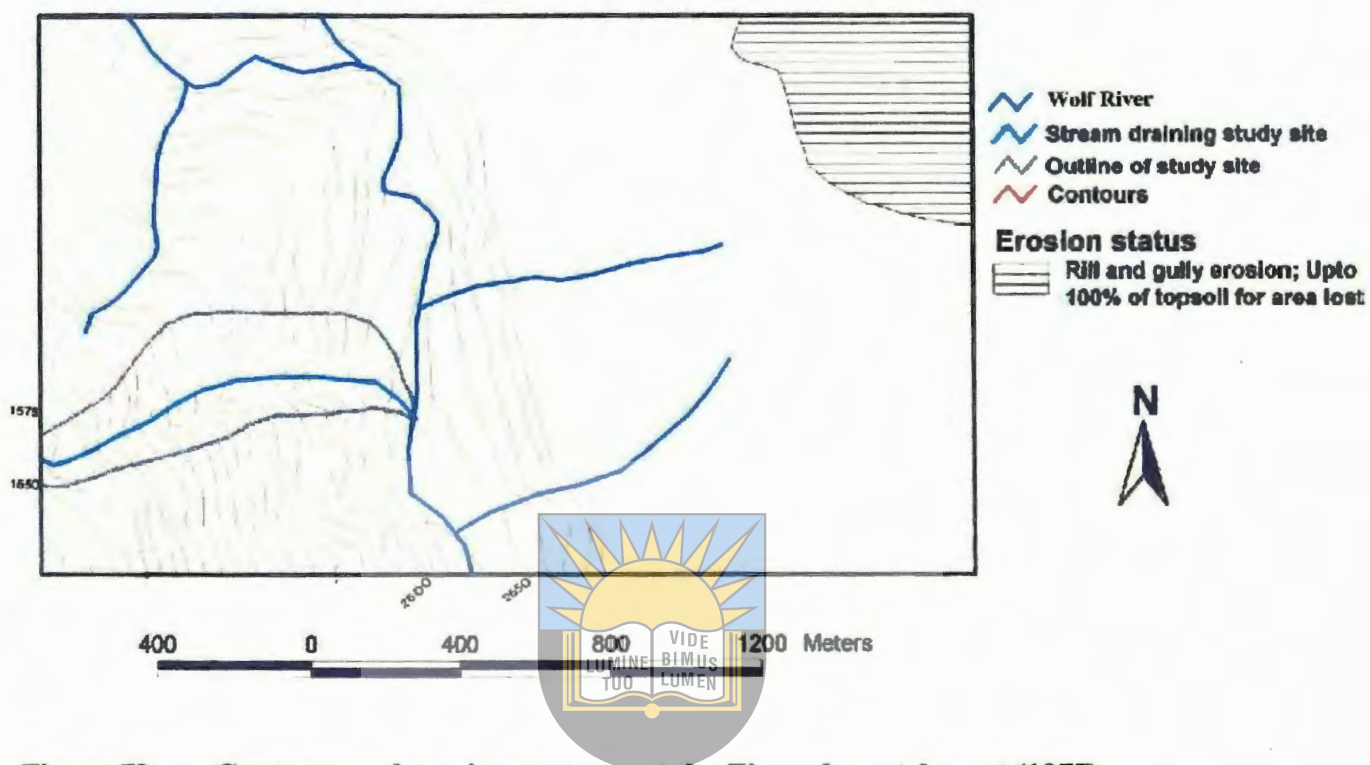


Figure 72 Contours and erosion patterns at the Zingcuka catchment (1977)

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Vegetation

The site was characterised by two types of veld, namely Afromontane forests (Acock's Dohne Sour veld) and Subarid thorn bushveld (Acock's Submontane and coastal grasslands) (Figure 73). Afromontane forests covered approximately 43% of the area and Subarid thorn bushveld covered 28% of the catchment area. Afromontane forests were mostly confined to kloofs and gullies where water was a key limiting factor (Lubke & McKenzie, 1996). Subarid thorn grasslands on the other hand were characterized by *Acacia karroo* bushclumps or individuals with an intact grass layer except where severely grazed (Lubke & Bredenkamp, 1996). An additional 29% of the area was used for cultivation (Figure 73).

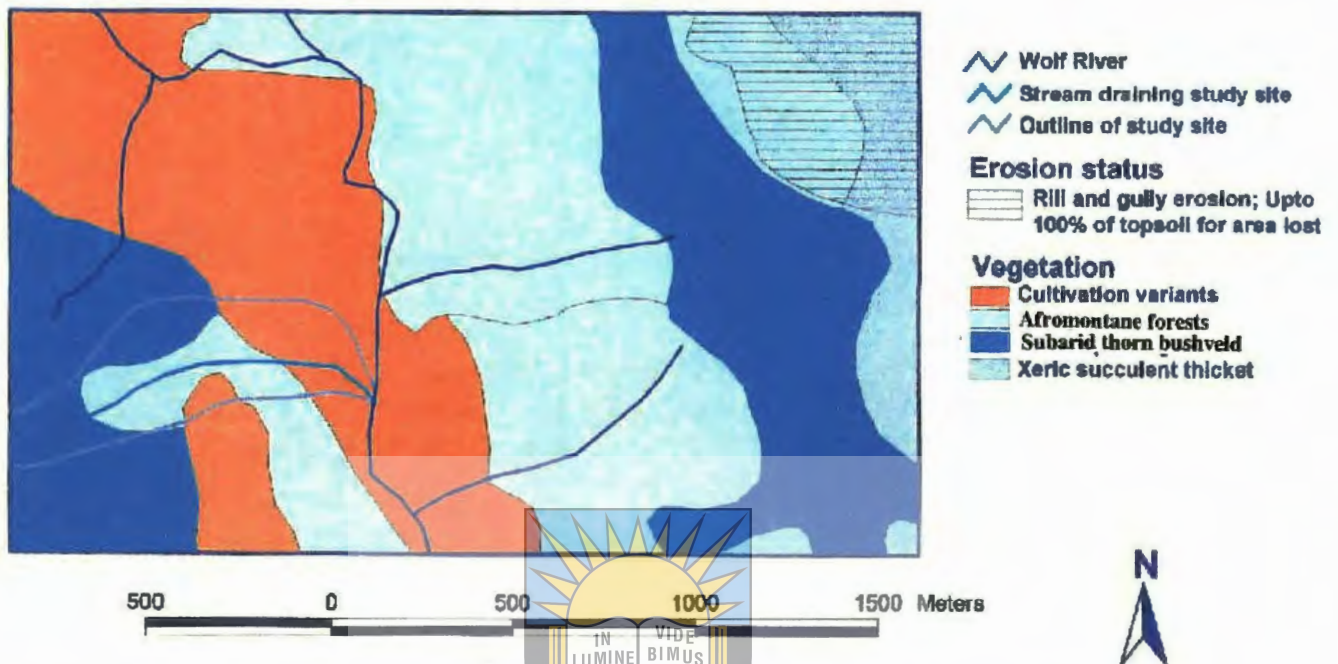


Figure 73 Vegetation and erosion patterns at the Zinguka catchment (1977)

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Status of land use as surveyed by GIS *Together in Excellence*

The land use practices characteristic of this catchment area in 1977, were, grazing stock, the use of the land as arable land and for the conservation of indigenous forests and thickets (Figure 74). More than 40% of the catchment area was used for the conservation of indigenous forests and thickets and approximately 29% of the remaining area used for grazing.

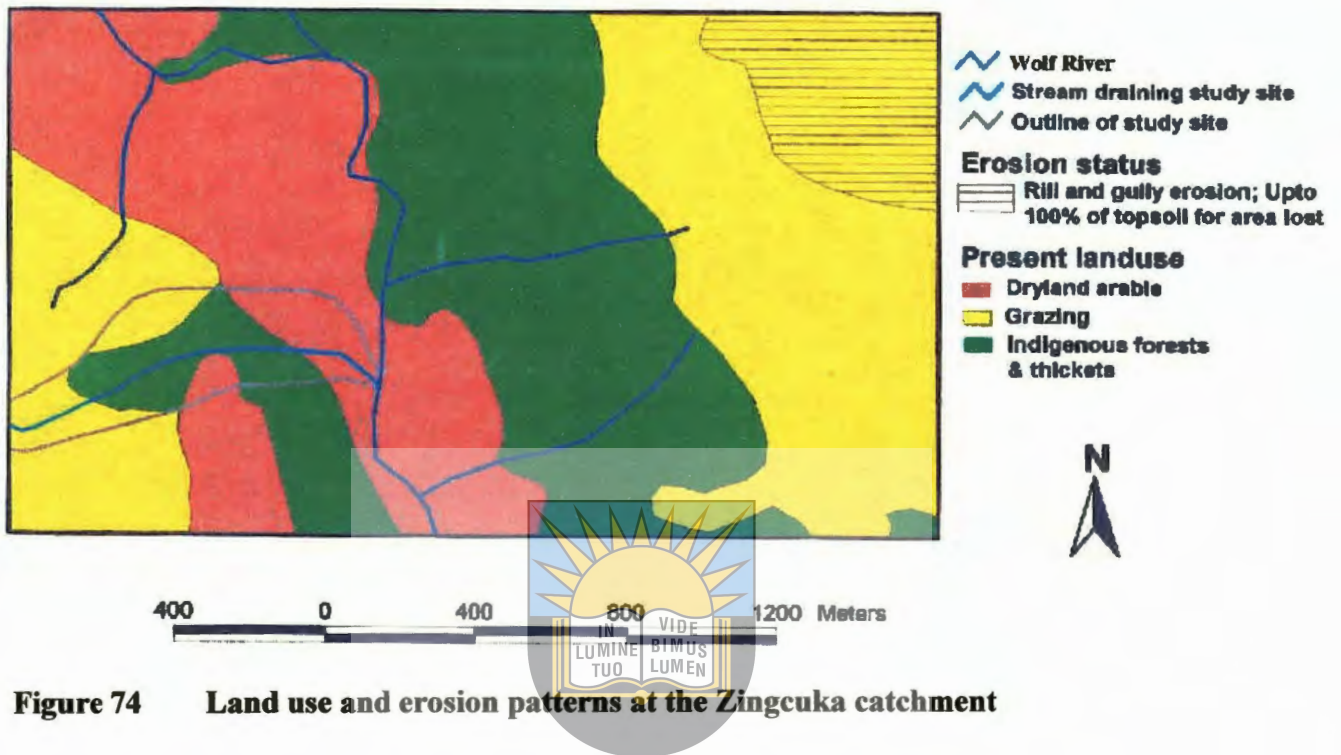


Figure 74 Land use and erosion patterns at the Zingcuka catchment

Figure 75 depicts a map of the recommended land use practices as per the recommendations from HKS (1977). According to these recommendations, approximately 60% of the catchment area was to be used for semi-intensive livestock production or as a reserve for grazing. The remaining 40% of the catchment was to be used for the conservation of forests, thickets and grasslands.

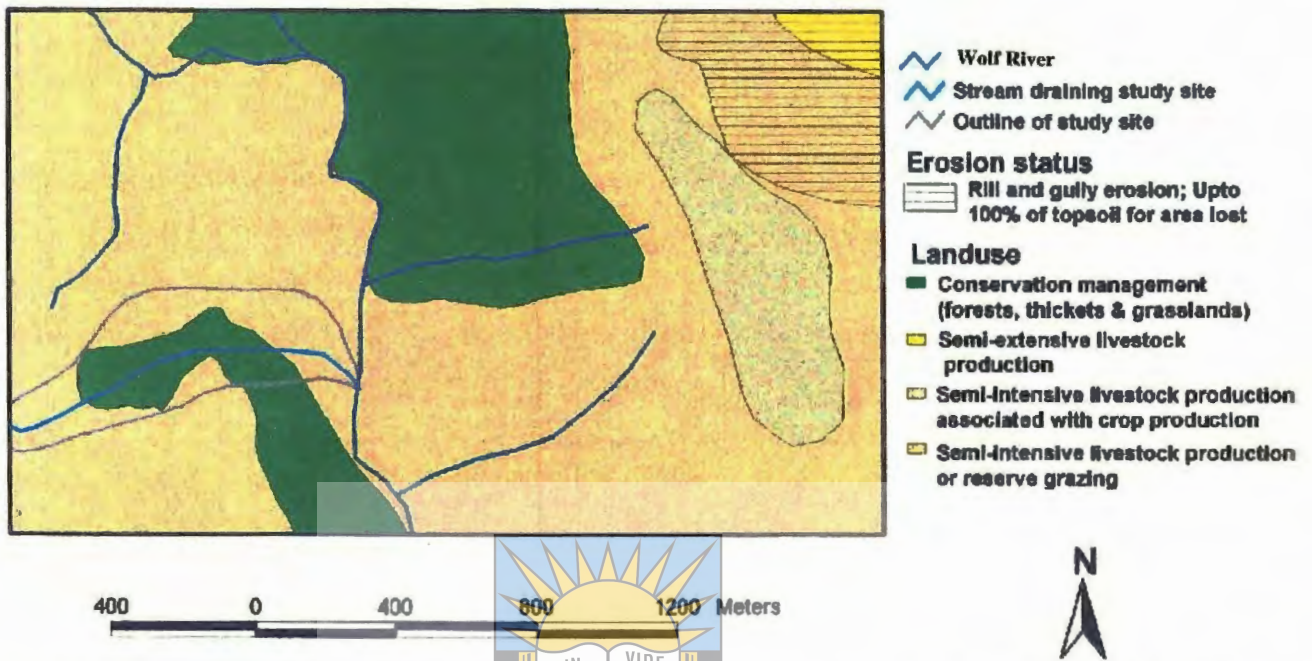


Figure 75 Recommended land use and erosion patterns at the Zingcuka catchment (1977)

Catchment Characteristics at Zingcuka during the 1998 Survey

Figure 76 illustrates the catchment characteristics at the Zingcuka site. The figure depicts that there has been a change in the vegetation structure of the catchment area. Afro-montane forests have moved towards the tops of the mountains (Figure 76). The Subarid thorn bush veld on the other hand has come to be confined to the less steep areas within the catchment area. Cultivated fields have been reduced to 6% as compared to 28% previously. These cultivated fields are probably not actively cultivated. The figure also shows a small patch of sheet erosion. This is a new development as there had not been any visible erosion previously (Figure 75). The site is characterised by only one farmhouse within the catchment area.

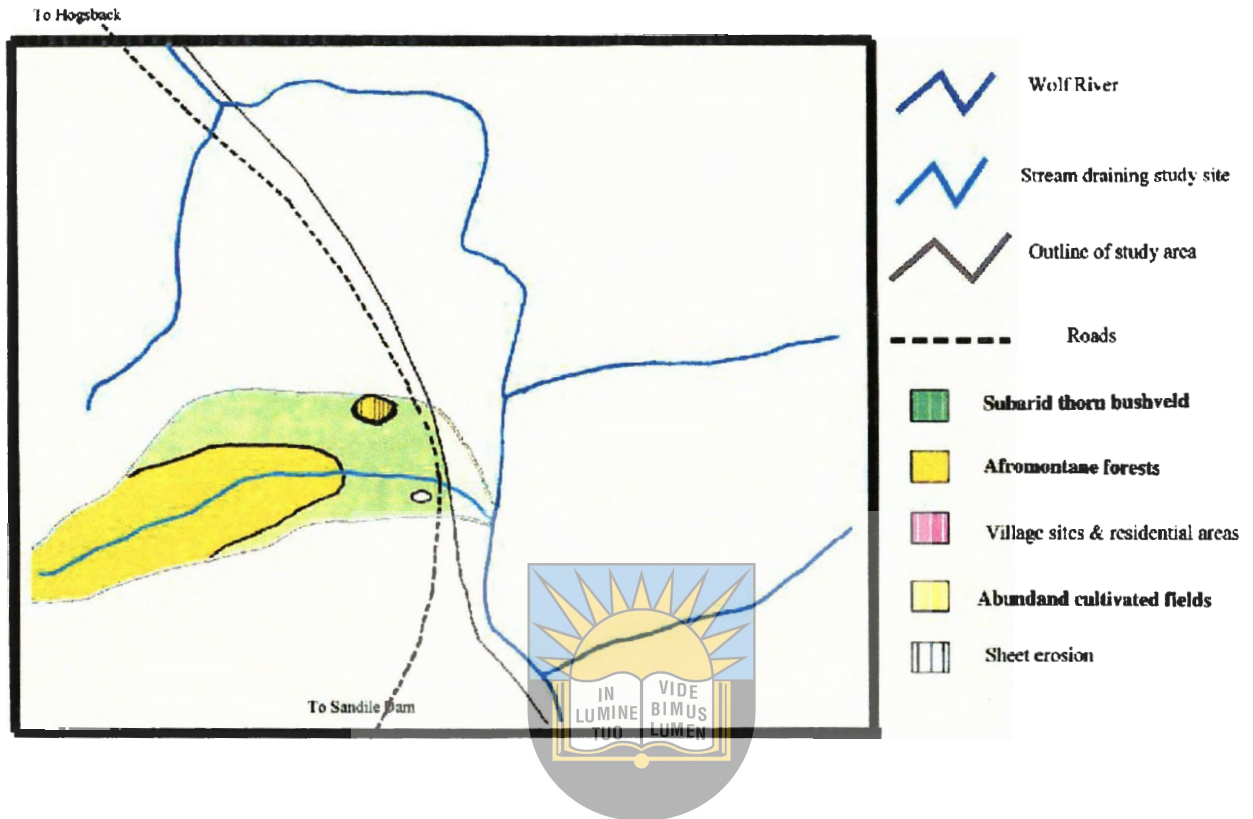


Figure 76 Catchment characteristics at the Zinguka catchment (1998)

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DISCUSSION

The five small catchments assessed for this study could be placed on a gradient from a state of severe degradation to the least degraded catchment. In reaching this conclusion, the following were taken into consideration: ecological status of the grasses, the vegetation type(s), land use practices (i.e. cultivated lands, grazing, collection of woodfuel etc.), ground cover and the extent of erosion over time. These variables were then related to TSS measurements at each site. TSS measurements from each site could be placed into context by comparing it with that recorded in the main river course, the Keiskamma River.

Sediment Concentrations

Mean TSS values for Ngqele, Hogsback 1 and Zingcuka were higher than the sediment concentrations recorded for main Keiskamma River at Middledrift while Saki and Hogsback 2 gave lowest values. The assessment of sediment concentration was also related to other catchment characteristics, such as soil type, land use, the vegetation type etc. Additional land use factors such as poor farming practices, footpath erosion etc. were also cited by (Stocking, 1978; Garland, 1985; Beckerndahl *et.al*, 1988 and Marker, 1988) as contributing factors to soil erosion due to the destruction of the topsoil layer.

It therefore appears that the catchments assessed for this study represent a fair range of the possible catchment types and erosion states prevalent in the upper Keiskamma River Basin.

There was, however, no significant difference in TSS concentrations under different weather conditions. Buermann *et al.* (1995) states that a relatively small flood could transport a large amount of sediment after a lengthy dry period, while a large flood after a wet period would transport only a small amount of sediment. The above statement made by Buermann, could however not be tested or validated as available rainfall data collection stations, present within the study area, tended to be far removed from the selected catchment. As such no rainfall data was made available for this study. Looser (1989) noticed in the Mfolozi catchment that suspended solid concentrations increased rapidly, peaked for a short time and then decreased rapidly during a flood. Hoffmann (1995) also showed that the suspended solids in the

Hennops River valley showed seasonal variation, as they were higher on the first storm event than subsequent ones. The availability of suspended material is an important factor influencing sediment concentrations (Knighton, 1984; Olive & Roger, 1985). The other possibility is that, in the Keiskamma River Basin, the amount of rainfall and the intensity thereof was not sufficient enough to transport the available sediment. The other possibility is that the catchments was so badly eroded such that there was no more transportable material to be transported by either wind or water erosion.

The transportable of suspended sediments could also carry with it pesticides, phosphates, chemical that have potential to alter the water quality in the rivers, thereby posing danger to the users, be it people of animals.

Vegetation Analysis

- *% Ground Cover*

Ground cover is closely related to the relative area covered with bareground. According to Coetzee (1995), vegetation and ground cover are the primary factors affecting soil loss and runoff. Rogers and Schumm (1991) showed that sediment yield increases rapidly as vegetation cover decreases.

The Saki catchment represents the most severely degraded catchment with about 43 % of the area covered with bareground. According to Rowntree and Wadson (1999), a good vegetation cover can reduce erosion by an order of magnitude when compared to that from bare soil. To backup this statement, Hoffmann and Ries (1991) states that as ground cover increases, soil sediment in runoff decreases. This means that the status of the Saki catchment could have increased with a reduction in bareground and an increase in ground cover. It should however be noted that the protective effect of vegetation to erosion is also dependent on the species composition and the structure of the vegetation. A good ground cover of grass is far more effective than the equivalent aerial cover offered by shrubs and trees.

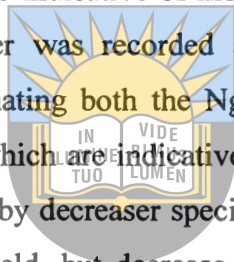
The catchments with the least recorded bareground were Zingcuka (5.6%) and Hogsback2 (7.1%). There was also a strong correlation between soil structure and the



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occurrence of soil erosion. The dominant soil types at Saki was Mispah, Valsrivier and Lindley which are highly erodible; Williamson at Hogsback 1, Williamson and Glendale Makatini at Hogsback 2 and Williamson and Lindley at Zingcuka. Soils of Mispah, Valsrivier, Williamson, Lindley and Glendale Makatini are highly susceptible to erosion, especially on steep slopes (Eloff, 1973; HKS, 1977; and d'-Uuyvetter & Laker, 1985). Therefore all the catchment sites except for Ngqele are characterised by soils that are prone to erosion.

The Saki site was found to have the lowest grass cover of species of all the sites selected for study. The grasses found were mostly dominated by increaser IIb and IIc species, which, according to Trollope (1986), are indicative of moderate and severe overgrazing. The highest percentage of grass cover was recorded at the Ngqele, Zingcuka and Hogsback 2 sites. Grass species dominating both the Ngqele and Zingcuka sites were dominated by increaser grass species, which are indicative of overgrazing, Grass species at the Hogsback 2 site were dominated by decreaser species. Decreaser grasses are those grass species that dominates in good veld, but decrease when the veld is mismanaged (Van Oudtshoorn, 1996).



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Sites with the highest percentage tree-cover were the two Hogsback sites and Zingcuka. There were no trees recorded at the Saki site, though, the site was characterised by a considerable percentage of shrubs. The shrub layer found at Saki and Zingcuka included *Chrysocoma cilliata* and *Acacia karroo*. The presence of *Chrysocoma tenuifolia* (= *C. cilliata*) is a sign of veld deterioration and it increases in places where overgrazing occurs (Hobson *et al.*, 1975). Lubke and Bredenkamp (1996) attribute the presence of *Acacia karroo* to overgrazing and the subsequent loss of grass cover.

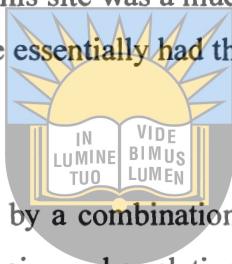
- *Vegetation Clustering*

DCA ordination plots work on the principle that distance equals dissimilarity. Therefore on an ordination plot, plant species that were distributed further apart from each other would consequently represent different plant communities.

DCA plots of all sites plotted individually for all sites, showed very distinct quadrat groupings at each site. The species ordination for the Saki site depicted a distinctly

degraded site, characterised by a high percentage bareground (43%); a plant community dominated with increaser grass species (e.g. *Aristida diffusa*, *Cynodon dactylon* and *Sporobolus africanus*) and shrub species such as *Chrysocoma cilliata*. The plot depicts a degraded plant community.

The Ngqele site showed a similar vegetation structure, with *Chrysocoma cilliata* and *Acacia karroo* being the most dominant shrub species. Grasses found were a combination of increaser and decreaser species. Increaser species were, however, the dominant of the two with *Cynodon dactylon* covering approximately 36 % of the catchment area. Decreaser species found were *Digitaria eriantha* (19%) and *Sporobolus fimbriatus* (6%). The percentage bareground recorded at this site was a much lower 13 % compared to that recorded at the Saki catchment. This site essentially had the characteristics of a degrading or degraded veld.



The Hogsback 1 site was characterised by a combination of good and bad veld, with a mix of decreaser and increaser grass species and a relatively high percentage bareground. Bareground at this catchment accounted for approximately 7 % of the total catchment area. The grass layer was dominated by increaser grasses, such as *Cynodon dactylon*, *Hyparrhenia hirta*, *Pennisetum clandestinum* and *Sporobolus africanus*. Trees covered approximately 8 % of the catchment area. This was the highest percentage tree cover of all the sites selected for study.

The Hogsback 2 site was characterised by a very low percentage bareground (7.1 %), the highest presence of trees (8.1%) and a fair grass cover dominated by decreaser grass species (35.4%). Given the characteristics of this site, the site can be described as a well-managed site.

The Zingcuka site revealed an abundance of trees, a dominance of increaser grass species and the presence of the stream stabilizer, *Phragmitis australis* along the stream channel. The percentage bareground at this site was the lowest of all the sites selected for study. The abundance of decreaser grass species, tree species and the presence of *Phragmitis australis* are indicative of good veld. However, the presence of increaser grass species is contradictory to the afore-mentioned description. The low percentage bareground shows

that the site is not badly managed and that is the reason for the low percentage bareground. The vegetation characteristics of this site can be considered to be in a transitional state from a very good veld to a degrading one.

Both the quadrat ordination and the species ordination of all sites together revealed the same characteristics of the individual sites. The vegetation clustering grouped the plant communities of the different sites into three groups ranging from the most degraded sites, through to those sites that are in a transitional state between the most degraded and the least degraded and also a community depicting the least degraded sites. In terms of this grading, plant communities representative of the Saki and the Ngqele site were represented by community “A” which was characteristic of degraded sites. The transitional community “B” was representative of both the Ngqele and the Zingcuka sites. Community “C” was characterised by the least disturbed plant communities found at the two Hogsback sites. Of the two Hogsback sites, Hogsback 2 was found to be the least degraded of the two.



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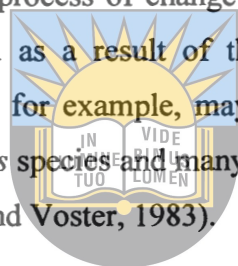
Land Use

All sites depicted a dominance of single and married women, with most men working away from home. The Ngqele catchment recorded the highest percentage of respondents who owned land, however, some of the respondents did not cultivate their lands. Traditionally, the men were responsible for cultivating lands, but history details that many of these men left their homes in quest of work in the big cities. This resulted in the women becoming burdened with the responsibility of undertaking their household tasks and also being expected to cultivate the fields. This state of affairs resulted in most lands not being cultivated and the land left fallow. According to a study, conducted on soil erosion in a catchment near Alice, South Africa, by Marker (1983), much of the sheet erosion can be attributed to abandoned cultivated land. Unvegetated soils tend to be low in soil fertility, and subsequently the soils are easily washed away especially during heavy falls.

Of the lands that were cultivated the greater percentage was cultivated only for subsistence use and not for commercial gain. All sites also recorded the cultivation of kitchen gardens, which were cultivated continuously without resting also increasing the likelihood of erosion

within the catchment areas. The respondents at all sites however recorded that they were aware of erosion taking place within their different catchments. Most indicated that they were also practicing some intervention strategies in an effort to minimise erosion. These interventions included, the avoidance of cultivation of areas characterised by steep slopes, digging furrows, and using tyres to help stabilise denuded riverbanks and gullies.

All sites recorded a high percentage of ownership of stock. The highest numbers of stock owned were recorded at Ngqele and the lowest were recorded at Saki. Stock grazed in the veld continuously without rotation. According to Rowntree and Dollar (1995), continuous grazing leads to the selective utilization of the most palatable grass species, resulting in a negative effect on the grass cover. In this process of change unpalatable, unproductive and undesirable species would have increased as a result of the selective grazing habits of livestock. Troublesome poisonous species, for example, may increase at an alarming rate. Woody species such as *Acacia karroo*, *Rhus* species and many more may spread and thicken-up gradually leading to aridisation (Roux and Voster, 1983).



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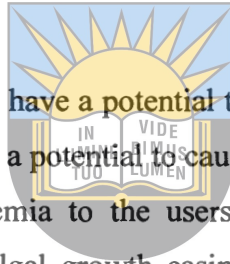
Trollope (1986) explained that rotational grazing system is the best system to be implemented, as the grazing area is sub-divided into grazing camps that can be used rotationally. Under these circumstances, portions of the grazing area can be rested annually to replenish the nutrients in the soil. This system is defined by Tainton (1981) as the successive occupation of different areas of land by a group of animals during the year so that not all the veld is grazed simultaneously. There was also a fair occurrence of goats at all sites. Goats are prolific feeders and if confined to a locality, might damage vegetation (Joss *et al.*, 1986).

The most common source of fuel at this catchment was through the burning of trees. This meant that there was a lot of tree-cutting within the different catchment areas. There is a likelihood that some of the riparian vegetation was removed in this way. The Hogsback sites recorded the highest amount of wood fuel collected of all the sites. These were the sites with the highest occurrence of trees. According to Bembridge and Tarlton (1990), in their study on "Woodfuel in Ciskei", the basic factor in the collection of firewood is the type of vegetation and its accessibility. This means that, the greater the variety, the more accessible the wood will be and consequently the greater the amount of wood collected. Consequently, the respondents at Hogsback walked the least distance for collecting wood. These

respondents at Hogsback also gave information about the use of cow-dung for fuel as an alternative to woodfuel. This, according to Barrow (1991) was the start of a catastrophic decline in soil fertility, as the soils tend to become more easily erodible.

Only the two Hogsback and Zingcuka sites recorded the use of water from the nearby streams, namely, the Tyume and the Wolf river, respectively, for domestic purposes. The respondents perception on the water quality was that it was good for both streams. Both the inhabitants of Saki and Ngqele used tap water for their daily domestic use. Consequently, the quality of tap water was bad when compared with water from the streams. People using tap water complained about the hardness of the water and the fact that the water was not good for washing clothes.

According to bush & Mayer (1982), nitrates have a potential to cause health problems for the users. The nitrate contained in the water has a potential to cause nitrite contamination causing a condition referred to a methamoglobinemia to the users (e.g. in infants and pregnant mothers). The nitrate can also stimulate algal growth casing eutrophication of the waters making it inaccessible to the users.



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Geographical Information on Land Use Patterns at Saki

Catchment characteristics for the Saki catchment depicted a site in a state of severe degradation. Approximately 43% of the catchment was covered by bareground. This was the site with the highest percentage bareground of all the sites selected for study. According to Hoffmann and Ries (1991), percentage bareground is the most important factor explaining soil loss. As ground cover increases, soil sediment in runoff also increases. This site was also characterised by the lowest grass cover and the lowest percentage of trees. Grasses found were dominated by increaser grass species. Increaser grass species are those species that increase with overgrazing (Trollope, 1986).

The soils characterising this site were highly susceptible to erosion, especially on steep slopes (HKS, 1977). Almost the whole catchment area showed signs of erosion. A comparison of the erosion status between 1977 and field surveys conducted in 1998, showed that the erosion

had increased over time (HKS, 1977). Gully erosion had increased by 3% and sheet erosion, which was already visible during the 1977 study, was also worsening. There had however, been no significant change in the vegetation type originally characterising the site, except for a strip of cultivated variants along the northern edge of the catchment area.

Geographical Information on Land Use Patterns at Ngqele

The catchment characteristics of this site revealed a site, which was in transition between a degraded state and the least degraded state. The Ngqele catchment was characterised by the highest percentage grass cover of all the sites. 43 % out of a total grass cover of 75% was dominated by increaser grass species. The bush layer was dominated by *Chrysocoma ciliata* and *Acacia karroo*. The presence of *Chrysocoma ciliata* is, according to Hobson *et al.* (1975), a sign of veld deterioration. Consequently, *Chrysocoma ciliata* increases with overgrazing. Lubke and Bredenkamp (1996) attributed the presence of *Acacia karroo* to overgrazing and the subsequent loss of grass cover. This, however, did not appear to be the case in this catchment as there had not been any obvious loss in grass cover. Percentage bareground only accounted for 13% of the total catchment area. This was the second lowest percentage bareground recorded of all the sites selected for study.

Soils found at this site were Sharrock soils, which were not prone to erosion. Approximately 28% of the catchment was covered by rill erosion, of which 8% had developed into gullies over the previous 21 years. The area was not characterised by any particular vegetation type. The area covered by cultivated fields had over the previous 21 years decreased by 12%. Only 2% of the remaining 8% of the cultivated fields was occupied by active fields. The remaining 6% was left uncultivated. There was however no sign of sheet erosion occurring within this particular catchment area.

Geographical Information on Land Use Patterns at Hogsback 1

This catchment was found to be in a transitional state, between the least degraded and a degraded catchment. The catchment was characterised by a 78% vegetation cover with 22% bareground. Williamson soils, which, according to HKS (1977), are highly prone to erosion, especially on steep slopes, were the characteristic soil type found on site. The catchment had

an average slope of a steep 31 degrees. The vegetation community was mainly composed of Subarid thorn bushveld and Afromontane forests. The Subarid thorn bushveld is mainly used for grazing (Lubke & Bredenkamp, 1996). These authors further characterised this vegetation type as being poorly conserved, mainly in the Ciskei region. According to HKS (1977), the most suitable land use practice for this area is grazing. Information gathered from a questionnaire administered 21 years later, following the HKS study, found that the catchment area was still used mainly for grazing purposes.

The perpetual use of this catchment for grazing purposes was contradictory to the recommended land use practices as suggested by HKS (1977). According to these recommendations, the catchment area was to be divided into three segments. Approximately 65% of the catchment area was to be used for semi-intensive livestock production, 23% for semi-extensive livestock production and the remaining 12% for both semi-intensive livestock production and crop production.



There had been a progression in soil erosion taking place within the catchment area over time. Twenty-one years previously, gullies covered only 5% of the catchment and overtime these gullies had spread and were covering 18% of the area. There was also evidence of sheet erosion taking place, covering 6% of the area. This was a new development as there had previously been no sign of this form of erosion within the catchment area.

Geographical Information on Land Use Patterns at Hogsback 2

This catchment was classified as the least degraded of all sites. The catchment is characterised by the highest percentage of trees and the second lowest percentage of bareground of all the sites selected for study. The veld type characteristic of this catchment during the 1977, HKS study was Afromontane forest. At the time of this study, the vegetation had undergone a transformation. Results from this study indicate that, the site had been colonised by approximately 60% Subarid thorn bushveld. The grass layer at this site was dominated by decreaser species.

Glendale Makatini and Williamson soils characterise the soils at this catchment. These soils are highly prone to erosion, especially on steep slopes (HKS, 1977). The slope characterising

the site was 48 degrees. Despite this steep slope, sheet erosion was low and there were no gullies or any sign of erosion taking place within this catchment area. Consequently, this site recorded the lowest TSS value of all the sites. The results indicate that the area was well-managed and as a result the yield in TSS was low. The land at this site was mainly used for grazing stock (96%) and the conservation of indigenous forests and thickets (4%). The most dominant land use practice on site was grazing.

Geographical Information on Land Use Patterns at Zingcuka

This catchment was found to be in a state between the most degraded and the least degraded. This catchment was characterised by a good vegetation cover and the lowest percentage bareground. Grasses accounted for approximately 56% of the vegetation cover. The grass was however, dominated by increaser species, such as *Cynodon dactylon*. The lawn-like character of *Cynodon dactylon* plays a very important role in natural soil erosion control (Van Oudsthoorn, 1992). The site also had the second highest percentage of trees growing within the catchment.

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The dominant soil types were Lindley and Williamson soils, which according to HKS (1977), are highly prone to erosion, especially on steep slopes. The average slope at this site was at a steep 47 degrees. The site was also characterised by Afromontane forests and Subarid thorn bushveld. The most common use for Subarid thorn bushveld was grazing (Lubke & Bredenkamp, 1996). Grazing was consequently one of the land use practices on site. Portions of the site were also used for livestock production. This land use practice was clearly not the most suitable land use practice and as a result 21 years after the HKS study was conducted, there were signs of sheet erosion taking place within the catchment areas. The recommended land use as per findings from the HKS study, suggested that portions of the land be used for livestock production and a portion for the conservation of forests, thickets and grassland. The catchment characteristics according to the 1998 survey revealed that portions of the catchment showed signs of sheet erosion. This was a new development as there had previously been no signs of erosion taking place within the catchment area.

CONCLUSION

The objectives of the study were to assess the land use practices within the catchments and determine their effect on the consequent vegetation cover, erosion patterns and the resulting deposition of sediments in the nearby streams. GIS information sourced from a study conducted by HKS (1977) was used as baseline information to determine changes with regard to vegetation, land use practices and the progression of erosion within the different catchment sites.

The study showed that there is a definite correlation between sediment produced by the different catchments, the land use practices on site, the vegetation characteristics especially with regard to the grasses found on site. Differences in the aspects listed above tended to yield relative sediments accordingly. Except for the situation at the Saki site, where the sediment production is recorded to be low. However, this was the site with the highest % bareground, a vegetation community dominated by increaser grass species and no riparian vegetation along the banks of the stream. The site was also badly eroded and suspected to still be eroding further. This was partly as a result of the use of the site as grazing land for stock. This land use practice was also not in line with the recommended land use practices as suggested by the HKS study, which was conducted in 1977. High stocking densities and unmanaged grazing practices might have contributed to the deterioration of the natural veld. The assessment of these characteristics would ideally have yielded the highest amount of sediments. The only rational conclusion that can be taken in this case is that the site has eroded to the extent that there is no more material to be transported either through the agents of wind or water.

The Hogsback 2 catchment as compared to the Saki site yielded low TSS measurements. This was the site with the highest percentage of trees colonising the banks of the stream draining the catchment and grass species dominated by decreaser species. There was no sign of erosion taking place within the catchment as the land use practices on site were in accordance with the recommended land use practices as suggested by HKS (1977).

Most South African rivers carry considerable loads of sediment consisting mainly of particles smaller than 0.2 mm in size. The Keiskamma river basin is characterised by shale and mudstone of the Beaufort Series of the karoo system, which are particularly susceptible to erosion. Spectacular examples of advanced sheet and donga erosion in these formations may be found in the north-eastern Cape Province. The Keiskamma River has high suspended sediment concentrations in relation to other South African river systems. These sediments include sediment sources originating from perennial tributaries that pass through a disturbed catchment.

By far the greatest proportion of sediment loads are transported during floods, but the relationship between sediment load and flow is by no means simple as it depends to a large extent on the immediate past history. A small flood following a long period of drought will for instance transport a far larger sediment load than a large flood following a period of rains. There were however, no rainfall measurements collected as part of this study. This therefore means that in terms of the scientific methods tested, there is no correlation between the rate of rainfall and the sediment produced. Samples taken and tested were collected during raining and none-raining events. For instance, some of the samples that were collected on particularly heavy rain events, recorded low sediment concentrations as compared to the other sites. For example, samples collected during a flooding event on 24 August 1999 recorded varying concentrations of sediment with Ngqele and Hogsback 1 being the only sites exhibiting high sediment concentrations.

Generally, pollution emanating from the upper reaches of a river would normally be transported to the lower reaches, thereby influencing the water quality of rivers downstream. The findings of this study are again counter to this theory. In terms of the distribution of the sites within the entire Keiskamma River Basin, the Hogsback sites are located at the headwaters, followed by Zingcuka, then Ngqele and finally Saki. Following this logic, one would have expected Saki to bear the highest sediments. On the contrary, Saki recorded the lowest concentration of sediments with Ngqele recording the next highest concentration. In terms of the gradation of catchments from the headwaters up to the lower reaches. It is logical for Ngqele to record such high volumes of sediments, since the cumulative impacts of bad catchment management practices or condition of the site upstream might have been

transported downstream. It however illogical for Hogsback 1 to have such high sediment loads, as it is located upstream.

Other factors such as soil type, land use practice, percentage bareground, coverage of vegetation and vegetation type, have an effect on the soil erosion and the associated water quality and should therefore be taken into consideration when assessing sediment loads in rivers. It is recommended that partnerships be forged between the Local Government and communities in these degraded sites, in an effort to remedy the soil erosion using BMP suggested by this study.

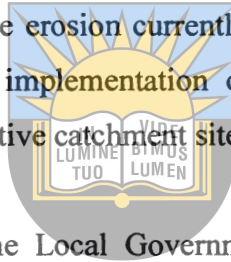


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FURTHER RESEARCH

The study has shown the potential sources of sediment and the courses of erosion and the impact of bad land use practices. The impact of rainfall on the sediment loads at the different tributaries needs to be assessed and quantified. I could not undertake these investigations, as the gauging stations were far removed from the sampling sites.

The resident populations within the different catchment areas need to be made aware of the HKS study that was undertaken in 1977 and the recommended land use practices that were suggested by the study. Relevant environmental education on aligning practices by the community with the recommended land use practice identified during the 1977 HKS study, needs to be undertaken in order to curb the erosion currently taking place. It is quite clear from the current study that without the implementation of the recommended land use practice, the prevailing erosion at the respective catchment sites will progress.



Partnerships between communities and the Local Government should be forged for the purposes of implementing some of the BMP as documented by this study, would be valuable in curbing the erosion. Water chemistry studies can be undertaken to help determine the toxicity of water within these area and also to advice communities accordingly, in terms of the use of the water.

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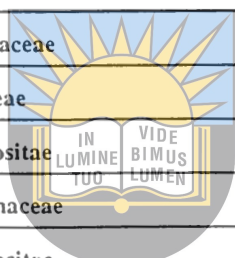
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Appendix A

Species Name	Family Name	Growth Form
<i>Acacia karroo</i>	Fabaceae	Shrub
<i>Achyrospis leptostachya</i>	Amaranthaceae	Shrub
<i>Adenopodia spicata</i>		
<i>Agapanthus sp.</i>	Liliaceae	Herb
<i>Anagalis sp.</i>	Primulaceae	Herb
<i>Artemisia affra</i>	Compositae	Shrub
<i>Asclepias fruticosa</i>	Asclepiaceae	Tree
<i>Berkheya deccurrens</i>	Compositae	Herb
<i>Bidens bilosa</i>	Compositae	Herb
<i>Bulbine sp.</i>	Asphodalaceae	Herb
<i>Calpurnia aurea</i>	Fabaceae	Shrub
<i>Canthium ciliatum</i>	Rubiaceae	Tree
<i>Cassine aethiopica</i>	Celastraceae	Tree
<i>Centella coriacea</i>	Umbelliferae	Herb
<i>Chrysocoma ciliata</i>	Compositae	Shrub
<i>Clutia affinis</i>	Euphorbiaceae	Shrub
<i>Dichondra repense</i>	Convolvulaceae	Herb
<i>Euphorbia esculenta</i>	Euphorbiaceae	Tree
<i>Felicia felifolia</i>	Compositae	Shrub
<i>Fern sp.</i>	Pteridophyta	Shrub
<i>Gazania krelosiana</i>	Compositae	Herb
<i>Gnidia nodiflora</i>	Thymelaceae	Shrub
<i>Helichrysum anomala</i>	Compositae	Shrub
<i>Helichrysum griseolana</i>	Compositae	Shrub
<i>Helichrysum petiolaris</i>	Compositae	Shrub
<i>Hippibromus pauciflora</i>	Sapindaceae	Tree
<i>Indigofera cylindrica</i>	Fabaceae	Shrub
<i>Lantana salvifolia</i>	Verbeanceae	Shrub
<i>Leonotis leonotis</i>	Laminaceae	Herb
<i>Lippia javanica</i>	Verbenaceae	Shrub
<i>Maesa refuscenus</i>	Myrsinaceae	Tree
<i>Maytenus heterophylla</i>	Celastraceae	Tree

<i>Opuntia aurantiaca</i>	Cactaceae	Shrub
<i>Oxalis duppressa</i>	Oxalidaceae	Herb
<i>Pelagonium reniform</i>	Geraniaceae	Herb
<i>Phragmites australis</i>	Poaceae	Forb
<i>Polygonum sp.</i>	Polygonaceae	Herb
<i>Protasparagus</i>		Shrub
<i>Ptaeroxylon obliquum</i>	Ptaeroxylaceae	Tree
<i>Rapanea melanophloeos</i>	Myrsinaceae	Tree
<i>Rhamnus prinoides</i>	Rhamnaceae	Tree
<i>Richardia sp.</i>	Rubiaceae	Her
<i>Rubus immixtus</i>	Rosaceae	Shrub
<i>Scaboisa tyrosinni</i>	Dipsacaceae	Herb
<i>Tephrosia dregeana</i>	Fabaceae	Herb
<i>Schistotephium</i>	Compositae	Herb
<i>Scutia myrtina</i>	Rhamnaceae	Shrub
<i>Senecio ptereophyllus</i>	Compositae	Shrub
<i>Senecio rhomboides</i>	Compositae	Shrub
<i>Sida dregei</i>	Malvaceae	Herb/Forb
<i>Sisymbrium</i>	Cruciferaeae	Herb
<i>Solanum aculeastrum</i>	Solanaceae	Shrub
<i>Solanum giganteum</i>	Solanaceae	Shrub
<i>Sonchus hypocloeris</i>	Compositae	Herb
<i>Spilanthes repense</i>	Compositae	Herb
<i>Stenoglottis fimbriatus</i>	Orchidaceae	Herb
<i>Stoebe vulgaris</i>	Compositae	Shrub
<i>Tephrosia dregeana</i>	Fabaceae	Herb
<i>Walafrida polystachya</i>	Selaginaceae	Shrub
<i>Verbena bonariensis</i>	Verbenaceae	Herb
<i>Ziziphus mucronuta</i>	Rhamnaceae	Tree



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Appendix B

SECTION A - DEMOGRAPHIC PROFILE

Name of village

Nearest town

Respondents No.

Gender of respondent

MALE		FEMALE	
------	--	--------	--

Marital Status

SINGLE	MARRIED	WIDOWED	DIVORCED
--------	---------	---------	----------

If married, is your husband / wife working ?

YES		NO	
-----	--	----	--

Where is he / she working ?

ALICE	MIDDLEDRIFT	KING	EAST LONDON	OTHER
-------	-------------	------	-------------	-------

If other, specify.....

SECTION B

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Where do you get your income ?

CULTIVATED LANDS		WORKING		HUSBAND/ WIFE	
---------------------	--	---------	--	------------------	--

Is this your only source of income ?

YES		NO	
-----	--	----	--

How many are you in your household ?

Does your family own land ?

YES		NO	
-----	--	----	--

Type of ownership.

COMMUNAL		PRIVATE		GOVENMENTAL	
----------	--	---------	--	-------------	--

If other specify

Do you cultivate your land ?

YES		NO	
-----	--	----	--

and how much do you cultivate?

If so, are you dependant on your land for cash?

YES		NO	
-----	--	----	--

If you use wood, where do you collect your wood ?

TREES		BUY		OTHER	
-------	--	-----	--	-------	--

If other specify

What other purposes do you use the wood for ?

COOKING		HEATING		LIGHT		OTHER	
---------	--	---------	--	-------	--	-------	--

If other specify

How many bundles of wood do you collect at a time per day ?

1		2		3		4		5		OTHER
---	--	---	--	---	--	---	--	---	--	-------

If other specify.....

How many bundles of wood do you collect per week ?

10		20		30		40		50		OTHER
----	--	----	--	----	--	----	--	----	--	-------

If other specify.....

How much time is spent for collecting per day ?

1hr		2hr		3hr		4hr		5hr		OTHER
-----	--	-----	--	-----	--	-----	--	-----	--	-------

If other, specify.....

How far away do you do to collect ?

1km		2km		3km		4km		5km		OTHER
-----	--	-----	--	-----	--	-----	--	-----	--	-------

If other specify.....

What is the most favoured type ? (Name of plant)

--

Why is it favoured ?.....

Which part of the tree do you pick ?

BRANCHES		TRUNK		BOTH	
----------	--	-------	--	------	--

What type of sanitation method do you use in your home- stead ?

PIT		BUCKET		MODERN		OTHER	
-----	--	--------	--	--------	--	-------	--

If other, specify.....

Do you have cattle, sheep and / or goats?

YES		NO	
-----	--	----	--

How many of each do you have ?

CATTLE		SHEEP		GOATS		OTHER	
--------	--	-------	--	-------	--	-------	--

If other specify and give the number you have

Where do they graze ?

VELD		OTHER	
------	--	-------	--

If other specify

Do you always use the same patch of land to graze your flock ?

YES		NO	
-----	--	----	--

If no, where else do you graze your flock ?

--

Do you have control over stocking numbers ?

YES		NO	
-----	--	----	--

Appendix C

Botanical Name	Family Name	Common Name	Xhosa Name
<i>Acacia caffra</i>	Liliaceae	Sweet thorn	Umthole
<i>Acacia karroo</i>	Liliaceae	Sweet thorn	Umnga
<i>Acacia melanoxylon</i>	Liliaceae	Black wattle	Idwabazi
<i>Aloe ferox</i>	Liliaceae	Bitter aloe	Ikhala
<i>Combretum caffrum</i>	Combretaceae	Cape bushwillow	Umdubi
<i>Diospyros dichrophylla</i>	Ebenaceae	Poison peach	Umbhongisa
<i>Grewia occidentalis</i>	Tiliaceae	Cross-berry	Umqabaza
<i>Olea europaea</i>	Oleaceae	Wild olive	Umnquma
<i>Pittosporum viridiflorum</i>	Pittosporaceae	Pittosporum	Umkhwenkwe
<i>Rhamnus prinoides</i>	Rhamnaceae	Dogwood	Unyenye
<i>Schotia afra</i>	Fabaceae	Karoo boer-bean	Umgqonci
<i>Scutia myrtina</i>	Rhamnaceae	Cat-thorn	Isiphingo
<i>Vepris undulata</i>	Rutaceae	White ironwood	umzani



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