ASSESSMENT OF SOIL EROSION IN THE MFOLOZI CATCHMENT, KWAZULU NATAL - IMPLICATIONS FOR LAND REFORM

BY

RAPHAAHLE RAMOKGOPA

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Supervisor : **Dr. H.K. Watson**

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DEDICATION

THIS THESIS IS DEDICATED TO THE THREE MOST IMPORTANT WOMEN IN MY LIFE:

1. MY MOTHER, SARAH MONI RAMOKGOPA
2. MY SUPERVISOR, DR. HELEN WATSON.
3. MY SISTER, LEHOTLO RAMOKGOPA

ABSTRACT

The Mfolozi, the second largest catchment in KwaZulu Natal, is already severely degraded over substantial areas. Its mean annual sediment load is extremely high and deposits on its floodplain have caused very serious financial losses. Previous studies in the catchment have attributed its soil loss to poor landuse practices by peasant farmers. There is a concern that this production will be substantially increased by landuse changes incumbent on the land reform programme. In order to ensure that this programme does not lead to increased degradation and exacerbate associated environmental and socio-economic problems, this study identified both subcatchments and landtypes that are highly susceptible to erosion and already highly eroded. An unpublished map showing the location of 19 categories of erosional forms and three categories of extreme relief features was available for use. The density (and areal extent in the case of badlands) of each of these forms within each of the 16 possible landtypes within each of the 43 subcatchments, was obtained and related to their dominant physiographic variables. The findings revealed that the catchment is not as severely or extensively eroded as suggested by previous studies. A substantial portion of the former Natal areas, mostly targeted for reallocation, have however, been shown to be unsuitable for this purpose.

DECLARATION OF ORIGINALITY

I Raphaahle Ramokgopa, hereby declare that this thesis is the result of my own work unless specifically stated to the contrary in the text.

Ramokgopa

Raphaahle Ramokgopa

13 - 03 - 1996

Date

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CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Of the many challenges that confront the New South African government, the issue of land remains the most emotionally and politically charged. Racial inequalities in terms of access to and use of land, levels of production and levels of earnings derived from agricultural production are a legacy of both the colonial and apartheid past. The former Bantustans most of which are not suitable for agricultural production, account for only 13 % of the land used for agriculture and consequently have been densely populated. For example, in the eighties their average population density was 76 per km^2 compared with 22 per km^2 on white farms (Mayende, 1993; Khosa, 1994).

South Africa is a land of striking contrasts. Its landscape reflects a physical environment of great range and diversity, a turbulent history of settlement and territorial expansion, and the contemporary stresses of racial division, resource exploitation and economic inequality. The 1913 and the 1936 Land Acts are generally regarded as the key legislative means by which dispossession, displacement and other processes of capitalist development were consolidated. The apartheid policies, since 1948, added a profoundly new destructive element to the deterioration of the country's soil and vegetation resources, particularly in the Bantustans (Unterhalter, 1987).

The new government has inherited a serious scenario with estimates of the country's soil loss exceeding those of soil formation by a factor of two or three (Randall, 1993). Presently, soil erosion is widespread throughout the whole country and this has major implications in terms of the economy, agriculture, water management and water quality. High erosion rates have a deleterious influence on the soil as a rooting, water and nutrient medium and hence on its crop yield potential (Braune and Looser, 1989).

The increased runoff from eroded catchments coupled with its diminished attenuation by wetlands increases the incidence and severity of flood flow. In addition to flood damage, increased costs associated with the disruption of river flow dynamics relate to increased pumping and cleaning effort in the maintenance of a constant supply of quality water, the loss of dam storage capacity and harbour dredging (Kriel,1983).

To deal with the land problems, the government of national unity has embarked on a "Land Reform" Programme which will be instituted in two ways, i.e., Restitution to those who lost land through forced removals (which will be done through the Land Claims Court), and redistribution of productive land to those who need it but cannot afford it (ANC, 1994). The Reconstruction and Development Programme's environmental policy foundation document (IDRC/ANC/COSATU/SACP/SANCO, 1994) acknowledges that the programme's success is dependent not only on its ability to redress the colonial and apartheid land access legacy, but also on safeguarding future sustainability by preventing further soil degradation.

Watson's (1990) literature review of temporal variations in KwaZulu Natal's erosional activity reveals that landuse changes have repeatedly accelerated it. Further studies by McAllister (1988; 1989) and Ramokgopa (1993) on the effects of betterment schemes, implemented by the previous government to decrease soil loss in the homelands, have also shown that there was a significant increase in soil erosion after they were implemented. Based on her finding that settlement by Zulu peasants in an area in the Mfolozi catchment that had been virtually uninhabited for a long period, caused a dramatic 25 and 11 fold increase in eroding and sparsely vegetated surfaces, respectively, Watson (1996), suggests that there is a likelihood that landuse changes associated with the land reform will increase soil erosion.

In order to ensure that the Land Reform Programme does not lead to increased degradation and exacerbate associated environmental and socio-economic problems, it is imperative that the suitability of land for specific purposes be assessed before landuse change is affected. While it may be true that there are a variety of possible uses for any land, it is important to note that not all land is suitable for all uses. According to Westman (1985), a landscape segment is composed of patches that are discontinuous in some physical or biological sense. These landscape patches may be observed by using soil, vegetation, landform, or other attributes as indicators of both landscape dynamics and of likely responses to human action. A soil type may, for example indicate both vulnerability to erosion and suitability for agricultural development. In this study landtypes that are highly susceptible to erosion and therefore most unsuitable for allocation to landusers lacking the technical and financial means to implement appropriate soil conservation measures, were identified.

MOTIVATION FOR THE STUDY AREA

The study was carried out in the Mfolozi catchment which with an area of about 10 000 km^2, is the second largest in KwaZulu Natal. Both the White and Black Mfolozi rivers rise in the north-west portion of the catchment and flow over nearly 400 kms on their course to the Indian Ocean (Begg, 1988). The rivers converge on the eastern border of the Hluhluwe-Umfolozi Park. Landuse activities carried out in the catchment include: (a) Privately owned commercial farming in former Natal, (b) subsistence use of communal lands in former KwaZulu, and (c) wildlife conservation in the Hluhluwe-Umfolozi Park and St. Lucia. The basin contains 14 geological, 11 soil, 10 vegetation and 8 bioclimatic type categories as identified by Kent (1980), Fitzpartrick (1978), Acocks (1988) and Phillips (1973), respectively. The catchment is therefore extremely diverse with respect to factors influencing the inherent erodibility of the soil and land capability.

A number of erosion related studies stimulated by Cyclone Domoina carried out in the catchment viz; Berjak, Fincham, Liggitt and Watson (1986), Bracher (1985), Kovacs, Du Plessis, Bracher, Dunn, and Mallory (1985), Looser (1985, 1989), Liggitt (1988), Liggitt and Fincham (1989) and Natal Town and Regional Planning Commission (1984) recognised the severity of erosion within it and perceived it as predominately human induced. More recent reports of such research viz; Botha (1992) and Watson (1990; 1993; 1996) show that while human activities have clearly induced and accelerated erosion in parts of the catchment, erosion has been repeatedly accelerated by climatic variations long before there was any human influence in the catchment.

The decision to carry out the present study was motivated by two factors, firstly, large parts of this most diverse and controversial catchment (especially those previously under the jurisdiction of Department of Development Aid) are destined to be redistributed in the Land Reform Programme. Secondly, the database necessary to assess land capability is both good and readily accessible viz, two 1:250 000 land type maps, that is, Vryheid and Richards Bay commissioned by the Institute of Soil, Climate and Water of the Agricultural Research Council (Land Type Survey Staff, 1986; 1988) and a 1:100 000 erosion map commissioned by the Institute for Water Quality Research (Looser, 1992).

AIM OF THE STUDY

This study aimed to identify those parts of the catchment that are most susceptible to erosion and therefore most unsuitable for inclusion in the Land Reform Programme. The primary output of the project will assist development agencies in selecting appropriate areas for distribution.

OBJECTIVES OF THE STUDY

1. To identify subcatchments that are highly susceptible to erosion.
2. To identify subcatchments that are already highly eroded
3. To identify landtypes that are highly susceptible to erosion.
4. To identify landtypes that are already highly eroded
5. To ascertain the extent to which the characteristic climate, substrate, topography, vegetation and land use properties have contributed to erosion and susceptibility to erosion in the subcatchments and landtypes noted in 1 - 4 above.

STRUCTURE OF THE REPORT

The second chapter reviews the history of land access in South Africa and highlights the role this played in land degradation. The success of the Land Reform Prpgramme as a mechanism for redressing these past imbalances is evaluated in the light of experiences in other countries. Chapter 3 describes the basic characteristics of the range of erosional landforms represented in the Mfolozi catchment. It also attempts to assess how these landforms influence the land capability in terms of use by people lacking the technical and financial means to implement appropriate soil conservation measures. Finally, it attempts to evaluate the potential influence of natural and human factors on the incidence and distribution of these landforms. The description of the study area in chapter 4 is in two parts: firstly, the general characteristics of the area are outlined, then a more detailed description of the characteristics of the 43 quaternary subcatchments delimited by Pitman, Middleton, and Midgley (1981) is given.

The fifth chapter firstly explains how data on the density of the 19 categories of potential sediment sources within the 16 landtypes within the 43 subcatchments was extracted from the erosion and landtype maps. It then explains how data on a wide range of biophysiographic characteristics were extracted from the landtype, veldtype and bioclimatic maps as well as other supplementary sources. The chapter goes on to describe the basis for selecting the use of Analysis of Variance, Multiple Regression Analysis and Principle Component Analysis to measure the significance of differences, degrees of association and functional relationships between these data sets.

The findings of this study are presented and discussed in chapter 6. The first part confirmed the higher erosion potential of the Middle Former KwaZulu. It further identified the landtypes that are highly susceptible to erosion. The second part revealed that gullies were better represented in the Upper Former Natal and the Middle Former KwaZulu than in the other landuse regions. Unconfined erosion was found to be well represented in the Middle Former KwaZulu; badlands in the Upper Former KwaZulu and the Upper Former Natal, and relief forms, though not well represented, were also found in the Upper Former Natal. Factors that influenced the distribution of the above mentioned erosion features are assessed. The last part revealed that overall, actual erosion in the Mfolozi catchment was neither severe nor extensive. The final chapter summarises the major findings described and discussed in chapter 6 and notes their implications. The findings of this study revealed that erosion in the former KwaZulu areas is not as severe as previous studies have suggested. They also revealed that a substantial portion of the former Natal areas (mostly targeted for reallocation) are severely eroded. These findings suggest that the Land Reform Programme is unlikely to improve the lives of peasant farmers and reduce the rate of soil loss in the catchment, unless serious precautions are taken before reallocations. In the last part of this chapter, recommendations regarding subcatchments and landtypes suitable and not suitable for inclusion in the Land Reform Programmes, as well as those regarding more general considerations are also made.

CHAPTER 2

LAND REFORM

2.1 INTRODUCTION

Of all the processes which have brought about the inequitable distribution of wealth and power that characterises present day South Africa, none has been more decisive and more immediately important to most black South Africans than the dispossession of land. To an agrarian community whose entire economic and social structure is based on the distribution of land, dispossession was an act akin to national destruction (Smith, 1994; Claasens, 1990; 1991).

It is hard to exaggerate the importance of the land question in South Africa, past, present and future. All people need land, if not as an immediate source of material sustenance, then at least as a place to live. The land question impinges on the nature of the agrarian economy which serves as the source of food for the country's population, and also on the distribution of residences in both rural and urban areas (Smith, 1994). Land has been, and continues to be an important source of power which some people can wield over others, from the chiefly prerogative of allocating land, through the privatization of ownership introduced by the colonizers, to the racialized control of the apartheid era (Smith, 1994).

The complexity of the land issue arises in part from the varying and conflicting ways in which people make claims to land. According to Khosa (1994) in traditional African societies, land was valued as a source of communal well-being, allocated according to the imperatives of group survival and reproduction. All families were entitled to a share of tribal land on which to grow crops or graze cattle, and this was regarded as theirs by usage or birthright. Membership of a particular family was crucial to the distribution of this collective asset: "the relationship between man and land was not purely economic". Members of society depended on land not only for subsistence, but also for recognition as members of social group. Farming is more than just a productive activity, it is an act of culture, centre of social existence and a place where social identity is forged (Khosa, 1994; Smith,1994).

Europeans brought their own values, in place of land as a communal asset to which people had a special personal responsibility as well as entitlement, ownership of land became one of the property rights associated with individual autonomy and liberty. Land thus came to be valued, through the market. Khosa (1994) refers to the situation as the development of capitalist agriculture, characterised by a quest for fertile soils and water resources on the part of white farmers. The conflict between African and European attitudes to land was resolved in favour of the latter by a combination of military and economic power. Racial identity was a crucial ingredient in a process which facilitated dispossession and displacement of the African population when in the way of settler interest. This led to a process of systematic political oppression, economic exploitation and labour relocation. The era was characterised by forced removals, victims were taken away from fertile lands to areas that were not suitable for agriculture (Smith, 1994).

The kind of development that has been possible in this country has largely been determined by our colonial past and our racially based capitalist economic system. The entrenchment of the migrant labour system and the artificial creation of Bantustans have scarred the rural landscape. Rather than working on developing alternative forms of development, opposition groupings have been fighting for liberation from these oppressive structures. However, a small number of NGOs working in rural areas have over the years been struggling to develop innovative ways of addressing the material ramifications (e.g. poverty, malnutrition etc.) of this history (Friedman, 1991).

In the new dispensation, *Land reform* seems to be the most favoured solution, by government, to redress the inequalities caused by this dispossession. Like all the other development programmes that have been implemented in this country, there is a likelihood that this programme might aggravate the problems it is supposed to alleviate. For example, environmental degradation has been one of the major problems that increased with every developmental programme implemented. This chapter focuses on the history of land problems in South Africa; the effects of the dispossession; the present state of affairs and the Land Reform Programme, which is aimed at redressing the past imbalances.

The introduction to this chapter gives the setting for the material to be covered in the chapter as well as briefly outlines the chapter's structure. The reason for including this chapter is that it gives an outline of South Africa's land problems, the main causes of the problems, and the steps that will be followed to resolve the problems. This is in line with the primary goal of this research, which is to assist developers and planners in identifying suitable areas when implementing the Land Reform Programme.

2.2 THE ORIGIN AND NATURE OF THE LAND PROBLEMS IN SOUTH AFRICA

2.2.1 Prior to Apartheid Era

During the period from the 19th century to around 1930, there was a rapid transformation of rural South Africa. Contributing to this process were: increased settlement in various parts of the territory; military defeat and subjugation of the African Kingdoms and Chiefdoms; and the expropriation of land held by the subjects; the discovery of large deposits of gold and diamonds and their subsequent exploitation; the process of industrialisation and the relocation of the vast majority of Africans to impoverished Bantustan regimes. While the changes set in motion in the agrarian sector were linked to these phenomena to a greater or lesser degree, another major aspect of agrarian change was the transformation of African peasant producers into wage labourers on white farms (Mayende, 1993).

The *1913 and 1936 Land Acts* are generally regarded as the key legislative means by which dispossession, displacement and the process of capitalist development in agriculture were consolidated. The 1913 Land Act delimited the area of African reserves termed scheduled land, and stipulated that no African could in future purchase or occupy land outside of them. Eight percent of South African land, with provision to increase to 13%, was demarcated for black occupancy (Mayende, 1993). At the same time, whites were barred from buying land in scheduled areas. Under the 1936 Land Act, additional land (total to approximately 13%) was added to the reserves as defined in 1913. The released areas were apportioned between provinces on a quota basis, and the land was administered by the South African Native Trust, which later changed to South African Bantu Trust. Both acts were important instruments in forcing Africans into reserves before the apartheid era, and were further responsible for providing labour for white farmers (Khosa, 1994; Mayende, 1993; Xulu, 1992).

2.2.2 Apartheid Era

The 1940s were characterised by black mass mobilisation against discrimination and segregation. By 1945 a significant proportion of Africans working in the mines, commerce and industry were unionised. Strikes were used to demand minimum wages and an end to migrant labour (Unterhalter, 1987). Shortages of housing and transport for Africans contributed to mass defiance of restrictive regulations in the form of squatter movements and bus boycotts. The African National Congress and the Indian Congress started building mass based organisations with precise demands for political participation in a common legislature. White farmers found that the section of the 1936 Land Act designed to force squatters into wage labourers on white-owned farms was not being enforced. With no binding labour contracts farm-workers were leaving the land for better paid jobs in industry. This resulted in traditional parties, Labour

Party and United Party, losing support. The National Party drew the support it required to win the 1948 elections mainly from the white farmers and the working class (Christopher, 1969; Bundy, 1979; 1981). The new government had two major aims:

- to suppress the mobilisation of black opposition that was placing white political power at risk; and
- to meet demands of white farmers and workers for an effective administration of influx control that would prevent Africans leaving the countryside to settle permanently in cities and undermine the jobs of white workers (Unterhalter, 1987).

In the 1950s, the Group Areas Act was passed. The Act aimed at allocating separate and unequal group areas for commercial and residential purposes to the various racial groups. Buffer strips or no go areas were created between any two groups. For whites who would otherwise have disqualified to acquire land, the Group Areas Act in its discriminatory mission, made it possible (Marcus, 1991; 1994). The fundamental aim of the Act was to preserve white status quo by giving them absolute control of ownership and occupation of land. "Landownership for humanity" became a symbol of power politically, economically, and socially (Claasens, 1991). The Act further affected mass removal and clearing of black spots in white areas. The released land was taken by government and in most cases without any compensation. The Act not only separated blacks from whites, but also blacks from blacks (Unterhalter, 1987).

Around 1959 and early 1960 black sovereign states, with their own local government based on tribalism and traditionalism, were created under the Bantu Self-government Act proclaimed in 1959. This was followed by the 1970 Bantu Homeland Act. The Act placed people in ethnic compartments. Bantustans had their own administration in the form of a legislative assembly with chiefs elected as members of parliament. Powers vested in Homeland governments depended on their ability to administer their territories to the satisfaction of the central government. The first Bantustan to receive independence was Transkei in 1976. Bophuthatswana and Venda became Homelands in 1977 and 1979 respectively. Ciskei followed in the early 1980s. Others remained internally self governing until after 1994 elections (Unterhalter, 1987).

The end result of this historical process is that Bantustans have been densely populated because of the policies of resettlement. There were a number of categories of removal, and the worst one was betterment schemes, which according to the government, was aimed at protecting the soil and raising agricultural productivity. The schemes are well known for the negative ecological, social, political and economic consequences they caused on rural areas countrywide. Studies conducted countrywide by various researchers, for example McAllister (1988; 1989) in the former Transkei and Ramokgopa (1993) in the Northern Province, found that these schemes disrupted people's lives, reduced the land available to them for farming, and provoked resistance to the local agents of the state.

The ecological consequences of the relocations are devastating. In many reserves, the vegetation cover has been totally stripped, both gullies and sheet erosion are well represented, and the rivers alternate between dry silted beds and raging torrents (Cooper, 1984).

2.3 PRESENT STATE OF AGRICULTURE IN SOUTH AFRICA

The inequalities in the agricultural sector today, in terms of access to as well as use of land, levels of production and levels of earnings derived from agricultural production clearly reflect the racial divisions characteristic of South African society. Of a total of 122^6 ha, 101^6 ha are used for agriculture. Eighty five percent of that is owned by white farmers. The Bantustans account for only 13%, most of which is not of sufficient quality for agricultural production. In the early nineties Mayende (1993) estimated that there were 65 170 white farmers and the average white owned farm was of 1 276 ha in size. In the Bantustans, there were 3 million rural households having access to a mere 1,5 ha on average.

Despite the dominance in land allocation, and tight control over agriculture, white farmers are not generally regarded as efficient (Robertson, 1989). Research done by the Department of Agriculture, the Development Bank of South Africa, and the Rand Afrikaans University found that only 20-30% of the white farming sector is productive while the rest is hopelessly inefficient and damaging the ecology (Claasens, 1990). The extent of the farming debt and the degree to which state assistance has been forthcoming raises serious questions about the future of agriculture (Robertson, 1989).

In its agricultural policy (undated manuscript), the ANC emphasizes that it recognizes the role that commercial agriculture has played in meeting the food and fibre needs of the country, however, the policies applied to achieve this have been at high cost to both the tax payer and the consumer, and have resulted in high levels of indebtedness and caused considerable environmental damage in some parts of the country. South Africa has a very bad environmental record. Monocropping has turned land into desert; levels of fertiliser use have led to the breakdown of the soil structure and rivers have been polluted with chemical leakage and sediments from eroded lands. The use of seeds, pesticides and drugs for animals led to a rise in the level of production. This has been done at the expense of health, environment and economic vulnerability. Land depletion means short term profits from production which are unsustainable (Dolny, 1990).

2.3.1 Agriculture's Declining Role in the Economy

According to De Klerk (1990), South Africa feeds itself and earns a substantial proportion of its foreign exchange from agricultural exports. In 1987 net food exports comprised of about R1,4 million, which is 5,5% of total non-gold exports. This was, however, done at the cost of substantial subsidies and protection from the former

Nationalist government. Worst of all is that food has been, and continues to be exported in the face of widespread malnutrition among the citizens of this country (Skweyiya, 1990).

Dolny (1990) argues that the place of agriculture in the economy has changed dramatically over the years. Presently, it accounts for only 5 - 6 % of the GDP having decreased by almost 10 % since 1950.

Dolny (1990) asserts that because the investment requirements necessary to create additional employment are far greater in other economic sectors, the agricultural sector provides better possibilities for ameliorating the unemployment crisis than any other economic sector. Dolny (1990) estimated that more than 50% of the country's population is still dependent on agriculture for survival. In 1985, 13% of the economically active population was employed in commercial agriculture (De Klerk, 1990). This includes farm-workers, women and children coming from Bantustans for seasonal work and illegal workers from Mozambique.

For agriculture to play a major role in resolving the unemployment crisis, Dolny (1990) states that there is a necessity to pursue a strategy of rural transformation which tackles the entire rural economy, that is, the land, the fixed improvement and fixed capital stock. On the other hand De Klerk (1990; 1991) argues that agriculture can no longer be seen as an easy way to make a living, particularly for resource poor people. He further states that rural incomes are in general below urban incomes, this has resulted in more people abandoning agriculture in favour of the industrial sector. The proportion of people seeking to earn their living from agriculture will diminish further in years to come. The preceding section gives an outline of the problems associated with commercial agriculture. It is important to note that both the government and non-governmental organisations (NGO's) encourage small scale farmers to grow cash crops within cooperatives and employ agroforestry, and it is for this reason that weaknesses relating to these activities are highlighted.

2.3.2 PRESENT FORMS OF AGRICULTURAL ORGANIZATIONS

Agriculture in South Africa is organised in different ways, viz, individual farming, state farming, agribusiness and cooperatives. These forms of agriculture cater for people from different backgrounds. In terms of the Land Reform Programme, it is necessary to identify the form of agriculture that will assist in uplifting the life of the poorest people in the country and it is for this reason that this section is included.

2.3.2.1 Individual Land Ownership and Production

This refers to a situation where people have access to land, either for residential purposes or for subsistence farming. Many South Africans, black and white, cherish the thought of a rural homestead and land which they can call their own. Provisions are made in the IDRC *et al* (1994) for individuals to own land. This kind of ownership is not profit-orientated and has been a characteristic of many African societies.

2.3.2.2 State Farming

The development of managerial, technical and organisational skills of farm workers is a prerequisite for the establishment of state farms. If implemented in the right way, these farms have the potential to be the means of ensuring a more equitable distribution of land. Dolny (1990) warns that premature implementation of state farms, would neither realise the productivity goal nor the transformation relations of production.

2.3.2.3 Agribusiness Farming

Agribusiness farming involves ownership of agricultural land by big companies. In several cases, companies have a different investment base and a broader taxation framework. They are also well known for their inconsistency with regard to the objective of state policy to maintain rural communities. They are more profit oriented, and thus often ignore the development of local communities. Labour exploitation is also common in this kind of farming (Dolny, 1990).

2.3.2.4 Cooperatives

Cooperative farming refers to a joint venture where small hold farmers collaborate to form a big company. The political and economic success of cooperatives depends on a combination of voluntary association, democratic practice, the availability of technical and managerial skills and ideological cohesion with commonly shared objectives. Flexibility is required on the part of the new state including the need to encompass the desires of people in given situations (Dolny, 1989; 1990).

Current cooperatives which were established in terms of the Cooperatives Act of 1981 are a major economic force in the agrarian economy, but have been built on apartheid practices. If they were to continue in their present form, status-quo in the rural areas will remain unchanged (ANC Agricultural policy, undated). In terms of the Cooperatives Act of 1993, a cooperative may act as an agent for its members with respect to insurance; establishing take over or acquiring interests in companies; hiring, buying, producing, letting, selling or otherwise supplying articles of consumption, and rendering other services, including those relating to buying, selling and leasing of agricultural property.

The new government is committed to encouraging the formation of cooperative structures facilitating legislation and providing support services. People who have been discriminated against in the past should gain membership of cooperatives on terms that will enable them to make a meaningful input into cooperative policy, management and administrative structure (ANC, 1994).

2.3.3 STATUS OF AGRICULTURE IN KWAZULU NATAL

KwaZulu Natal comprises 7,5 % of South Africa yet supports 18,3 % of its population. The majority of this population lives in the former KwaZulu, which is mainly rural (Erskine, 1982; 1985). The region is also following the country's trend of imbalance in respecting of the distribution of land (Khosa, 1984). Former Natal has 5,0355 million ha of land, whereas former KwaZulu has 3,3 million ha (Erskine, 1982). The prime causes of soil loss in this region, especially former KwaZulu are inadequate access to land, unequal access to other factors needed in agricultural production - financial subsidies, fertilisers, good seeds, market outlets and expert advice.

In terms of agricultural production, the region is rated amongst the most important productive areas in the South African context (Erskine, 1982; Natal Town and Regional Planning Commission, 1984). However, only the former Natal is responsible for this good production. The production is done at the expense of natural vegetation. According to research done by the Department of Agriculture and Fisheries (1981), landuse intensification during the period 1971 - 1979 indicates that there has been a significant increase in the area of irrigated agriculture and dryland land agriculture, covering 52% and 37% of former Natal, respectively.

Sugarcane and poultry are the most important enterprises, with beef, dairying, maize, pigs and sheep following in decreasing order, according to value (Erskine, 1982). From the above mentioned examples, it is evident that livestock production is very important part of agriculture in former Natal, both in terms of land-use and production value. While this is good for the country's economy, several researchers including Natal Town and Regional Planning, 1984; Looser, 1985; and Watson, 1990 identified livestock farming as a major factor that has accelerated soil erosion in KwaZulu Natal.

2.4 AGRARIAN REFORM AND RURAL DEVELOPMENT

If rural areas are to be empowered to take charge of the development process in their areas, many changes will have to take place in the way in which developmental activities are conceptualised or implemented. There is a need for agriculture, in particular, to change its image. The image of agriculture currently projected is split into subsistence agriculture, seen as hopeless and backbreaking, and the white agricultural sector, seen as exploitative of farm workers, animals and environment. Agrarian reform seems to be the only solution to this sector. Agrarian reform deals with modification of conditions affecting the agricultural sector; it remains embodied in the land reform. Noting the effects of racial domination Mbongwa (1990) believes that agrarian reform should start by constitutional reform, which is required to attenuate the right to property and enables the state to reallocate land. Presently, the Anon (1993) allows everyone the right to acquire, hold and dispose of any property, land included. It is clear and unambiguous on individual, family, community and women's rights to access, ownership and investment in land for productive and residential purposes. These rights are also enshrined in the bill of rights. It further recommends the implementation of a land reform policy based on affirmative action, taking into account the status of victims of forced removals (Afra News, 1993). Within such a programme of land reform and redistribution, an affirmative action programme should include the following:

a. Respect for Land: Ownership and use of land carries with it both rights and duties. Landholders should be required by law to recognise the need for protective use of land as a productive asset for the country as a whole (Afra News, 1993).

b. Acquisition of land: Land acquisition for the landless and dispossessed cannot be left to the forces of the market, government will have to play a key role in the acquisition and allocation of land. The state should therefore have the power to acquire land in a variety of ways, including expropriation in accordance with the provisions set out in a new constitution and a bill of rights (Afra News, 1993).

The ANC Agricultural Policy (Undated) emphasises that it is the democratic right of every individual to determine what forms of agricultural enterprise to engage in. However, people should be urged to be responsible for the effective management of their land. The role of the State should be to establish a policy framework within which services to farmers, and incentives to them, support wise decision making about the use of resources for agricultural production and not to impose models and systems of production.

The government's Land Reform Programme will enable many people to return to the land. More equitable distribution of agrarian land will be implemented through a combination of policy instruments, state intervention, and market measures (Hanekom, cited in Afra News, 1993). According to the ANC (1994) a range of support services with extension services will be provided to farmers not only for technical advice, but helping them play as a cooperative, and gain access to the resources they need. The main idea of these services is that fruits of science should be extended to the farmer who is not formally educated and therefore unaware of certain technical and productive means (ANC, 1994).

Sangweni (1993) argues that the system of subsidies previously provided by the government led to inappropriate and unsustainable agricultural practices and contributed to the debt problems presently facing commercial farmers. He emphasises that though there is a need for removal of subsidies, the removal should not take place across the board. Instead, a carefully designed package of subsidies should be instituted to facilitate entry of interested black farmers into commercial farming. Farmers associations and cooperatives on a non-racial and non-sexist basis should be encouraged to advance the interests of all farmers. Government should support the creation of these institutions through training programmes for their members and personnel (Sangweni, 1993).

The scope of promoting rural employment outside agriculture, for those living in rural areas who are unable or do not want to find employment in cities, should increase. The promotion of industries and related non-farming activities in rural areas could reinforce the rural development effort by slowing down if not arresting, the leakage of incomes from rural to urban areas and could actually facilitate agricultural modernisation by providing cheaper inputs and related services (Erskine, 1985).

2.4.1 PRIVATE VERSUS COMMUNAL TENURE

Debates about which kind of tenure, i.e., between private and communal, is most suitable for South Africa have been going on for years. Up to the present, no agreement has been reached. According to Afra News (1992) the former government was in favour of private tenure for South Africa. It emphasised that private ownership gives people a stake in the land and also stimulates an awareness of the importance of the preservation of this valuable resource. In 1992, two acts were passed to concretize the belief in the value of private ownership:

(i) **Upgrading of Tenure Act** = this Act provides for inferior forms of tenure to be upgraded to full private ownership. Examples of such inferior forms of tenure are leasehold, quitrent, permission to occupy and certificate of occupation.

(ii) **Informal Township Establishment Act** = the Act makes communal residential occupation and development of land bought on the market subject to state control and approval. The Act further emphasises that land which a tribe wishes to use on a communal basis for residential purposes must first be declared suitable for such use by the administrator.

Cross (cited in Afra News, 1992) argues that there is little evidence that private tenure is necessary for productive agriculture. The tenure has not promoted transfer of land to efficient farmers; it has not significantly improved security tenure, nor has it encouraged a land market or helped with the provision of production or commercial goods.

The traditional land tenure system or communal tenure is characteristic of the African rural areas, and is generally condemned as the most serious obstacle holding back agricultural development. Under this system, each family is allocated a homestead site, an area of cropping land which is strictly limited (not more than 2 ha in most areas), and has the right to graze stock on communal grazing. The fact that grazing is free contributes to overstocking because any family that does not keep up its stock numbers is liable to surrender available grazing to other families. Under such system of tenure, incentives to improve agricultural standards are lacking; any farmer is unable to exercise initiation (Erskine, 1982; 1985). Erskine (1982) stated that the communal land tenure system is amongst the factors that have contributed to poverty, and hence soil loss in former KwaZulu. This tenure slowed down the technological progress.

There are organisations which support communal tenure, for example the WorldBank Group (Afra News, 1992). According to this group, communal tenure provides security of tenure; is ecologically effective and sustainable and can be upgraded to sustain sound land use practice even in crowded conditions. It further allows marginal groups in the community, e.g. women and youth, to retain their land use and transfer rights whereas private tenure locates control in a single owner, usually male.

Cross (cited in Afra News, 1992) identified two areas of need regarding rural tenure options, i.e.,

(i) The need for Tenure reform in areas currently occupied by African people.
(ii) Tenure options to serve land reform itself.

Cross (Cited in Afra News, 1992) argues that in rural areas occupied by Africans the present need is probably to maintain the subsistence production and to preserve survival strategies people have built up. In these areas, the poor are in the majority and they need the tenure that preserves their existing land rights and lays the basis for mobilising their resources. Tenure forms that risk loss of land would be highly problematic. Most rural people are not in a position to move to urban areas and for those who are interested, their chances of being employed there are limited.

2.4.2 LESSONS FROM AFRICAN COUNTRIES

The size of the reform sector varies considerably from one country to another, and is largely determined by the particular historical, political and economic conditions which generated the Land Reform Programme. In Botswana, 71 % of the total area was affected by reform (Segosebe, 1991 cited in Marcus, 1994), while in Zimbabwe about 47 % was affected (Palmer, 1990). The reform sector also invariably encompasses a large part of the population, by far mostly the poor who range from the landless, to small and medium scale peasants farmers. Most, if not all, of these social groups are expected to benefit from land reform, although in practice, few do (Marcus, 1994).

This section looks at a variety of ways in which new and old land was allocated in different countries under state policies. Examples of Kenya, Botswana, Zimbabwe and Nigeria are used as they point to common issues and trends arising from different emphases.

2.4.1.1 KENYA

In Kenya the 1-million-acre programme allowed Africans to buy or lease land which had been freed by white settlers. This programme was designed to defuse the time bomb of the landlessness without disrupting the productivity of agriculture. The programme began while Kenya was still under colonial rule and administered by the colonial office. The colonial orthodoxy was that land was not for the landless or unemployed but rather for those with farming experience who had managed to accumulate some capital. In 1965, the newly created Agricultural Development Corporation took over the orthodoxy as well as the responsibility for this land. It either leased back the land to suitable tenants (mostly the white farmers) from whom it had been bought or held it until suitable African tenants or purchasers could be found. The outcome was that people holding political office were able to raise loans to buy land while those, most in poverty, were the least catered for (Sorrenson, 1967).

2.4.1.2 BOTSWANA

The praised land reform experience of Botswana raises similar issues. Here the reform sector was the tribal lands, covering 71% of the country, held under communal or traditional tenure and mostly subsistence farmed. Two principal programmes were ushered under the Tribal Land Act of 1968. The first one was the *Tribal Land Grazing Programme* (TLGP) which aimed at ensuring grazing control, better management and increased productivity. This was done through fencing of land, thus safeguarding the interests of small owners of livestock from those who owned no livestock. It was argued that when resources were held in common, their management was poor and they were liable to abuse as nobody felt responsible for them (Segosebe, 1991 cited in Marcus, 1994).

The other programme aimed to keep the customary system of land tenure intact but sought to alter the agency of land distribution and management. Local boards were to assume all the powers vested in chiefs, according to customary law, in respect of land. As elsewhere, the results of the land reform were unfortunate and unintended.

The TLGP not only failed to achieve its objectives but worsened the conditions of the poor. It facilitated acquisition of land by the rich and the politically powerful. By 1990, 58% of the 480 demarcated ranches had been allocated. However, there was not any indication that these ranches were better managed or more productive than the communal areas. Rather, ranchers continued to use their low input, low cost, low grazing systems because they could continue to rely on the advantages of their previous system. Rather than reducing land pressure and soil degradation in the communal areas the TLGP aggravated it because people built up their herds during years of good rainfall and transferred them to communal areas in times of drought. The TLGP also led to land dispossession because of its false assumption that much land zoned for commercial purposes was uninhabited and unused. The land of many San was encroached upon by the zoning. Their nomadic life as hunters and gathers has been dislocated by the fencing which blocked the migration path of the wildlife they depend upon as well as denying them free movement over vast terrain so essential to their survival (Segosebe,1991 cited in Marcus, 1994).

2.4.1.3 NIGERIA

Land reform in Nigeria took place under the *Land Use Decree Act enacted in 1978* by the Nigerian Federal Government. It was designed to pose a direct challenge to alternative sources of societal authority by relegating all private transactions in land to governmental agencies. The Land Use Decree envisaged improvements on a grand scale in economic productivity, land use planning, and equitability of access to land resources for all citizens. To accomplish this all rights over land administration were summarily vested in the offices of the state governors, to be held in trust and administered for use and common benefit of all Nigerians. All subsequent transactions in land (whether sales or inheritance) were to be managed by the administration agencies created under the terms law. The nationalisation exercise meant that for the first time in Nigerian History, the country was endowed with a uniform set of rules and administrative procedures governing all aspects of land tenure (William, 1992).

The decree contained provisions to constrain the amount of land that can be legally held by individuals. For example, statutory rights of occupancy in urban areas were strictly limited to 0,5 ha of undeveloped land. Customary rights of occupancy were confined exclusively to rural areas, where plots were permitted to be as large as 500 hectares of farmland or 5000 ha for grazing. A growing body of evidence seems to suggest that the benefits of Nigeria's land development and plot allocations schemes are chronically imbalanced. Studies suggest that those with wealth and close connections to state governments are the overwhelming beneficiaries of these programmes (William, 1992).

2.4.1.4 ZIMBABWE

Historically, there had always been bitter competition for land and resources in Zimbabwe (formerly Rhodesia), with the state providing extensive and crucial support for white agriculture. Land reform took place under the Lancaster House agreement which set the market as the basis for the release of new land to Africans. After the political struggles of the 1960s and the guerilla wars of the 1970s, both the contending parties and the British government sat down at Lancaster House to discuss an independence constitution. Britain offered a compromise under which in return for the Zimbabweans guaranteeing existing property rights, the British would underwrite half the costs of a resettlement programme, however, this took place for a ten period only. Land could change hands only on willing seller, willing buyer basis. Only under-utilised land, which was required for resettlement or other public purposes, could be compulsorily acquired by the new government, but the owners would have to be paid immediately and at the full market price (Palmer, 1990).

The constraints of the Lancaster House agreement ruled out any significant redistribution of land, thus the question of land reform for much of the 1980s tended to be confined very narrowly to the issue of resettlement, onto land willingly sold by whites. There was a tendency among white farmers to hold on to the productive core of their farms and to offer for sale only the most marginal parts, which they were happy to dispose of, especially when land prices began to rise as a result of political stability. The government bought over 3 million ha, mostly from large scale farmers, to settle 50 000 households. The Zimbabwe programme which initially aimed at the landless and the unemployed, was soon opened up to experienced communal area farmers out of concern that scarce resources were allocated to those least able to use them. The argument ignored the fact that poor farmers were being given useless farms and thus it was difficult for them to produce effectively. By 1990 communal area farmers represented 85% of all new settlers. This did not in any way improve the situation in Zimbabwe, but rather worsened the circumstances (Palmer, 1990; Alexander, 1991).

From the above programs, it is clear that poor people, especially women and children did not benefit. While the aim of all the Land Reform Programmes in the above mentioned countries was to improve the lives of the disadvantaged communities, without sacrificing the environment, the end result was that the rich were made to be richer and no improvement has been made in terms of sustaining the environment.

2.4.3 THE PRESENT CONTEXT OF LAND REFORM IN SOUTH AFRICA

The abolition of racially based Land Acts (Native Land Act of 1913, and the Native Trust and Land Act of 1936), announced by the former President, Mr F.W. De Klerk at the opening of parliament in 1991 marked the turning point in South African history. The new Act also abolished the Group Areas Act of 1966, the Black Communities Development Act of 1984, and repealed or amended other racist legislation (Francis and Williams, 1993; Mayende, 1993). The legislation did not only go beyond opening the rights to property in land to all races. "It protected the quality and integrity of the title in land". The government declared opposition to any form of redistribution of agricultural land whether by confiscation, expropriation or nationalisation (Francis and Williams, 1993).

It is important to recognise that the abolition of Land Acts and the Group Areas Act, even if followed by abolition of the Bantustans system and reintegration of the old reserves into South Africa, did not signify anything, especially to the people who have been discriminated against in the past. It only prohibited private racial restriction on the right to buy or lease land - it did not address the exclusion of the landless poor who cannot buy land (Claasens, 1991; Xulu, 1992).

With the end of forced removals, rural communities began to demand restoration of their land rights, lost under apartheid. The Nationalist Party government saw things differently emphasising that people must forget about the past. For those who have been forcefully removed, this did not make sense, and many of them began reoccupying their expropriated land (Afra News, 1994b).

After several negotiations with other political parties, and other organisations representing the victims of forced removals, the National Party agreed that provisions need to be made to restore land tenure rights to the victims of forced removals, but it emphasised the provision should not endanger existing land tenure rights (Gcabashe and Mabin, 1990; Afra News, 1991). The Advisory Commission of Land Allocation (ACLA) was established to identify state owned land for restoration by government to victims of forced removals. In June 1993, the government published an amendment bill to the Abolition of Racially Based Land Measures Act of 1991 and ACLA was converted to a Commission of Land Allocation with powers to make decisions on Land Allocation (Afra News, 1994a). It was through this Commission that communities such as Alcockspruit, Roosboom and Charlestown, in KwaZulu Natal, got back their land (Afra News, 1990; 1991; 1994b; Khosa, 1994).

After the 1994 election, a new Land Reform Programme was written. According to the IDRC *et al* (1994), land reform should be demand driven and supply residential and productive land to the poorest section of the rural population and aspirant farmers. It should raise incomes and productivity. It should also secure tenure, regardless of the land holding system, and remove all discrimination in women's access to land (Hanekom, 1993). Two aspects of land reform are identified:

1. **Land Restitution** = The purpose of restitution is to redress the suffering caused by forced removal policies. Land will be restored to South Africans who were dispossessed of it by discriminatory laws and have specific claims. This will be done through the land claims courts; which will be made accessible to the poor and the illiterate. The cut-off date for specific claims is 1913. All claims are to be lodged within 3 years of the start of the restitution process (Afra News, 1994a; IDRC *et al,* 1994).

2. **Land Redistribution** = According to the Ministry of Land Affairs, a key element addressing general landlessness will be the government's redistribution programme which was poised for implementation in 1995. A mixture of market and state mechanisms will be used to address the land hunger and to redress the racially skewed land holding pattern in South Africa. These include incentives to bring land onto the market, taking over indebted or under-used land, removing financial and legislative obstacles to black land acquisition, strengthening existing tenure rights to people who already occupy land and state grants or subsidies. The target for redistribution will be state owned land, indebted land and under-used land (IDRC *et al,* 1994). Important test sites for redistribution will be the provincial land reform pilots, one in each province. Pilot districts will act to test sites for identifying appropriate financing mechanisms for planning, land transfers and service delivery, and appropriate systems and institutions to administer land in a sustainable way (Afra News, 1994b).

2.4.4 PROBLEMS ENVISAGED

The South African situation differs from other countries in that different kinds of institutions will be needed to implement the programme. The imposition of land ceilings and redistribution to existing tenants is unlikely to be an appropriate way to proceed in this country. The selection of recipients will be a major problem for the South African land reform Programme as an account will need to be taken of conflicting historical claims to land and also the fact that the amount of land initially made available is unlikely to be sufficient for those who want land to get it (Mbongwa,1990).

There is a great fear that the land claims court is unlikely to be able to solve all land claims, since it cannot help those who did not manage to maintain their identity and links to their land. It will deal with relatively few cases where black people did have land, and will not deal at all with the issue of redistribution (Khosa, 1994). The practicality of the said redistribution programme is also questionable, considering the amount of land available.

The other major difficulty in South Africa will be maintaining existing levels of agricultural production. Although agricultural over-production does help to cushion fluctuations in food-production at present, any major disruption in production would cause food prices to rise sharply with severe consequences for the poor, both urban and rural; and this will result in a threat to overall stability for the new government (Budlender, 1992). In many countries in Africa, land reform led to a decrease in agricultural production and the poor who were supposed to benefit from the programme suffered the most.

Most of land in South Africa is already privately owned. Since we have the property right clause that is entrenched in the interim constitution and the bill of rights, it is unlikely that the dream of equal distribution of land will ever be achieved (Claasens, 1990; 1991; Budlender, 1992). For the government to get land, it will have to buy from existing farmers. It goes beyond doubt that existing farmers will be happy to dispose of land that is deemed unproductive. The implication of this is that peasant farmers will only receive unproductive land.

Ownership of large scale profitable enterprises is clearly being defended in the interests of maintaining production and exports (Dolny, 1989; 1990). Like in Zimbabwe, the South African government might end up in a situation where black farmers are said to be unproductive, thus giving back land to those people who benefited from apartheid laws.

2.4.5 INTENDED CONTRIBUTION OF THIS STUDY

Given all these problems, it is important that land that is not suitable is not allocated to poor people. Despite the fact that poor people may not be able to afford the costs associated with rehabilitating this unsuitable land, it is also important to note that the country may find itself faced with serious ecological damage which will eventually cost the country a lot of money. In identifying suitable areas for redistribution, the researcher hopes to assist developers and planners to avoid the ecological damages that may arise as a result of the land reform Programme.

CHAPTER 3
SOIL EROSION

3.1 INTRODUCTION

Soil erosion is usually defined as the process of predominately mechanical detachment and transportation of soil constituents by water, wind and ice (Faniran and Areola, 1978). This chapter describes the basic characteristics of the range of erosional landforms represented in the Mfolozi catchment. This range includes those derived from mass sediment transfer processes, and from both the unconfined and confined movement of water. Wind has clearly exerted an influence on some of these landforms. However, as no research on wind erosion in the catchment is known to this author, an assessment of its potential role was considered beyond the scope of this study. This chapter also attempts to assess how these landforms influence the land capability in terms of use by people lacking the technical and financial means to implement appropriate soil conservation measures. With particular reference to the findings of research carried out in the catchment to date, this chapter further attempts to evaluate the potential influence of natural and human factors on the incidence and distribution of these landforms.

In her extensive review of literature grappling with the conceptualisation of the distinction between natural and anthropogenic erosional activity, Watson (1990) noted that while natural or geological erosion is generally perceived to occur at rates conducive to the development of a "normal" soil profile, these rates may be accelerated by natural phenomena. She also noted that while human activities are generally perceived to increase erosion rates above the geological norm, some activities actually reduce these rates to below this norm.

Garland (1987) noted that the time dimension can complicate the distinction between natural and human induced erosion. Poor landuse practices gradually reduce the soil's intrinsic resistance to erosion. Once this falls below the critical threshold, a rainstorm intensity that previously had a limited effect, may trigger a catastrophic event. The contributing anthropogenic influence on such events remains unidentified. Although the earlier soil erosion related research effort in the catchment stimulated by Cyclone Domoina viz; Berjak *et al*, (1986), Bracher (1985), Kovacs *et al* (1985), Looser (1985, 1989), Liggitt (1988), Liggitt and Fincham (1989) and Natal Town and Regional Planning Commission (1984) recognised the catchment's high natural potential for erosion, erosion within it was perceived as predominately human induced. More recent reports of such research viz; Botha (1992) and Watson (1990, 1993, 1996) show that while human activities have clearly induced and accelerated erosion in parts of the catchment, erosion particularly gully erosion on the slope pediments of the Masotcheni formation has been repeatedly accelerated by climatic variations long before there was any human influence in the catchment.

3.2 UNCONFINED EROSION

Rainsplash: Soil erosion by raindrops is usually described as splash erosion because when falling raindrops strike the ground surface, the soil particles fly in all directions (Faniran and Areola, 1978). The impact velocity of raindrops varies depending on droplet size and mass, wind speed and rainfall intensity (Summerfield, 1991). This detachment of soil particles as a result of raindrop impact has come to be recognised as fundamentally important and often the initial phase of soil erosion. The quantity of the detached soil is proportional to the detaching capacity of the raindrops and the detachability of the soil (Cooke and Doornkamp, 1978).

Rainsplash erosion is generally considered to be more efficient in detaching sediment particles than in transporting them. It also appears that rainsplash erosion is more effective on sandy surfaces than on those containing a high proportion of clay and silt-sized material, apparently because the presence of finer particles contributes to cohesion (Morgan, 1986; Summerfield, 1991). Rainsplash erosion occurs wherever vegetation does not entirely cover the ground, although it is a more potent erosive agent in environments where there is little or no vegetation.

Sheet Erosion: Sheet erosion is the more or less uniform removal of soil from an area caused by the detachment of soil particles through raindrop splash action and subsequent transport by runoff water (SARCCUS,1981). Infiltration excess is the most common means by which surface runoff is generated. When it rains, water penetrates down through unsaturated soil at a rate determined by its structural, textural and biological characteristics. During the process of infiltration, swelling of colloids and repacking of surface sediments occurs which result in a decrease in the soil's permeability, hence accumulation of water in and on the soil resulting in surface runoff (Faniran and Areola, 1978; Watson, 1990).

This type of flow is commonly evidenced by the presence of raised soil levels under tufts of grass, and does not have a pronounced channel (Morgan, 1986). The primary importance of this flow lies in the capacity to remove material already loosened by other processes and consequently in cultivated areas, this process results in the accumulation of soil downslope and an increase in fertility at the foot as nutrients are carried with sediment particles (Hudson, 1981). It is a rather inconspicuous type of erosion because the topsoil is evenly eroded and the total amount removed in any storm is usually small (Rapp,1975).

This detachment and transportation of soil particles, which is often on a large scale, has extremely unfavourable consequences for agriculture and forestry considering the long process of soil formation. As the top soil layer is washed away, it removes plant nutrients, thus decreasing soil fertility. This in turn reduces productivity, increasing production costs on these soils. Although fertilizers can compensate for most or all topsoil losses, they cannot compensate for soil degradation and loss of the natural resource bases (Lal, 1985). It is unfortunate that the type of people most likely to be affected by the Land Reform Programme in the Mfolozi catchment and the target of this study are the poor are unlikely to be able to compensate for fertility losses with fertilisers. Unconfined erosion also involves the process of elutriation, or the washing out of the more valuable parts of the soil, such as humus and other nutrients, and leaves an impoverished soil behind. Raindrop impact may disperse surface clay particles and lead to the formation of dry crust which reduces infiltration capacity, thus promoting surface runoff. The decrease in the amount of water entering the soil coupled with the soils reduced water holding capacity means that dry seasons and droughts are felt more acutely (Statham, 1979; Cooke and Doornkamp, 1978; Morgan, 1986). However, a study conducted by Brinkcate and Hanvey (1996) in the North West province found that although the southern portion of their study area was severely sheet eroded according to ratings using the SARCCUS system, the mostly uneducated poor people in their study area did not perceive this insidious unconfined erosion process as a problem.

3.3 CONFINED SURFACE EROSION

Rill Erosion: Rill erosion appears when sheet erosion is extensive resulting in channel flow. Initially this takes the form of shallow drainage channels only a few centimetres deep which change their patterns between storms (Knapp, 1979). De Ploey (1981) states that crusting is a major factor in the formation of the rills, which are developed by the retreat of scar lines (steps) sustained by the crust. The presence of rills depends on the forces exerted by the accumulated sheetwash exceeding the resistance of the soil. Sheetwash rapidly becomes concentrated, as water is diverted round objects, into very small channels or rills. The water in a rill has a sufficient depth for considerable turbulence to develop in it, and rill flows can therefore entrain larger particles than sheetwash (Selby, 1982). Parallel rills on a surface may become integrated into a drainage network as overtopped rills break down and become diverted into a deeper rill (Statham, 1979). Rills can also form when subsurface water becomes concentrated into areas of deeper soil, called percolines, above the zone of normal channel flow (Selby,1982). Most of these landforms are discontinuous, that is, they have no connection with the main river system and they are generally temporary phenomena and may be destroyed by a variety of processes such as cultivation and bioturbation (Statham, 1979).

Gullying: Gullies are permanent steep-sided water courses which experience ephemeral flows during rainstorms. They are characterised by a head-cut and various steps as knick-points along their course. They have relatively greater depth and smaller width, carry large sediment loads and display very erratic behaviour so that relationships between sediment discharge and runoff are frequently poor (Morgan, 1979; 1986). Gullies may form at any break of slope or break in vegetation cover when the underlying material is mechanically weak or unconsolidated. They nearly always start because either there is an increase in the amount of runoff, or the capacity of water courses to carry the runoff is reduced due to changes in vegetation cover (Selby, 1982). In her study area in the lower reaches of the Mfolozi catchment, Watson (1990; 1993) found that most gullies were associated with poorly constructed roads, footpaths, and animal tracks, which served to channel surface runoff.

Deep rills and gullies are some of the most damaging forms of water erosion. Besides ruining fertile land through land loss, they cut agricultural land into uneven plots reducing the possibility of efficient mechanical tillage. They further interfere with farm operations, endanger livestock and decrease the chances of development of a particular area or farm (Lal, 1985). Brinkcate and Hanvey 's (1996) findings in the northern part of their study area in the North West province where gully erosion was rated severe using SARCCUS, reveals that the poor black people perceived it as a problem. For example, in rainy seasons gullies are filled with water and small children fall into them and drown; water-filled gullies attract snakes which they fear; gullies were also seen to be responsible for encouraging houses to crack, for hindering passage and dividing the village.

3.4. CONFINED SUBSURFACE EROSION

Subsurface erosion is the lateral movement of water downslope through the upper layers of the soil. Soil water flow contributes only about one percent of the total material eroded from a hillside and this is mainly in the form of colloids and minerals in ionic solution (Elwell and Stocking, 1976; Morgan, 1979). As collapsed soil pipes play a significant role in the origin and development of gullies in the study area (Dardis, Beckedalh, Bowyer-Bower, and Hanvey, 1988), it was deemed necessary to include this section.

Most researchers (Beckedahl, 1977; Humphrey, 1983) list duplex soils as a major factor in soil pipe initiation. A duplex soil allows free infiltration through the topsoil but less permeable subsoil forces the water to flow laterally downslope along the line of greatest permeability. The morphology of the impermeable horizon or spatial variations in permeability in the upper horizon layer may restrict the flow along certain discrete paths. In this kind of situation, combining flows may occur creating percolines which may eventually erode into soil pipes (Heede, 1971). Another necessary condition for soil piping is the presence of a surface soil layer with sufficient strength to support the roof of a pipe. The strength properties of the soil surface layer will determine to a large extent the onset of roof collapse, which will occur when the stress within the roof exceeds the strength of the roof materials and its inherently strong arched form (Heede, 1971; Baillie, 1975). Tree roots can also contribute to the strength of the roof since they hold the soils together (Elwell and Stocking, 1976).

The most important effect of subsurface flow in its unconcentrated form is to bring about the accumulation of moisture in the soil in the foothill and concave parts of the landscape and thereby enhance the likelihood of saturation overland flow (Morgan, 1986). In soils which are easily exposed to the effects of water erosion, especially loess, groundwater scours the subsoil which it disturbs and accumulates on the impermeable layer. The tunnels which are thus formed reduce the stability of the overburden. In many cases the tunnel roofs collapse in thereby forming deep gullies. The concentrations of base minerals in the water are twice those found in surface flow. Essential plant nutrients, particularly those added in fertilizers, can be removed by this process, thereby impoverishing the soil and reducing its resistance to erosion (Roose, 1970 cited by Morgan, 1986). In Brinkcate and Hanvey's (1996) study in the North West province, erosion in the form of piping, which was extensive according to ratings using the SARCCUS system, was found to be recognised by some people in the area, but it was however, not regarded as a problem.

3.5 MASS MOVEMENTS

Mass movement refers to the transportation of sediment in which large quantities of sediments move together in close grain to grain contact (Statham, 1979). These features are of significance in terms of soil loss, hence they are also considered as forms of soil erosion. These phenomena may occur naturally or they may be triggered by human interference. Several examples of these movements, including landslides, slumps, and terracettes, common in the study area are discussed.

Landslides: Landslides refer to a fall of earth or rock material as a result of gravity and rain lubrication. They occur within a soil or rock where shear is confined more or less to a well-defined slide plane. Landslides are usually separable into shallow or deep-seated failures according to whether cohesion is present as a measurable strength factor or not (Statham, 1979). Landslides may occur on steeper hillslopes as a sudden movement of soil or weathered rock, creating a slide scar (Rapp, 1975). Landslides that begin with a sliding movement often change into viscous flows as they move down the slope. Such flowing masses of loose material are composed of soil or rock debris called debris flows or mudflows (Dietrich, Wilson, and Reneau, 1986; Botha, 1992).

Slumps: Slumping is a type of mass movement involving an actual shearing of the rocks, a tearing away of a mass of material, usually with a distinct rotational movement on a curved concave-up plane. This is particularly common when more massive rocks overlie clay or a weak shale, along a sea cliff or an escarpment (Statham, 1979).

Terracettes: a series of parallel or sub-parallel furrows or steps in the soil surface, each with a greater throw in the same direction (SARCCUS, 1981). In his study of southern Drakensberg terracettes, Garland (1987) found that they are polygenetic in nature and processes involved in their initiation include soil slippage, soil flow and soil creep. Once formed, they are subjected to a range of erosional and denudation processes. In her study in the northern Drakensberg terracettes, Watson (1988) concluded that their origin and development is attributable to a combination of topographic, soil and vegetation factors. She also noted that animal disturbance may be instrumental in triggering the initiation process or facilitating their subsequent development.

Mass movements render an area unstable (Selby, 1982). While terracettes may assist animals and humans to climb up very steep slopes, slopes affected by or prone to mass movements generally debilitate land capability. Houses constructed on these are prone to cracking, and in the worse case scenario the additional mass on the shear plane associated with their construction may trigger slope failure. Fences, roads etc. on such slopes are all prone to repeated realignment, and being buried by debris from mass failures.

3.6 FACTORS THAT INFLUENCE SOIL EROSION

The factors which are commonly considered to exert an influence on soil erosion are the climate, the nature of the substrate, the land surface configuration, the vegetation cover and the extent of human interference.

3.6.1 RAINFALL

One of the most important factors affecting the spatial variability of soil erosion is the erosivity of the erosive agent. Holy (1980) defines erosivity as the potential ability of rain and its associated runoff to cause erosion. It is a function of its intensity and duration, and the mass, diameter, and velocity of raindrops. The drop size characteristics and hence intensity vary with rainfall type (Weaver and Hughes, 1985).

The dependence of soil loss on the kinetic energy of rainfall was confirmed by Wishmeier (1959), who after processing data from 35 experimental stations arrived at a conclusion that the most convenient estimator of the relation between rainfall and soil loss is a parameter expressing the product of kinetic energy of the rainfall and its maximum 30 minute intensity. The said parameter of erosivity was described as EI_{30} index. Although this index has been proven reliable in the United States and other parts of the world and, it does not satisfactorily account for soil loss in tropical regions. In South Africa, the Department of Agriculture has recommended the use of EI_{30} as the best index of erosivity (Crosby, McPhee and Smithen, 1983; Watson, 1990). In order to obtain rainfall erosivity in the catchment, EI_{30} values were extracted from Rooseboom, Verster, Zietsman and Lotriet (1992) rainfall erosivity index map as detailed in section 5.2.3.

3.6.2 SOIL

Weathered bedrock often rises to the surface and is denuded by water and wind. In many cases, the surface is quickly disturbed and rills, gullies, and ravines which spread and deepen quickly, are formed. Bedrock conditions the principal properties of soils, namely, their structure, texture, and the content of mineral and chemical substances which together with the organic substances regulate the soil formation processes. Soils formed on limestone and dolomite formations are relatively resistant to erosion. Less resistant are soils on igneous rocks. The most susceptible soils are those derived from various sediments, namely, sandstone, loam, clay, chalk formation and loess sediment (Holy, 1980).

During the Pleistocene the equilibrium between the formation and erosion of KwaZulu Natal's soils was controlled by climatic changes. The low sea levels associated with sub-humid to semi-arid glacial periods rejuvenated erosional and aggradational activity. Infilling and soil formation occurred during the humid interglacial periods. KwaZulu Natal's soils are consequently very young (Maud, 1968; Partridge and Maud, 1987). The parent material therefore has strong influence on the soils (MacVicar, 1984), and hence erosion in the study area.

Geology is therefore a good indicator of erosion. Studies conducted in the Mfolozi catchment by (Berjak *et al.*, 1986; Liggitt, 1988; Liggitt and Fincham, 1989) found that Dwyka Tillite showed highest incidence of erosion in sharp contrast to the Natal Group Sandstone. The Karoo Dolerite and Ecca Shales had levels of erosion not significantly different to the mean. The erosion levels on the PreCambrian Rocks were slightly higher. Botha (1992) found the highest concentration of donga erosion in areas underlain by Vryheid Formation, Beaufort Group and dolerite bedrock. Very low concentrations of erosion were found in the Dwyka and Natal Groups. Weaver (1988) also found that erosion in the Ciskei is less severe in soils underlain by dolerite than in those underlain by sedimentary rocks.

Soil erodibility refers to the liability of the soil to suffer erosion due to the forces causing detachment and transport of soil particles (Lal, 1977). Some soils are much more susceptible to erosion than others (Lal, 1975). According to Renard and Foster (1983), during the same rainfall event some soils can erode faster than the others. Olson and Wishmeier (1963) found that long-term average soil losses vary more than thirty fold due to differences in soil erodibility alone. Although erodibility varies temporarily and spatially with variations in rainfall, vegetation, and landuse, and spatially from one slope to another, the properties of the soil, whether physical, chemical or biological, are the most important determinants. These properties include soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content (Lal, 1977; Morgan, 1986). All these properties are regulated to a greater or lesser degree by the soil's structural stability. Soil structure refers to the arrangement of particles and aggregates, and the corresponding size, shape and arrangement of pore spaces between them (Watson, 1990). Soils with favourably developed structure retain more water and are more resistant to the destructive force of surface runoff than soils with an insufficiently developed structure (Holy, 1980).

Wischmeier, Johnson, and Cross's (1971) K-value nomograph was accepted as a composite measure of soil erodibility worldwide. The nomograph was based on the interaction of five soil properties viz:- percent silt and very fine sand, percent sand greater than 0,1 mm, organic matter content, structure and permeability. Although Wischmeier *et al* 's (1971) erodibility nomograph has been widely used and its predicted values have generally correlated well with measured values, it could not be implemented in some regions. For example, in tropical regions where there is high content of aluminium and iron, the test could not be applied as it does not cater for chemical properties (Roose, 1976, 1977). Wishmeier *et al*'s (1971) K - value estimates have also been widely accepted in South Africa. In South Africa many researchers, including (Platford, 1982; Schieber, 1983; Watson and Poulter,1987) used the K - value estimate and rated it as the most efficient method of estimating erodibility of South African soils. Working with important soils in KwaZulu Natal's sugar cane producing area, Platford (1982) correlated the USLE's K-values calculated from measured soil losses from standard simulated rainfall runoff plots, with K-values derived from Wishmeier *et al*'s (1971) erodibility nomograph. He found that the values for less structured soils were highly significantly correlated, while those for well structured soils were less well correlated.

The Soil Loss Estimation Model for Southern Africa (SLEMSA) was developed in response to the poor predictive ability of Wishmeier *et al*'s (1971) erodibility nomograph in other regions (Hudson, 1987). The model was originally developed to assess soil loss in Zimbabwe. The model is based on three properties and has the form:

$$Z= K.C.X.$$

Z = mean annual soil loss
K = bare fallow
C = Cropping factor

The erodibility of most of South Africa's soil series was rated using the erodibility index of the Soil Loss Estimator Model for Southern Africa (SLEMSA, 1976). Both the SLEMSA (1976) and Wishmeier *et al*'s (1971) K - value estimate are suitable for Southern African soils. The Department of Agriculture, however, recommends the use of Wishmeier *et al*'s (1971) nomograph values to measure erodibility of the soils. In order to obtain estimates of the erodibility of full range of soils considered in this study, it was necessary to extract both the F and K estimates from appropriate sources as detailed in section 5.3.2.

3.6.3 TOPOGRAPHY

Water erosion is conditional on surface runoff from slopes. Various slope parameters including angle, length, shape, aspect and location within the area may interact to increase or decrease the efficiency of soil removal processes (Holy, 1980). The influence of these parameters vary according to the type of landform unit in which the slope occurs, the position of the slope in relation to the catchment as a whole, and variations in individual catchment characteristics (Morgan, 1979; 1986; Kirby, 1980).

The interdependence of slope gradient and the erosion intensity as given by various authors (including Toy, 1977; Morgan, 1986), shows that the intensity of the erosion process increases with the growing tangential stress and velocity of the surface runoff which are predominantly a function of slope gradient. In this situation, the water particles are more likely to flow across the surface than to infiltrate into the soil. In his studies in Ciskei, Weaver (1988) found that slope angle and altitude have exerted a strong influence on the distribution of soil erosion. Liggitt (1988) and Liggitt and Fincham (1989) found that gully erosion in a 525 km^2 area of the Mfolozi catchment around Ulundi was most severe in areas with high drainage density and on flatter slopes, less than 9^0.

The influence of slope length on soil is largely dependent on the predominate erosional processes operant (Watson, 1990). In areas where rainsplash is the major removal agent, soil loss decreases with increasing slope length. Where unconfined erosion predominates, soil loss generally increases with increasing slope length. This is generally attributed to the increased volume of surface flow (Morgan, 1986).

3.6.4 VEGETATION COVER

Vegetation is the key factor controlling soil erosion. Its growth varies from one season to another, which makes its net influence on soil loss time dependent. Morgan (1986) stated that the major roles of vegetation are intercepting raindrops by mainly canopy cover and detaining runoff by basal cover. Rainfall interception decreases the quantity of water reaching the soil and alters the spatial distribution of that water through stemflow and throughfall with concentrated drip points (Wiersum, 1985; Stocking, 1988). Some of the water intercepted evaporates before reaching the soil (Stocking and Elwell, 1976). Hudson (1981) found that soil loss from bare plot was more than one hundred times that of covered plot.

Vegetation basal cover comprises litter and roots, both of which impede the flow of water over the soil's surface, thus decreasing sediment detachment and transportation. The rate of soil loss increases substantially as vegetal cover decreases. In their study in Zimbabwe, Elwell and Stocking (1976) found that vegetation cover is the principal determinant of specific erosion rates, such that the threshold for high erosion rates is below 30 %, intermediate rates between 30 and 60 %, and low rates over 60 %. Weaver (1989) also found that severe soil erosion rates in Ciskei were due to poor cultivation and overgrazing.

In KwaZulu Natal most of the erosion is restricted to a few bioclimatic regions (Phillips, 1973). In their study in the middle reaches of the Mfolozi catchment centred around Ulundi, Liggitt (1988) and Liggitt and Fincham (1989) found that the potential for and the severity of soil erosion decreased as the fasciations of vegetation represented in the veld types and bioclimatic regions become moister. The Moist Upland and the Highland Submontane regions were the least eroded, the Riverine Interior Lowland and Lowland Upland regions were moderately eroded, while the Dry Upland region was the most severely eroded. By contrast, Botha (1992) in his study of a 1 360 km^2 area surrounding Dundee - Nqutu and Vryheid and comprising a substantial portion of the upper reaches of the Mfolozi catchment, found that the Moist Upland and the Dry Upland were severely eroded, the Riverine Interior Lowland and Lowland Upland regions were moderately eroded, while the Highland Submontane was the least eroded. Scotney's (1978) report based on observations throughout KwaZulu Natal indicates that the Coastal Lowland and Mistbelt regions are the least eroded, the Highland Submontane and Moist Upland regions moderately eroded, and the Dry Upland and the Riverine interior lowland regions the most severely eroded. Botha (1992) further found that the Southern Tall Grassveld veld type was the most severely eroded. The Northern Tall Grassveld, Natal Sandy Sourveld, Highland Sourveld and Zululand Thornveld were all moderately eroded, while the Lowveld was the least eroded.

3.6.5 LANDUSE

Due to its widespread occurrence, agriculture is said to be one of the most important causes of soil erosion. Agriculture may be either in the form of grazing or crop cultivation. Soil erosion related to agriculture depends upon land ownership, system used, the intensity of cultivation, and the type of crop grown, among other things (Blaikie, 1985; Blaikie and Brookfield, 1987). In their study in the Mfolozi catchment, Liggitt (1988) and Liggitt and Fincham (1989) found that soil erosion was more severe in communal lands as opposed to commercial farmlands. Differences in gully erosion were small viz. 15 and 11 % on the communal and commercial lands, respectively. However, there were very substantial differences in sheet erosion between these lands, viz, 40 and 23 %, respectively. In contrast to these findings, Weaver (1988), in his study in Ciskei found that gully erosion was worse on communal lands, but sheet\rill erosion was worse on commercial lands. Whitlow (1988) in his study in Zimbabwe also found more severe erosion in communal lands as compared with commercial agricultural lands.

Heavily used roads, footpaths, and other excavations by man, apart from stripping the soil of its vegetation cover, concentrate runoff and so initiate concentrated soil erosion, including, in suitable locations the development of wide gullies (Elswaify and Cooley, 1980). Dunne, (1979, cited Dunne, Wahome, and Aubry, 1981) estimated that 35% of sediment yield in Zimbabwe was caused by non-surfaced roads, tracks and footpaths. Okigbo (1977) also identified footpaths as significant sediment sources in African traditional communal lands. Watson's (1990; 1996) observations in the Mfolozi catchment indicate that the construction of the major road through her study area initiated the gullies found in it.

FAO (1980, cited by Blaikie, 1985) suggests that in many countries, the number of people on the land exceeds its carrying capacity, and that this increases the likelihood of erosion. Whitlow (1988) found a strong relationship between increasing population density and the increasing extent of erosion within the communal lands in Zimbabwe. However, in Kenya, Tiffen, Mortimore and Gichuki (1994) found the opposite. They found that through decades of population growth in excess of 3 % per annum, the Machakos district has sustained agricultural intensification, improved conservation and increased output. In most instances population density is the most accessible and reliable indicator of the pressure imported on the land. What the Kenyan study has shown is that it is not simply population that is important but whether good or bad landuse practices are carried out. Good soil conservation can mask the influence of increased population.

Watson 's (1990) literature review of temporal variations in KwaZulu Natal's erosional activity shows that it was repeatedly accelerated by landuse changes. She further revealed that these landuse changes favoured gully erosion processes. In her study on the short and long term influence on soil erosion of settlement by peasant farmers in the Mfolozi catchment, Watson (1996) found that in an area that had been virtually uninhabited, soil erosion increased dramatically during the first few years after settlement. Over the following decades erosion continued to increase, but at substantially lower rates despite the continued increase in human and livestock numbers. Studies conducted by McAllister (1988; 1989) and Ramokgopa (1993) on the effects of betterment schemes on soil erosion also revealed that there was severe soil loss after the implementation of the programme. The above findings suggest that soil erosion is more sensitive to a change in landuse than in intensification in them. They further suggest that landuse associated with the Land Reform Programme may rapidly increase soil erosion and that once adjustments to these had taken place, erosional activity will stabilise at decreased rates (Watson, 1996).

CHAPTER 4

DESCRIPTION OF THE STUDY AREA

4.1 INTRODUCTION

The Mfolozi is the second largest catchment in KwaZulu Natal. It covers over 10 000 km^2, extending from the highlands around Vryheid to the coast (refer to fig. 4.2). Both the White and the Black Mfolozi rise in the North-west portion of the catchment but in different physiographic regions and at different altitudes. Their respective sources are on the Skurweberg Plateau 1620 m.a.s.l, 20 km north-west of Vryheid and on the Hlobane Ceza Block, 1 524 m.a.s.l, 20 km north of Glukstadt (Natal Town and Regional Planning, 1984; Begg, 1988). Fig 4.1 and 4.2 show the location of the of catchment within South Africa and the province of KwaZulu Natal, respectively. Most of the upper reaches of the catchment is covered by the white commercial farmlands, and most of the middle reaches by traditional subsistence farming. The confluence of the Black and White Mfolozi river is at the eastern corner of the Mfolozi Game Reserve. Below the confluence, the river passes through the Mfolozi Flats before it reaches the sea (Bracher and Kovacs, 1985; Looser, 1985). The Mfolozi catchment is divided into three major sub-catchments (refer fig 4.3). Table 4.1 shows the sizes of the three major subcatchments. The catchment is further divided into 43 subcatchments as delimited by (Pitman *et al*, 1981) (refer to fig 4.4).

SUB-CATCHMENT	**SIZE (KM^2)**
White Mfolozi	5285
Black Mfolozi	3638
Lower Mfolozi	1155
TOTAL	**10078**

Table 4.1: Sizes of the Major sub-catchments (Begg, 1988)

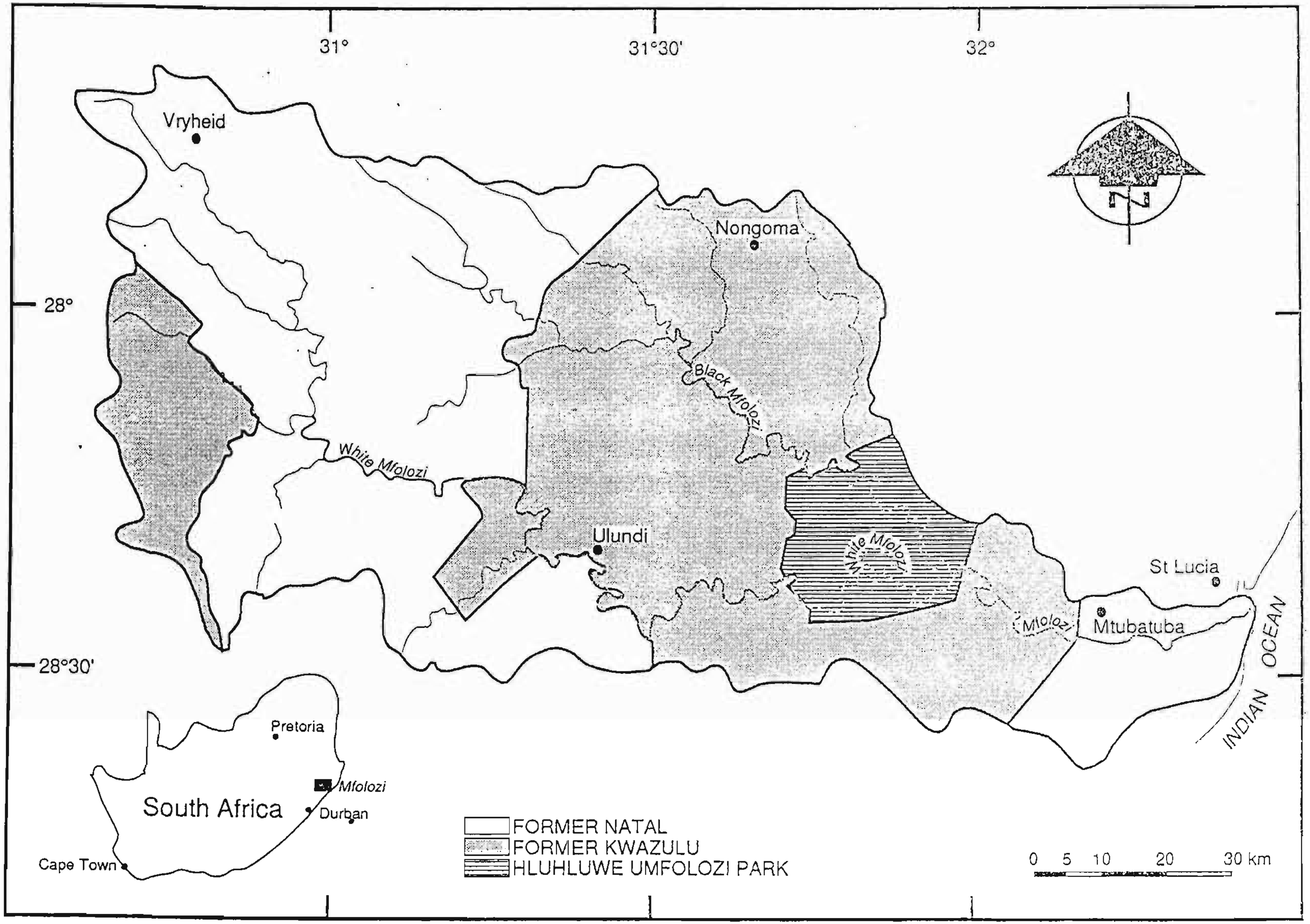


Figure 4.1: Location of the Mfolozi Catchment within South Africa

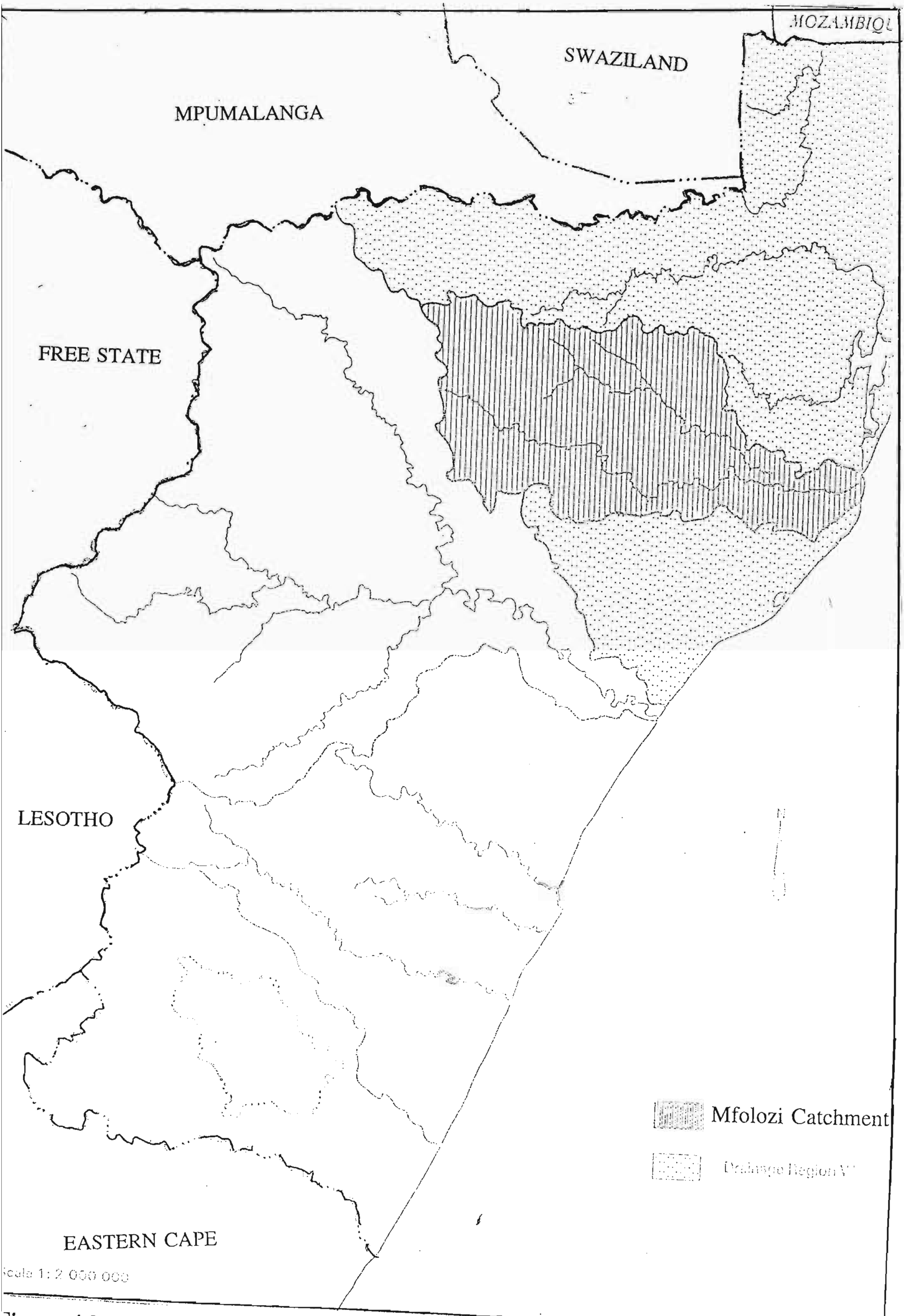


Figure 4.2: **Location of the Mfolozi Catchment within KwaZulu Natal (Begg, 1988)**

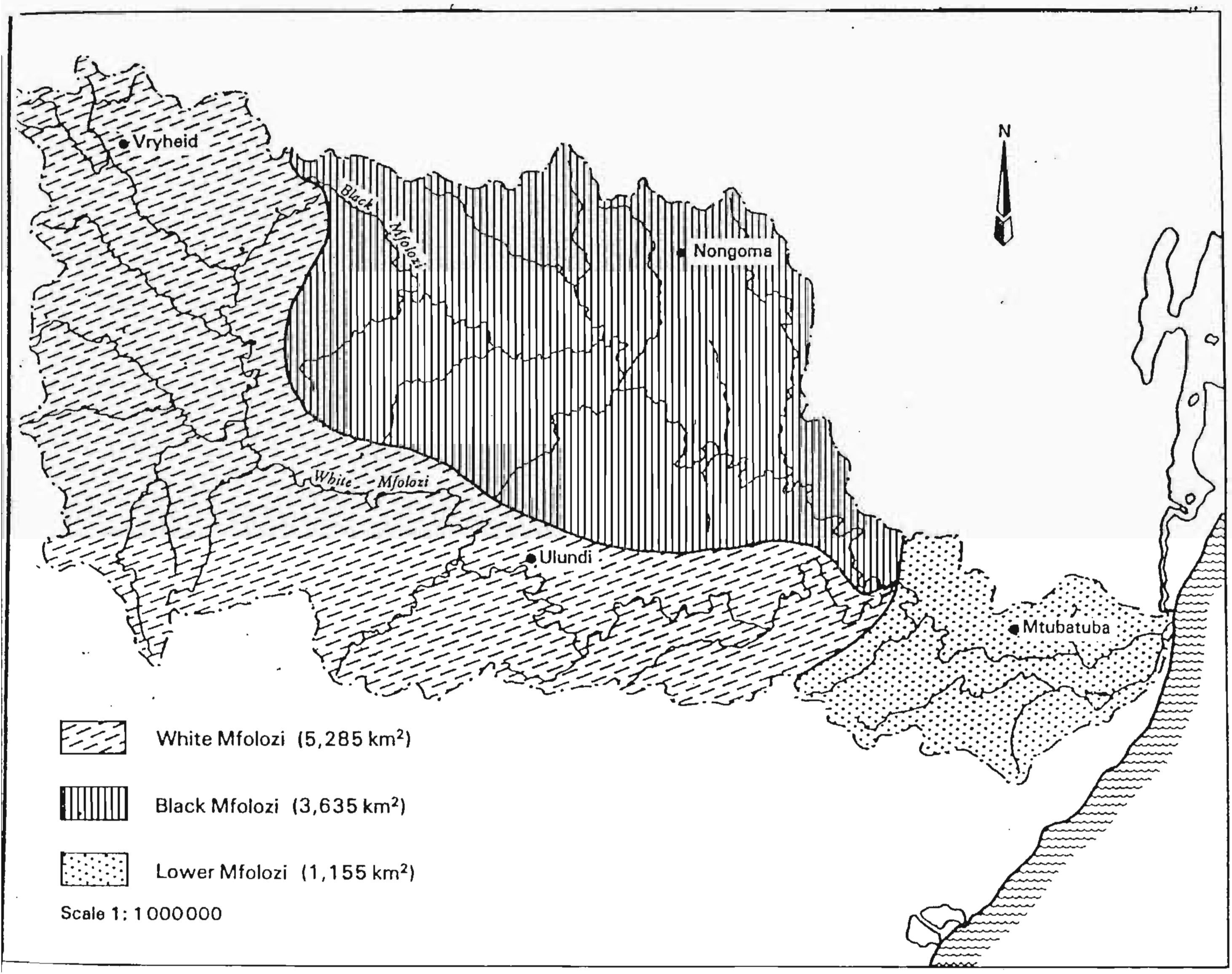


Figure 4.3: Major subdivisions of the Mfolozi Catchment

Figure 4.4: Subdivision of the Mfolozi catchment into 43 Quaternary Subcatchments defined by Pitman *et al*, 1981

4.2 COMPONENTS OF THE MFOLOZI RIVER SYSTEM

According to Coleman (1976), a river drainage system is made up of the drainage basin or catchment, an alluvial valley, and a receiving basin or the coastal component. The Mfolozi catchment displays all these components. The White and Black Mfolozi Rivers each have a mountainous drainage basin at elevations in excess of 500 m.a.s.l. Their lower reaches flow through an alluvial valley in which the southern most Umfolozi portion of the Hluhluwe-Umfolozi Park is situated. This valley, has numerous biologically very productive pans and wetlands which in addition to supporting prolific wildlife are a valuable resource for Zulu subsistence farmers (Looser,1985; Begg,1988). The Black and White Mfolozi Rivers then converge to form the Mfolozi which flows through the Mfolozi flats, the largest fluvial coastal plain in South Africa. Prior to 1928, the flats comprised swamps and marshes which supported large numbers of wild animals and especially water fowls. Natural productivity of the area was replaced by productive and extensive sugar-cane plantations. Following the Domoina Cyclone, sugar cane farmers were paid by the state to move off the land (Natal Town and Regional Planning Commission, 1984; Looser, 1985; Begg, 1988).

4.3 CLIMATE

Marked differences in altitude, topography, and distance from the sea within the catchment are reflected in its eight bioclimatic regions characterised in Table 4.2 and represented in Fig. 4.5 following Phillips (1973). Only 28% of the catchment experiences moist climate, favourable for agricultural purposes.

The catchment experiences a wide range of rainfall conditions with crippling droughts alternating with devastating floods over relatively short intervals (Natal Town and Regional Planning Commission, 1984). The mean annual precipitation for the catchment is 849 mm, and 80% of this falls in the summer months. Rainfall is highest near the coast and decreases inland except for areas above 1200 m.a.s.l. (Begg, 1988). Looser (1985) states that one of the major roles played by climate within the coastal component and alluvial valley is controlling the composition and quality of sedimentary deposits. He further states that during summer months, that is, when precipitation is higher than evapotranspiration, the processes of mechanical and chemical weathering are accelerated. This results in large amounts of water and sediments in the drainage basin.

The Mfolozi catchment generally experiences warm to hot temperatures. The mean annual temperatures vary from 16 to 18^0 C in the upper reaches. Hot and humid conditions occur near the coast where frosts are rare. At higher elevations the winters are cold and regular frosts occur (Natal Town and Regional Planning Commission, 1984).

REGION NUMBER	AREA(%)	NAME OF THE REGION	CLIMATIC CONDITIONS
8 9 10	30% 11% 31%	Dry Upland Lowland-Upland Riverine Interior Lowland	Mild Arid to Sub arid Climate
1 2 3 4 6	4% 2% 6% 6% 10%	Coastal Lowland Coast Hinterland Mistbelt Highland Submontane Moist Upland	Moist climatic condition

Table 4.2: Bioclimatic regions and their climatic conditions

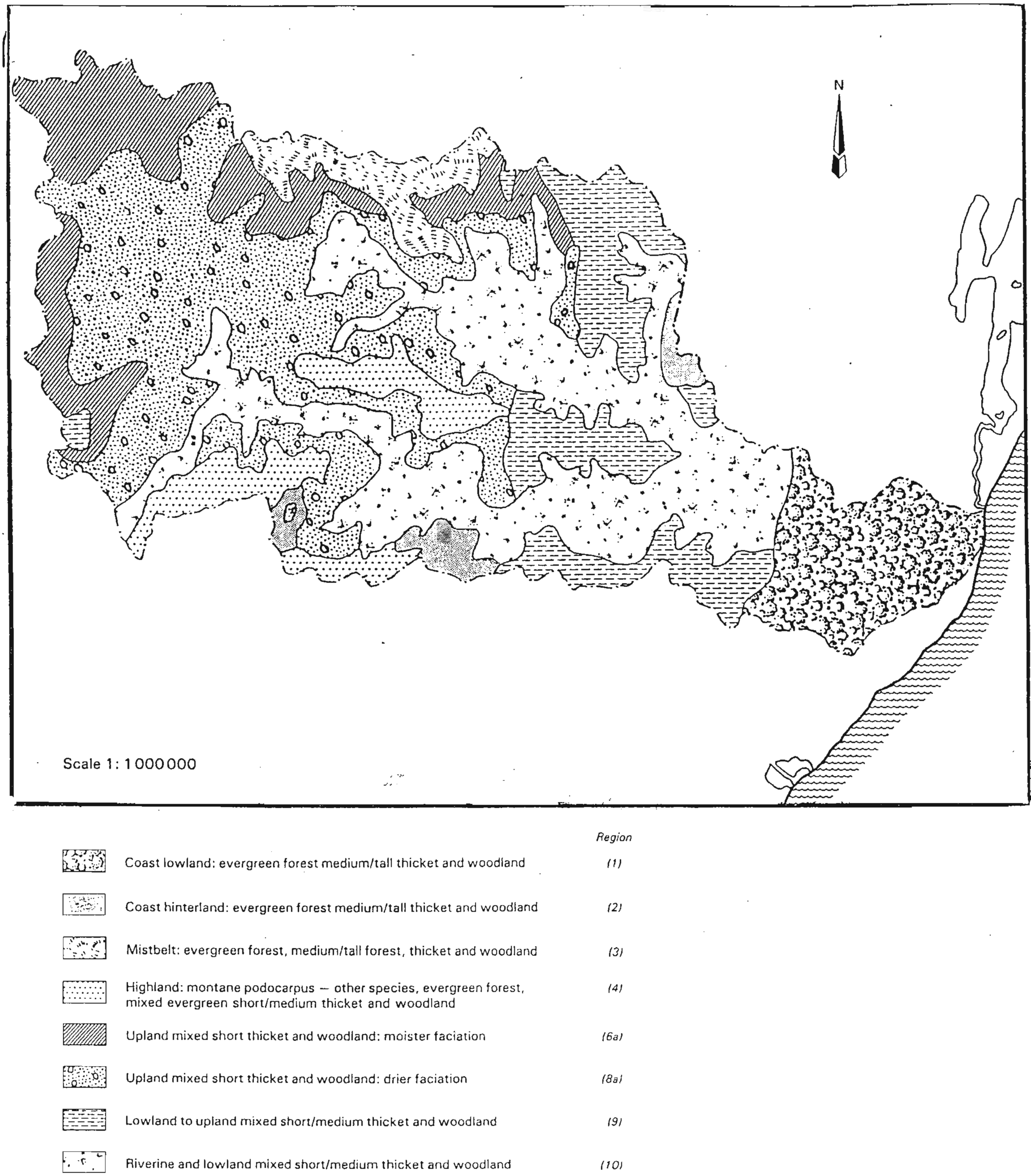


Figure 4.5: Bioclimatic Regions of the Mfolozi Catchment according to Phillips (1973)

4.4 GEOLOGY AND SOILS

There are eleven geological formations represented in this catchment (refer to fig. 4.6) and the most dominant of these include the Shales of the Ecca group (50 %), Dwyka formations (18 %) Basement complex (13 %) and Natal Group (5 %). Throughout most of the catchment, these formations tend to give rise to soils with inherent physical limitations including shallow depth, low moisture supply and high erosion hazard (Natal Town and Regional Planning Commission, 1984). The highly productive floodplain in the catchment and the areas around the Mziduzi rivers consist of young alluvium. Toward the upper and the middle reaches of the catchment, there are extensive coal deposits (Looser, 1985).

Many soil types are represented in the catchment, ranging widely in texture and degree of leaching. Highly weathered soils are, however, very limited in extent. Experiments detailed by MacVicar (1984), reveal a very strong relationship between the parent rock and the soils derived from them. It was found that in the catchment, Ecca Shales and Dwyka, i.e, (the most dominant geological formations), produce shallow clay soils; granite yielded coarse abrasive soils, and dolerite resulted in heavy deep red or shallow black clays. Pitman *et al* (1981) found that about two thirds of the catchment above Mtubatuba have a high runoff potential. The area consists of shallow soils and impermeable clays. In the sub-catchment of the Black Mfolozi, the percentage of less permeable soils was found to be more than 80 percent.

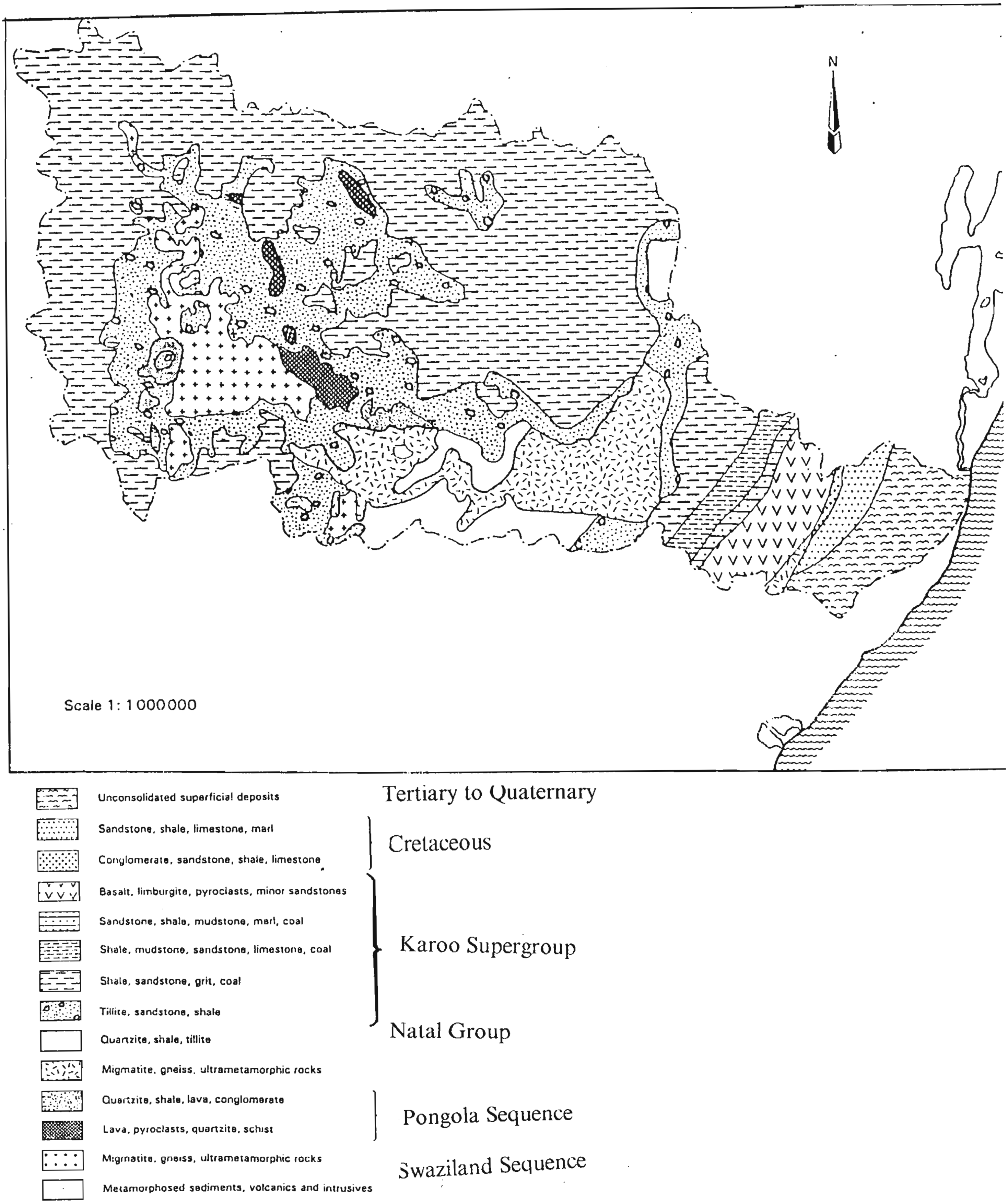


Figure 4.6: Geology of the Mfolozi Catchment as adopted by Begg (1988)

4.5 TOPOGRAPHY

The catchment's altitude drops rapidly over a distance of 150 km from 1300 m at Vryheid to sea level (Natal Town and Regional Planning Commission, 1984). Randall (1993) identified four main topographic types in the catchment: the mountainous areas in which the rivers arise; the hilly terrain downstream; the undulating terrain downstream of the confluence of the Black and White rivers and the Mfolozi flats. Nhlazatshe peak between Melmoth and Vryheid at 1445 m.a.s.l. is the highest point in the catchment.

4.6 VEGETATION

Fig 4.7 shows eleven veld types as defined by Acocks (1953; 1988) within the catchment, which reflect its climatic and topographic diversity. The most dominant veld types include Lowveld (28%), Zululand Thornveld (11%), Northern Tall Grassveld (22%), and the Natal Sour Sand veld (14%). Under normal climatic conditions, these veld types do not facilitate quick runoff. However, very little of the contemporary vegetation remains in a pristine state. Surveys carried out in white farmlands found stocking rates of 2,4 ha/Au in Tall Grassveld and 2,3 ha/Au in Thornveld are far in excess of their respective grazing capacities of 3,9 ha/Au and 7,0 ha/Au (Natal Town and Regional Planning Commission, 1984).

Bracher and Kovacs (1985) reported evidence of poor veld condition in almost all veld types. Likewise, Looser (1985) reported that substantial portions of former KwaZulu areas were totally denuded of cover due to prolonged droughts, bush encroachment, overgrazing, and overpopulation.

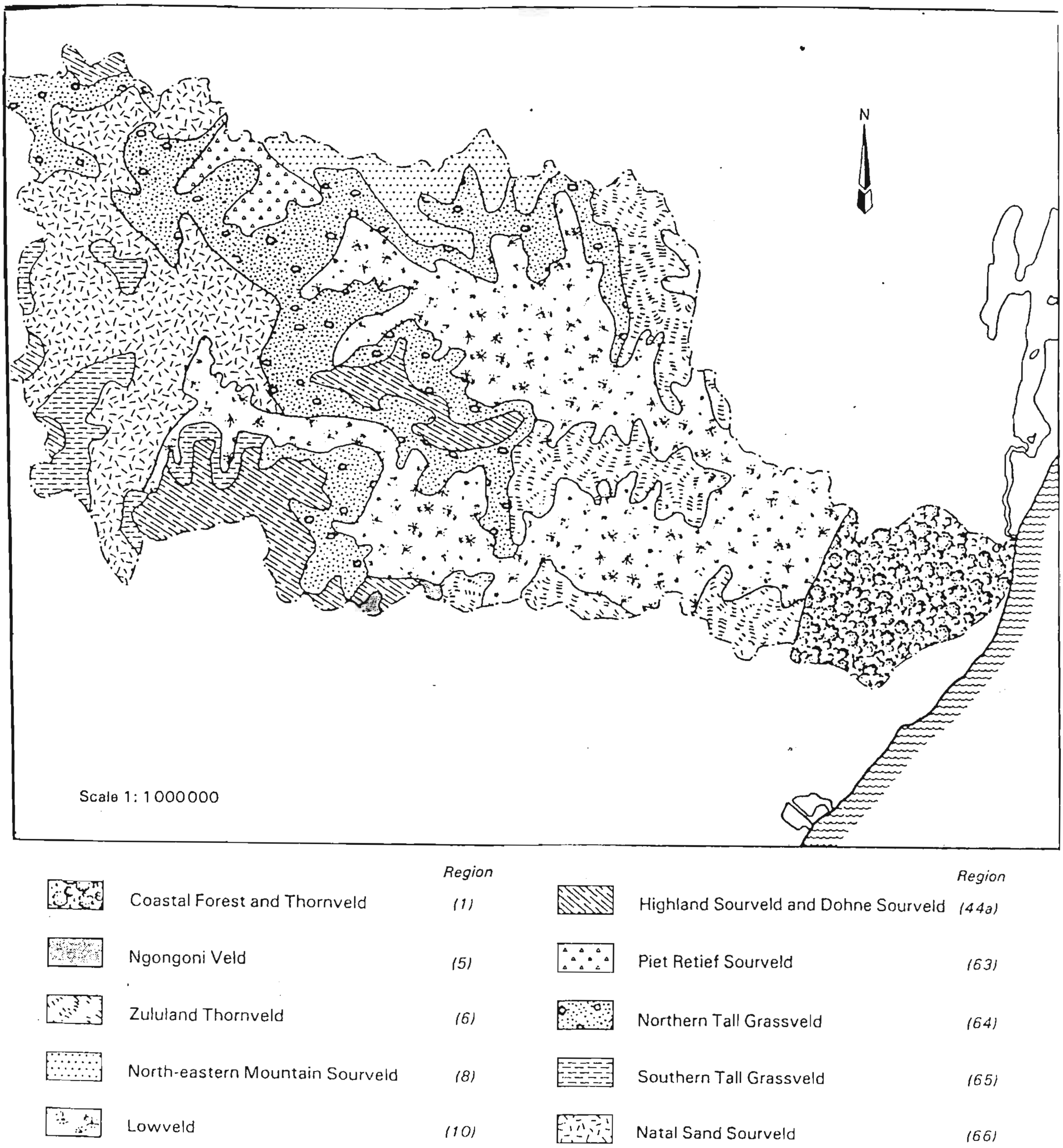


Figure 4.7: Vegetation of the Mfolozi Catchment according to the veld types defined by Acocks (1988)

4.7 WATER RESOURCES

The mean annual runoff is estimated to be 887 m^3. Many small farm dams are scattered throughout the catchment, larger dams - Klipfontein, near Grootverwacht, and Bloemveld dams near Vryheid and Mondlo near Nqutu occur only in the upper reaches of the catchment (Natal Town and Regional Planning Commission, 1984).

The limited number and poor distribution of water facilities pose a serious problem to the local populations, especially those living within the drier parts of the catchment. In many parts of former KwaZulu there is a dire need for the provision of water, for both domestic and stockwatering purposes. Presently, many of these areas are dependent on boreholes and rivers, most of which are dry for prolonged periods (Looser, 1985). According to the Mfolozi Catchment Planning Committee Report (Natal Town and Regional Planning Commission, 1984) there is an annual programme of sinking boreholes and constructing stock dams in order to improve the situation. In the upper reaches of the Black Mfolozi River, investigations have revealed that there is extensive acid mine pollution. Also in the White Mfolozi, there is a potential hazard of high nutrient loads which could be detrimental to impoundments near Vryheid (Department of Environmental Affairs, 1983 cited by Natal Town and Regional Planning Commission, 1984).

According to Begg (1988), prior to 1970, the Mfolozi catchment contained 1485 wetlands covering 502 km^2 or (5%) of the catchment. Over the intervening period to 1981, 58% of these wetlands have been altered to the extent that viable systems now cover less than 2,1% of the catchment. The extent of these losses has varied from one region to another in accordance with different land use pressures, and differences in susceptibility to disturbance of the various wetlands encountered. Erosion is the most important factor that has contributed in the destruction of wetlands in the catchment. He found it to be prevalent in 57% of the wetlands. Begg (1988) further reports that the extent of erosion in wetlands has been exacerbated in recent times by factors such as overgrazing, crop cultivation, expanding populations and private ownership of wetlands which qualify as state assets. The damage to wetlands was found to be greater in Former Natal than in Former KwaZulu.

4.8 LAND USE

A wide range of land use practices are carried out in the catchment. Watson (1993) distinguished four land use regions within the catchment viz:

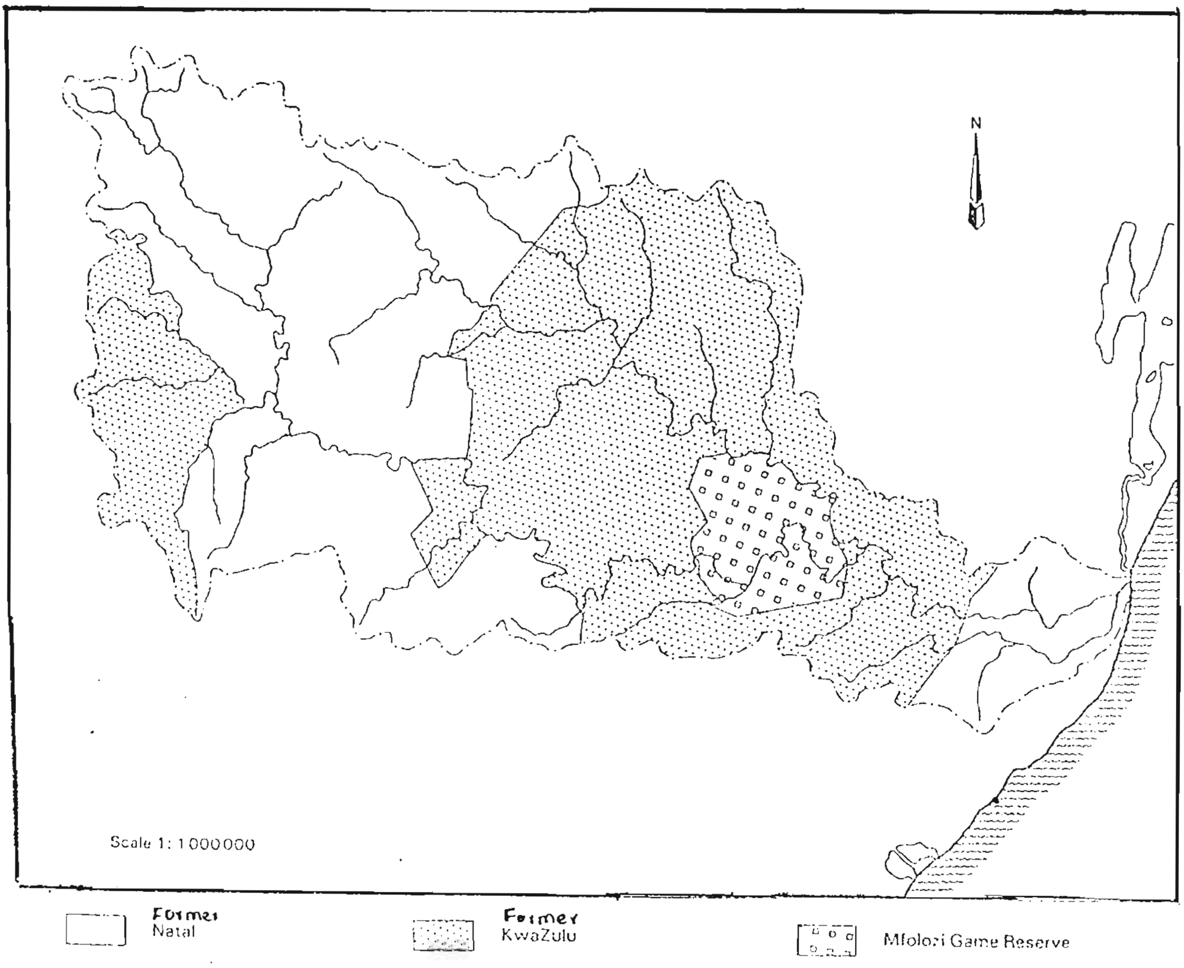


Figure 4.8: Landownership of the Mfolozi Catchment according to Begg (1988)

4.8.1 The Upland Basin Plain

This area is situated to the South-East of Vryheid, where commercial mixed farming (which include beef, sheep, and maize production) is the dominant activity. Timber, tea, cotton, and potatoes are also grown in this region (Watson, 1993). The area is privately owned by white farmers who generally employ technically advanced farming methods (Natal Town and Regional Commission, 1984). Overstocking of veld is however, also prevalent in this region and according to Natal Town and Regional Commission (1984) has led to old dongas being reactivated.

4.8.2 Former KwaZulu

With the exception of Ulundi and Nongoma, the respective homeland and royal capitals, these areas, previously administered by the KwaZulu government, are predominantly rural and under the jurisdiction of the tribal chiefs. The major activity in this region is subsistence farming (Watson, 1993). Numerous small and often scattered patches of arable land are cultivated primarily for the production of maize. Other crops grown include cotton, beans, potatoes and some sorghum. The Natal Town and Regional Planning Commission (1984) emphasises that communal grazing is the major cause of veld degradation and low levels of animal production as stocking rates far exceed the veld's carrying capacity. Looser (1985) and Natal Town and Regional Commission (1984) also highlighted the problem of overpopulation and poor roads in this region.

4.8.3 Conservation Areas

These include the southern portion of the Hluhluwe-Umfolozi Park and the St. Lucia Park, which are both currently administered by the Natal Parks Board (Natal Town and Regional Planning Commission, 1984; Watson; 1993) and the Dukuduku Forest

Reserve; Maphelane State Forest and Ntendeka Wilderness Area which are administered by the Department of Environmental Affairs (Natal Town and Regional Commission, 1984). These areas cover a total of 6% of the catchment (Watson, 1993) (refer to fig. 4.8).

4.8.4 The Mfolozi Flats

The area was used exclusively for the production of sugar cane until after Cyclone Domoina, when the State was prompted to buy land back from land owners and to place this land under the jurisdiction of the Directorate of Forestry. Presently, the area is owned by three parties:

a. **The State:** control the eastern edge of the coast which is mainly natural forests.

b. **The Umfolozi Co-operative of Sugar Planters (UCOSP):** comprising sugar cane farms occupying the upper and the middle reaches of the plain.

c. **Timber Companies:** The farms owned by Timber companies lie mainly in the area south of the Mfolozi Flats. The majority of the plantations are in subcatchment W266 and W267 and are owned by Waterton Timber Co (Begg, 1988).

4.9 EROSION IN THE MFOLOZI CATCHMENT

A number of erosion studies have been carried out in the catchment by several researchers. Natal Town and Regional Planning Commission (1984) Looser (1985) and Randall (1993) regard this catchment as severely eroded and claim that erosion is better represented in the former KwaZulu areas as compared to other landuse regions. Irrespective of whether they occur in the upper, middle or lower reaches, the Natal Town and Regional Planning Commission (1984) described extensive sheet erosion, large gullies and totally denuded areas comprising exposed subsoil material as being well represented throughout the former KwaZulu. In his research in three study areas around Ulundi, Nongoma and the confluence of the rivers, respectively, Looser (1985) used aerial photographs taken in 1960 and 1984 to examine erosion. He found that erosion in the first two areas increased from moderate to severe. Only in the third area was it rated slight. While all three areas he looked at were in former KwaZulu, the first two were in the middle reaches, while the latter was in the lower reaches. As noted in section 3.6.5, Liggitt (1988) and Liggitt and Fincham's (1989) findings also support the assertion that more damage to soil resources has occurred in areas that were previously administered by the KwaZulu government. While differences in gully erosion between KwaZulu area in the middle reaches of the catchment and upland commercial farming area were small, sheet erosion was 1,7 times better represented in the former. In her comparative study of soil erosion in the Umfolozi Game Reserve and adjacent KwaZulu area, Watson (1990) used five sets of sequential aerial photographs taken between 1937 and 1983 to assess erosion. She found that eroding surfaces comprised 0,1 and 4,6 % of the Reserve and KwaZulu study area, respectively. The comparable figures for the sparsely vegetated surfaces were 4,8 and 39,4 %.

The Mfolozi Catchment Planning Committee (Natal Town and Regional Planning Commission, 1984) used a simple qualitative technique to survey the natural erosion hazard potential of the catchment. Despite the findings that 67% of the former KwaZulu had a high natural predisposal for erosion, the Committee rather viewed overgrazing and poor cultivation practices as the predominant causative factors.

JURISDICTION	HIGH	MODERATE	LOW
WHITE FARMLANDS	46	43	11
KWAZULU (FORMER)	67	32	1

Table 4.3: Erosion hazard potential(%) Natal Town and Regional Planning Commission (1984)

The increase in erosion in two of Looser's (1985) study areas was attributed to the substantial increase in roads and tracks. Watson's (1990; 1996) study showed that traditional subsistence activities on communal lands exerted a significant influence. Prior to settlement in her study area, non-vegetated actively eroding surfaces were better represented in the Reserve. However, throughout the 25 year post settlement period, these localised surfaces became significantly better represented in the KwaZulu area. While most of them occurred on cultivated lands, an average 15 % was further accounted for by roads, footpaths, cattle tracks and homesteads.

According to Watson (1990) rainfall, soils, topography and vegetation characteristics rendered the former KwaZulu areas more susceptible to erosion than the Hluhluwe-Umfolozi Park. So, although she found less erosion in the Hluhluwe-Umfolozi Park, this could not be attributed entirely to the better land management in the conservation area. Studies carried out by Liggitt (1988) and Liggitt and Fincham (1989), Venter (1988) (in the Mfolozi Game Reserve) and Looser (1989) revealed that erosion was most closely correlated highly erodible soils, geology and vegetation cover. Liggitt (1988), Liggitt and Fincham (1989) and Looser (1989) noted the preferential occurrence of erosion on pediments covered with medium to deep colluvial deposits derived from Ecca and Dwyka rocks. All of the material reviewed in this section suggests that erosion in the former KwaZulu areas was not only due to poor landuse practices, but was also encouraged by their high natural predisposal of the area to erosion.

4.9.1 THE INFLUENCE OF EROSION ON THE INCIDENCE AND MAGNITUDE OF FLOODS

Combrie Greig (1984) presents a table of the thirteen flood peaks recorded in the Mfolozi river from 1880 - 1984 which clearly shows a progressive increase in the incidence and frequency of floods. This trend is attributed to progressive degradation caused by poor cultivation practices and overgrazing particularly in KwaZulu (Natal

Town and Regional Commission, 1984; Combrie Greig, 1984). This interpretation, according to Looser (1985) and Watson (1993), ignores the potential influence of the channel that was constructed across the flood plain, and wetland degradation in the catchment.

The canalization of the floodplain and its settlement by farmers commenced in 1918 and was completed about 1950 (Cooper, 1984). Looser (1985) states that prior to the commencement of farming on the flood plain, most of the river sediment load was absorbed by the plain. The water that consequently reached the coast was sediment free and thus assisted in keeping the estuary mouth open. Now, instead of the floodplain absorbing huge silt and water loads during flood periods, the waters are carried down the canalised Mfolozi River and deposited in the basin. The consequent siltation and closure of the mouth has contributed significantly to the increased incidence and severity of flooding, particularly in the lower reaches of the river (Van Heerden and Swart, 1985; Begg, 1988).

Cyclone Domoina, which was the most catastrophic flood to have occurred in the Mfolozi catchment, hit it in late January and February 1984 (Combrie Greig, 1984; Looser, 1985; Van Heerden and Swart, 1985). It caused a flood that peaked at 16000 m^3/s in the lower reaches of the Mfolozi river and had a total estimated flood volume of $2500 \times 10^6 m^3$ (Kovacs, *et al,* 1985). This flood deposited $80 \times 10^6 m^3$ of sediment on the Mfolozi flats. The amount of sediment deposited on the flats is 30 times more than $2{,}4 \times 10^6 m^3$, figure given by Van Heerden and Swart (1985) as the natural ability of the Mfolozi flats to absorb sediment to maintain base level. This resulted in a sugar cane production loss of R57 million (Begg, 1988). The estimate of total flood damage to the catchment was in excess of R 100 million and included three washed away bridges, destroyed buildings, roads and tourist facilities, power lines and telephone communications were also severely disrupted (Combrie Greig, 1984). From a conservation point of view, Gosling (1984) reports that the most serious loss was the almost total destruction of the riverine forest in the southern portion of the Hluhluwe-

Umfolozi Park. These forests, famous for their magnificent giant sycamore fig trees, were regarded by scientists as the richest and most productive in the whole park.

From the research carried out in the catchment to date, one cannot conclude that the increased incidence of flooding in the catchment is due to accelerated soil erosion, especially in former KwaZulu areas. Watson (1993) argued that severe erosion in KwaZulu areas was localised. Most gullies were found to be stable and thus do not contribute to the high rate of soil loss. Botha (1992) also argued that although former KwaZulu has a higher erosion potential and more erosion, particularly gullies, this does not mean that it is a major sediment production area. He found that most of the gullies are very old and inactive. The more severe degradation of wetlands in former Natal noted by Begg (1988) (refer to 4.7) may mean that they are actually the sediment production areas.

CHAPTER 5

METHODOLOGY

5.1 INTRODUCTION

Data sources for this study comprised: (i) Looser's (1992) unpublished map of soil erosion in the Mfolozi Catchment and (ii) Land Type Survey Staff's (1986; 1988), Richards Bay and Vryheid Land Type Maps and memoirs. These data sources were principally utilised to identify landtypes which are already severely eroded, as well a those that are highly susceptible to erosion. Both these categories should not be considered suitable for peasant settlements by the Land Reform Programme.

5.2 DATA SOURCES

5.2.1 EROSION MAP

Since 1928, the Department of Water Affairs has monitored the sediment yield of most major rivers in the Mfolozi catchment on a weekly or daily basis. Surveys of sediment deposition in dams have also been carried out at regular intervals. These data have primarily been used to estimate sediment load. The main drawback of these data is that little indication of the source of the sediment can be derived from them (Randall, 1993). The importance of identifying these sources was recognised in the wake of the damage caused by Cyclone Domoina described in section 4.9.1. The former Hydrological Research Institute commissioned Mr. J. U. Looser to set about carrying out this task by mapping the location and extent of the range of potential sediment sources prevalent in the catchment.

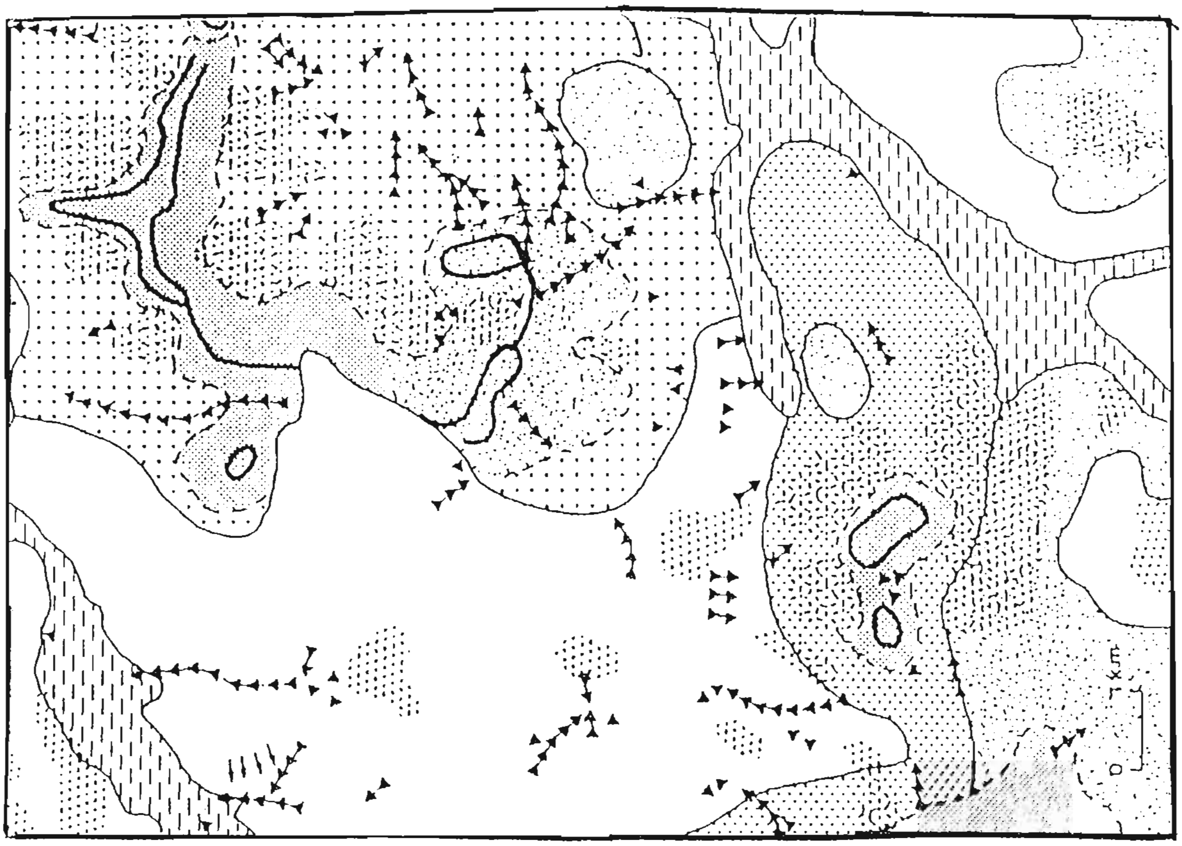
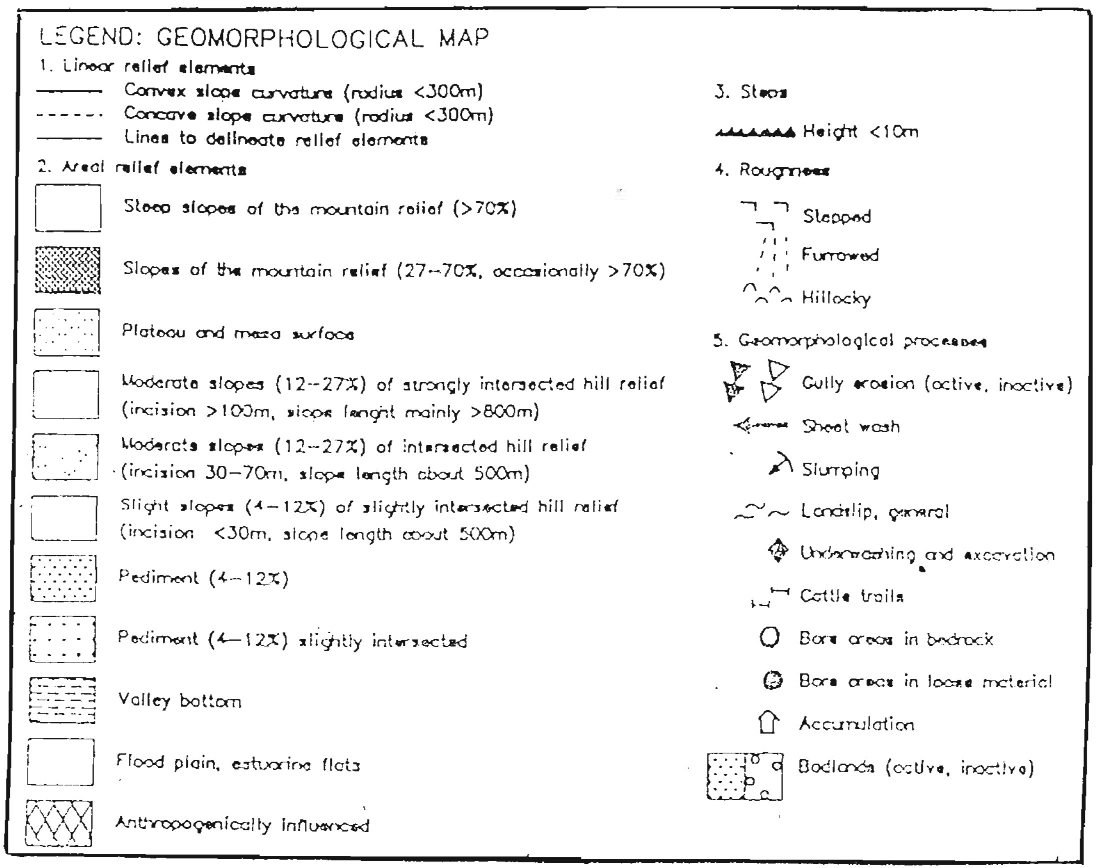


Figure 5.1: Map showing Erosion Features (Looser, 1988, 1992)



5.2: Legend of Erosion features (Looser, 1988; 1992)

Looser (1988; 1989) describes how he identified and integrated data from 1:30 000 aerial photographs taken in 1986, 1:50 000 topocadastral maps, and 1:10 000 orthophoto maps produced from 1:30 000 aerial photographs taken in 1983, to produce a 1:100 000 map showing the location of potential sediment sources over the entire catchment (refer to fig 5.1 and 5.2 for an example of the map and list of erosion features, respectively). At this scale sufficient detail regarding the potential sediment sources could still be shown without having an extremely large map.

The final map contains the following information:

(i) complete representation of different geomorphological processes;
(ii) boundaries of each of the 43 subcatchments identified by Pitman *et. al* (1981);
(iii) information on the length (represented by 1-11) of gullies

5.2.2 LAND TYPE MAPS AND MEMOIRS

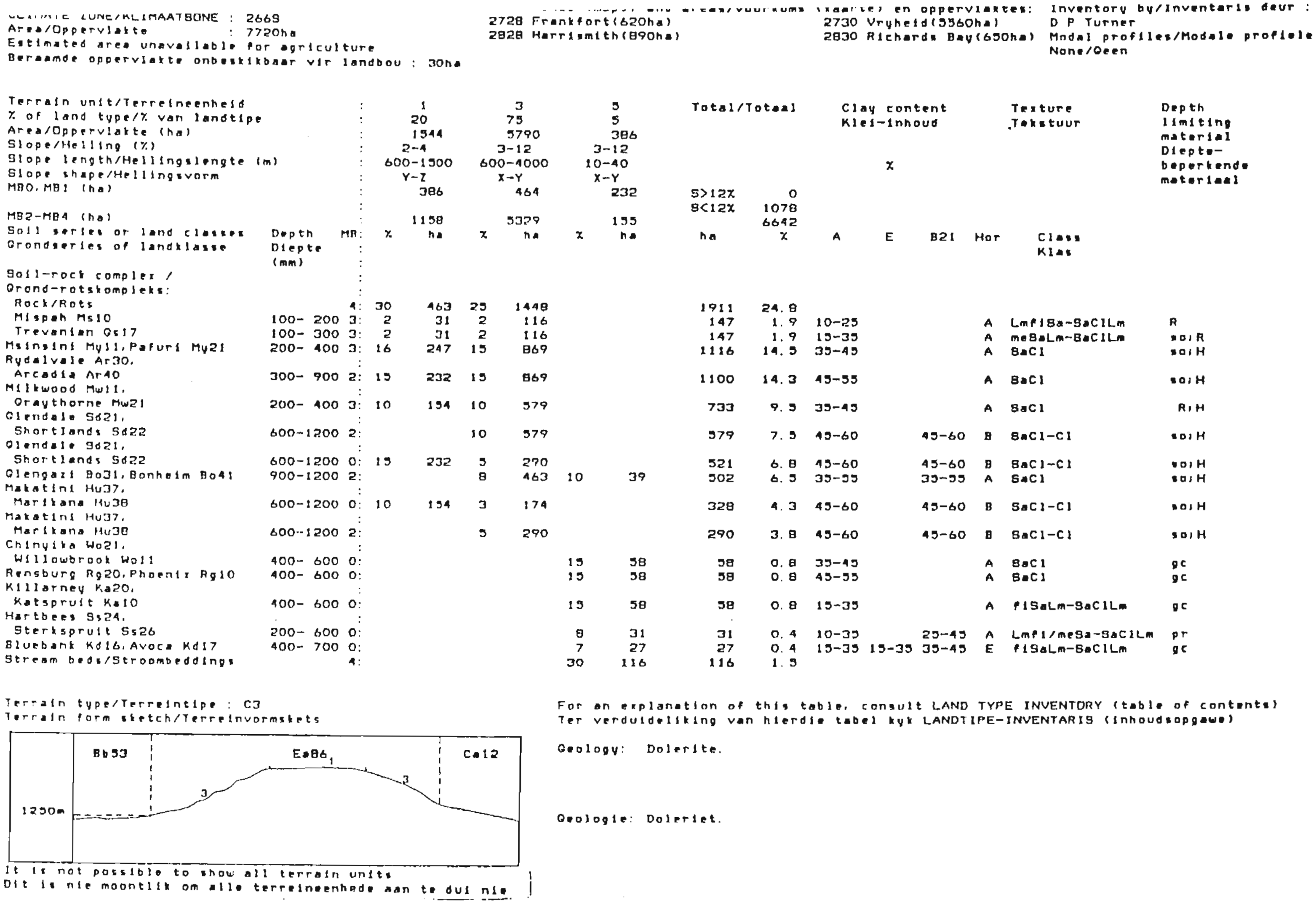
The landtype maps were commissioned by the Institute of Soil, Climate and Water of the Agricultural Research Council and produced by Land Type Survey Staff (1986; 1988). To facilitate data extraction from the two 1:250 000 Land Type maps covering the catchment, that is, Vryheid (2730) and Richards Bay (2830)), they were blown up to the 1:100 000 scale of the erosion map.

Land Type Survey Staff (1986; 1988) defines *Land Type* as an area that can be shown at 1:250 000 scale and that displays a marked degree of uniformity with respect to terrain form, soil patterns, and climate, all of which are major determinants of agricultural potential. In order to construct a common legend and enhance the readability of these maps, Land Type Survey Staff (1986, 1988) chose *Broad Soil Patterns*. Land types were numbered according to these broad soil patterns. For example, land type Ea39 was given the number 39 th land type which qualified for inclusion in the broad soil pattern or map unit Ea (Land Type Survey staff, 1986; 1988). Table 5.1 shows the broad soil patterns found in the study area, and the description which each represent.

Memoirs which detail information on the terrain types, soils, geology, and climate associated with each broad soil pattern were also used. Fig. 5.3 gives an example of the information in the memoirs' information content.

SOIL PATTERN	DESCRIPTION
Aa-Ai	Red - Apedal, freely drained soils
Ab	Red dystrophic and\or mesotrophic
Ac	Red and yellow dystrophic and or mesotrophic
Ad	Yellow dystrophic or mesotrophic
Ba- Bd	**Plinthic Catena: Upland Duplex and margalitic soils rare**
Ba	Dystrophic and\or mesotrophic: Red soils widespread
Bb	" " " : Red soils not widespread
Bd	Eutrophic: Red soils not widespread
Ca	**Plinthic Catena:Upland Duplex and margalitic soils common**
Da-Dc	**Prismacutanic and\or pedocutanic Diagnostic Horizons dominant**
Db	B horizons not red
Dc	land qualifies for inclusion in d, but have one or more of: vertic, melanic, red structural diagnostic horizons.
Ea	**One or more of vertic, melanic, Red structured Diagnostic horizons. This unit indicates land with high base status, dark coloured and\or red soils, usually clayey,associated with basic parent material.**
Fa-Fc	**Glenrosa and Mispah forms**
Fa	Lime rare or absent in the entire landscape
Fb	Lime rare or absent in the upland soils but generally in low lying soils
Ha,Hb	**Grey Regic Sands**
Ha	Regic sands dominant-occupy more than 80% of the area Regic sands and other soils-occupy less than 80% and more than 20% of the area
Ia-Ic	**Miscellaneous land classes**
Ia	Land types with soil patterns difficult to accommodate elsewhere, at least 60% of which comprises pedologically youthful, deep unconsolidated deposits.
Ib	Land types with exposed rock covering 60-80% of the area.

Table 5.1 Broad Soil Patterns found in the Mfolozi Catchment



CLIMATE ZONE/KLIMAATSONE : 2669
Area/Oppervlakte : 7720ha
Estimated area unavailable for agriculture
Beraamde oppervlakte onbeskikbaar vir landbou : 30ha

(maps) and areas/Voorkoms (kaarte) en oppervlaktes:
2728 Frankfort(620ha)
2828 Harrismith(890ha)
2730 Vryheid(5560ha)
2830 Richards Bay(650ha)

Inventory by/Inventaris deur :
D P Turner
Modal profiles/Modale profiele
None/Geen

Terrain unit/Terreineenheid			1		3		5		Total/Totaal		Clay content Klei-inhoud				Texture Tekstuur	Depth limiting material Diepte-beperkende materiaal
% of land type/% van landtipe			20		75		5									
Area/Oppervlakte (ha)			1544		5790		386									
Slope/Helling (%)			2-4		3-12		3-12									
Slope length/Hellingslengte (m)			600-1500		600-4000		10-40					%				
Slope shape/Hellingsvorm			Y-Z		X-Y		X-Y									
MB0,MB1 (ha)			386		464		232		S>12%	0						
									S<12%	1078						
MB2-MB4 (ha)			1158		5329		155			6642						
Soil series or land classes Grondseries of landklasse	Depth Diepte (mm)	MB	%	ha	%	ha	%	ha	ha	%	A	E	B21	Hor	Class Klas	
Soil-rock complex / Grond-rotskompleks:																
Rock/Rots		4	30	463	25	1448			1911	24.8						
Mispah Ms10	100- 200	3	2	31	2	116			147	1.9	10-25			A	LmfiSa-SaClLm	R
Trevanian Gs17	100- 300	3	2	31	2	116			147	1.9	15-35			A	meSaLm-SaClLm	so,R
Msinsini My11,Pafuri My21	200- 400	3	16	247	15	869			1116	14.5	35-45			A	SaCl	so,H
Rydalvale Ar30, Arcadia Ar40	300- 900	2	15	232	15	869			1100	14.3	45-55			A	SaCl	so,H
Milkwood Mw11, Graythorne Mw21	200- 400	3	10	154	10	579			733	9.5	35-45			A	SaCl	R,H
Glendale Sd21, Shortlands Sd22	600-1200	2			10	579			579	7.5	45-60		45-60	B	SaCl-Cl	so,H
Glendale Sd21, Shortlands Sd22	600-1200	0	15	232	5	290			521	6.8	45-60		45-60	B	SaCl-Cl	so,H
Glengazi Bo31,Bonheim Bo41	900-1200	2			8	463	10	39	502	6.5	35-55		35-55	A	SaCl	so,H
Makatini Hu37, Marikana Hu38	600-1200	0	10	154	3	174			328	4.3	45-60		45-60	B	SaCl-Cl	so,H
Makatini Hu37, Marikana Hu38	600-1200	2			5	290			290	3.8	45-60		45-60	B	SaCl-Cl	so,H
Chinyika Wo21, Willowbrook Wo11	400- 600	0					15	58	58	0.8	35-45			A	SaCl	gc
Rensburg Rg20,Phoenix Rg10	400- 600	0					15	58	58	0.8	45-55			A	SaCl	gc
Killarney Ka20, Katspruit Ka10	400- 600	0					15	58	58	0.8	15-35			A	fiSaLm-SaClLm	gc
Hartbees Ss24, Sterkspruit Ss26	200- 600	0					8	31	31	0.4	10-35		25-45	A	Lmfi/meSa-SaClLm	pr
Bluebank Kd16,Avoca Kd17	400- 700	0					7	27	27	0.4	15-35	15-35	35-45	E	fiSaLm-SaClLm	gc
Stream beds/Stroombeddings		4					30	116	116	1.5						

Terrain type/Terreintipe : C3
Terrain form sketch/Terreinvormskets

It is not possible to show all terrain units
Dit is nie moontlik om alle terreineenhede aan te dui nie

For an explanation of this table, consult LAND TYPE INVENTORY (table of contents)
Ter verduideliking van hierdie tabel kyk LANDTIPE-INVENTARIS (inhoudsopgawe)

Geology: Dolerite.

Geologie: Doleriet.

Figure 5.3 Example of Land Type Memoir according to the Land Type Survey Staff (1986; 1988)

5.2.3 CHARACTERISTICS OF LANDTYPES FROM ADDITIONAL DATA SOURCES

Information on the vegetation types and bioclimatic regions corresponding to each broad soil pattern was extracted from Acocks (1988) and Phillips (1973) maps, respectively. Information on rainfall erosivity indexes was extracted from Rooseboom *et al*'s (1992) map.

5.3 DATA EXTRACTION

The boundaries of 43 Quaternary subcatchments delimited by Pitman *et al* (1981) (refer to Fig. 4.3) and the boundaries of the 16 broad soil patterns delimited by Land Type Survey Staff (1986; 1988) were superimposed on the erosion map. On the 250 000 landtype series maps the coincidence of terrain form and macroclimate zone boundaries delimit landtypes within each broad soil pattern. As this research did not require such a detailed landtype depiction, the broad soil pattern boundaries were accepted as landtype boundaries. Data on each landtype's characteristic viz, topography, geology and pedology, veld type, and bioclimate and also rainfall erosivity indexes were extracted respectively from Land Type Survey Staff (1986; 1988), Acocks (1988), and Phillips (1973) and Rooseboom *et al* (1992).

The aerial extent of each landtype within each subcatchment was digitized. Except for both bad active and inactive badlands, the number of each of the 22 potential sediment sources (erosion features) within each landtype within each subcatchment was then counted, divided by both the landtype and subcatchment area and stored for retrieval for statistical analysis as density values. In their preliminary assessment of the reliability of using the number of each of the different erosion types represented in the

landtypes as an indication of their significance as sediment sources, Watson, Ramokgopa and Looser (1996) found that this methodological approach was not satisfactory for spatially extensive features. For example, a landtype with one badland surface covering a substantial portion of its area is obviously potentially a more significant sediment source than one with several small such surfaces. Of all the erosion features represented in the Mfolozi catchment, the badlands are the most spatially extensive. Therefore, in the case of badlands, the percentage of the corresponding landtype and subcatchment surface area affected by them was recorded.

An extensive survey of South African literature failed to reveal a system for classifying erosion severity based on density. Most ratings, (e.g, SARCCUS, 1981; Weaver, 1988; Whitlow, 1988) were based on the proportion of the area affected by erosion. In order to try to identify natural class boundaries in erosion severity for each of the different types of erosion, a frequency distribution of their density values (percentage of area covered in the case of badlands) were plotted on a semi-logarithmic graph paper. Gaps or steps in these plots were arbitrarily selected as representing the different severity boundaries.

EROSION FEATURE	**VALUE - RANGE** (number per unit area)	**ERODIBILITY CLASS**
OVERALL EROSION	> 1,5	VERY HIGH
	1,2 - 1,5	HIGH
	0,73 - 1,19	MODERATE
	0,42 - 0,72	LOW
	0 - 0,41	VERY LOW
GULLY 1	> 0,7	VERY HIGH
	0,4 - 0,7	HIGH
	0,27 - 0,39	MODERATE
	0,09 - 0,26	LOW
	0 - 0,08	VERY LOW
GULLIES 2, 3, AND 4	> 0,29	VERY HIGH
	0,17 - 0,29	HIGH
	0,1 - 0,16	MODERATE
	0,06 - 0,09	LOW
	0 - 0,05	VERY LOW
UNCONFINED EROSION	> 0,78	VERY HIGH
	0,63 - 0,78	HIGH
	0,45 - 0,62	MODERATE
	0,21 - 0,44	LOW
	0 - 0,2	VERY LOW
MASS WASTING PROCESSES	> 0,1	VERY HIGH
	0,08 - 0,1	HIGH
	0,05 - 0,07	MODERATE
	0,03 - 0,04	LOW
	0 - 0,02	VERY LOW
BADLANDS	> 0,32	VERY HIGH
	10,2 - 0,32	HIGH
	0,16 - 0,19	MODERATE
	0,12 - 0,15	LOW
	0 - 0,11	VERY LOW

Table 5.2: Boundaries for the different classes of erosion severity for the different types of erosion

5.3.1 TERRAIN TYPES

Land Type Survey Staff (1986; 1988) define a terrain type as a land surface over which there is a marked degree of uniformity. Within each terrain type terrain units and phases shown in Table 5.3 are further defined. The schematic profile adopted from Botha (1992) fig 5.4 gives a visual representation of these components.

UNIT	**DESCRIPTION**
1	CREST
2	SCARP
3	MIDSLOPE
4	FOOTSLOPE
5	VALLEY BOTTOM
3(1)	2ND PHASE MIDSLOPE
3(2)	3RD PHASE MIDSLOPE

Table 5.3: Terrain units in the study area and their description

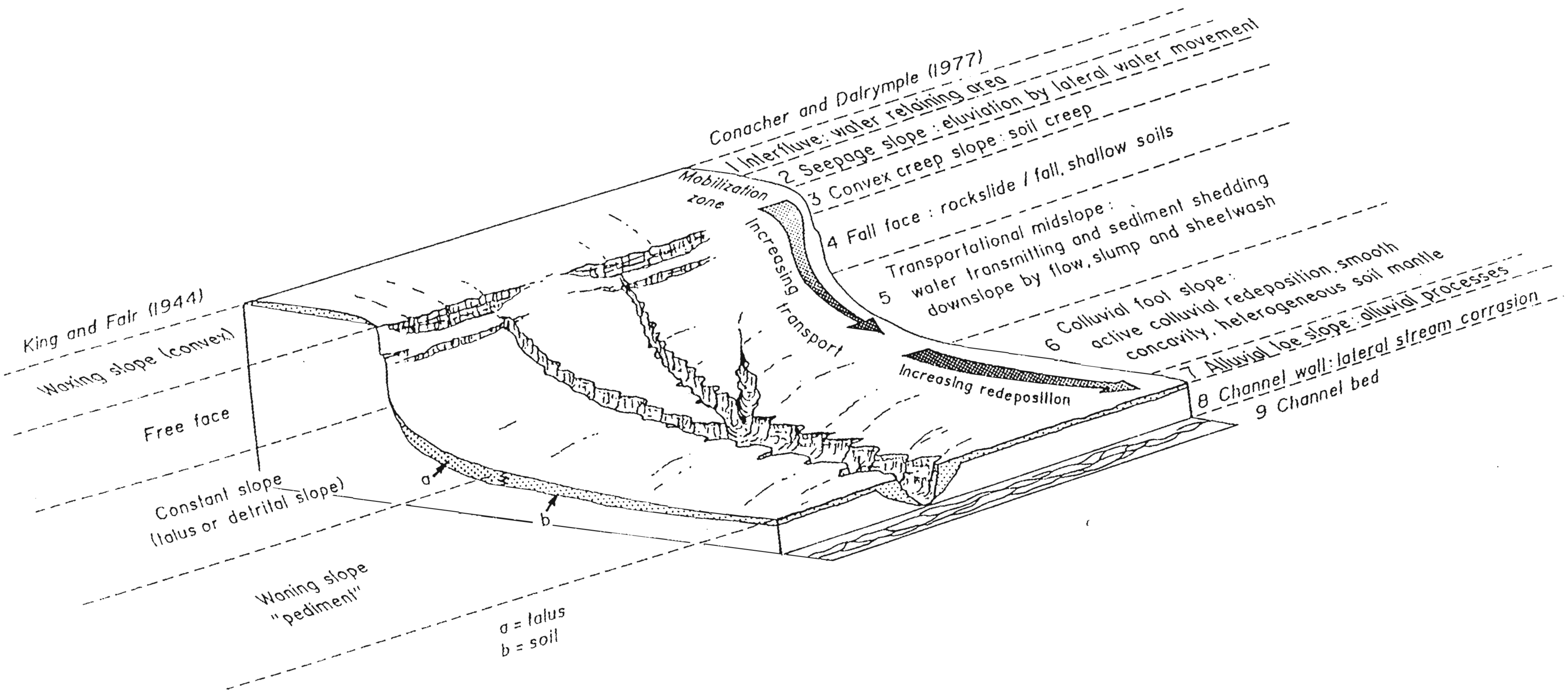


Figure 5.4 Schematic Profile of Topographic features adopted from Botha (1992)

As explained in Chapter 3 slope angle, length and shape are fairly reliable indicators of the influence of topography on soil erosion. The land type map memoir gave the areal coverage of each terrain unit within each land type. In this study, the characteristics of three dominant terrain types in each Land Type were extracted. In order to identify the range in slope length most representative of each of these terrain units, they were arbitrarily categorised into the following classes:

NUMBER	CATEGORY (m)
1	> 0 - 50
2	51 - 100
3	101 - 250
4	251 - 500
5	501 - 750
6	751 - 1000
7	1001 - 1500
8	1501 - 2000
9	2001 - 3000
10	> 3000

Table 5.4: Slope Length Ranking

Land Type Survey Staff (1986; 1988) used the following symbols to represent the different slope shapes, that is, X for concave, Y for convex and Z for straight slope. The dominant slope shape category corresponding to the dominant terrain unit was recorded. Slope angles were also chosen according to dominant terrain units. Refer to Table 5.4 for the slope angle categories. For example, if 3-midslope has the highest percent of areal coverage, it simply means that its shape, length and angle are also dominant.

NUMBER	CATEGORY
1	< 3,5
2	3,6 - 8,8
3	8,9 - 17,6
4	17,7 - 34,4
5	>34,5

TABLE 5.5: Slope Angle

5.3.2 GEOLOGY AND SOILS

The three most dominant soils within each landtype were recorded and classified into an erodibility class. Erodibility values for the full range of soil series represented in this study had to be obtained from two different sources, as neither gave a listing of them all, i.e, F - values from SLEMSA (1976) and K - values from MacVicar (1984). In addition to the most dominant soils, the three most highly erodible soils were recorded. The most dominant geology in every landtype was also recorded; erosion potential of geology was rated according to previous research conducted in the study area by Liggitt (1988), Watson (1990) and Botha (1992) as described in section 3.6.2.

5.3.3 VELD TYPES AND BIOCLIMATIC REGIONS

Veld types and bioclimatic regions corresponding to different subcatchments were identified. This was done by locating the different subcatchments on both the veld type and bioclimatic maps. Erosion potential of these factors was rated based on the information from Scotney (1978), Liggitt (1988) and Botha (1992) (refer to section 3.6.4).

5.4 DATA ANALYSIS

The overall susceptibility of the 43 quaternary subcatchments to erosion was based on the ratings of the erosion risk factors given by Rooseboom (1992) for EI_{30}, SLEMSA (1976) and MacVicar (1974) for soils, Watson (1990), Liggitt (1988) and Botha (1992) for geology, Scotney (1978) and Liggitt (1988) for bioclimatic regions and veld types as detailed in 5.3.1, 5.3.2 and 5.3.3. Erosion risk factors were classified into three categories: high, moderate, and low (refer to Table 6.1 - 6.6). For each subcatchment, set of six erosion risk factors, the most dominant rating was taken as representing its overall erosion risk.

Differences in topography, geology, pedology, climate and vegetation between the land type units are significant (Land Type Survey Staff, 1986; 1988). This study needed to establish whether differences in the type, extent and density of erosion between these land type units were significant. The first step in this computational assessment involved determining whether or not the database was parametric. The semi-logarithmic frequency distribution plot technique described by Fisher and Yates (1963) was used to verify the parametric nature of all data sets. The Standard Analysis of Variance Test was used at a 99% confidence level to assess the significant of differences (a) between the 22 potential sediment source data sets and (b) between the 10 landtype characteristic data sets. The absence of significant differences between several of the potential sediment sources enabled them to be regrouped into six categories as follows:

GULLIES LENGTH(M)	UNCONFINED EROSION	MASS WASTING	BADLANDS	MINE DUMPS	RELIEF
GULLIES 1 (< 125)	SHEET/RILL	SLIPPED SLOPE	ACTIVE	ANTHROPO-GENICALLY	ROUGHNES S HILLOCKS
Gully 2 (126-250)	CATTLE TRACKS	SLIPS	INACTIVE		VERTICAL DROP 10 m
Gully 3 (251-375)	BARE AREAS IN LOOSE MATERIAL	SLUMPS			BARE AREAS - OUTCROP GRANITE
Gully 4-11 (376-1375)		STEPPED			

Table 5.6: Erosion data categories

The Standard Pearsons Product Moment Correlation Coefficient test was used to measure the degree of association between the two major data sets (erosion data set and land type data set). As the number of inputs for each data set was in excess of 100, a coefficient of 0,19 was accepted as threshold for significance at 95 % confidence level following Table No. VII in Fisher and Yates (1963). Forward Stepwise Multiple Regression Analysis and Principle Component Analysis were both used to try to explain the functional relationships between these data sets. Forward Stepwise Multiple Regression Analysis was selected for its ability to eliminate the influence of multicollinearity amongst and so assess the relative importance of the independent land type variables (Shaw and Wheeler, 1985). Principle Component Analysis was additionally selected because of its capacity to indicate the way in which the variables are grouped together in terms of the amount of variation present in the data sets and investigate all the underlying dimensions existing within the data matrix (Davies, 1973).

CHAPTER 6
RESULTS AND DISCUSSION

6.1 INTRODUCTION

This study attempted to identify the landtypes in the Mfolozi catchment which are most susceptible to erosion and therefore most unsuitable for inclusion in a Land Reform Programme. In order to achieve this, the most severely eroded landtypes, and those most potentially susceptible to erosion within each of the 43 subcatchments were identified. This identification involved firstly, assessing the potential susceptibility to erosion of the landtypes and subcatchments. Then, the severity of actual erosion in the landtypes and subcatchments was determined. Finally, the Analysis of Variance, Pearsons Product Moment Correlation, Forward Stepwise Multiple Regression Analysis and Principal Component Analysis statistical tests were used to explain the influence of a range of biophysiographic factors on the spatial distribution of both the potential and actual erosion.

In this chapter the distribution of the erosion severity classes for each of the erosion types considered are presented. For the subcatchments, these distributions are presented in the form of maps, while for the landtypes, they are illustrated with bar graphs. In addition to presenting these findings, this chapter also discusses their implications in the context of the aim and objectives of the study, as well as the influence of the wide range of biophysiographic factors considered.

6.2 EROSION HAZARD POTENTIAL OF SUBCATCHMENTS

The overall susceptibility of the 43 quaternary subcatchments to erosion was based on the ratings of the erosion risk factors given by Rooseboom (1992) for EI_{30}, SLEMSA (1976) and MacVicar (1974) for soils, Watson (1990), Liggitt (1988) and Botha (1992) for geology, Scotney (1978) and Liggitt (1988) for bioclimatic regions and veld types as detailed in 5.3.1, 5.3.2 and 5.3.3. Erosion risk factors were classified into three categories: high, moderate, and low (refer to Table 6.1 - 6.6). For each subcatchment, set of six erosion risk factors, the most dominant rating was taken as representing its overall erosion risk.

6.2.1 THE UPPER REACHES: FORMER NATAL

Overall the upper reaches have a moderate erosion potential. Only four subcatchments in this region were rated as highly susceptible to erosion i.e. W231, W241, W242, and W243. All four are dominated by high altitudinal ranges of between 714 - 1134 m.a.s.l, an underlying geology of Dwyka Tillite which (as noted in section 3.6.2) is highly susceptible to erosion, and unfavourable bioclimatic conditions (viz; Dry Upland). Their rainfall erosivities are however, moderate. The other 8 subcatchments in this region were rated moderately susceptible to erosion. Although most of them have an unfavourable bioclimate, i.e., Dry Upland, their geology and soils of are resistant to erosion. Also with the exception of three of them, their rainfall erosivities are moderate.

NO.	SIZE km^2	RANGE IN ALTITUDE	EI_{30}	PREDOM. GEOLOGY	PREDOM. SOILS	VELD TYPES	BIOCLIMATE	RATING
W211	275	1665-1100 565 (H)	501-500 (M)	Sandstone vryheid(M)	Mispah(M)	Northern Tall Grassveld(H)	Moist upland(M)	M
W212	127	1250-950 300 (M)	501-500 (M)	Sandstone Vryheid(M)	Farningham, Balmoral(L)	Northern Tall Grassveld(H)	Dry Upland(H)	M
W213	240	1620- 1050 570 (H)	501-500 (M)	Sandstone Vryheid(M)	Farningham, Doveton(L)	Northern Tall Grassveld(H)	Dry Upland(H)	(M)
W214	280	1400-940 400 (M)	501-600 (M)	Sandstone Vryheid(M)	Hartbees,Sterk spruit(H)	Natal Sand Sourveld(M)	Dry Upland(H)	(M)
W215	130	1080-935 145(L)	601-700 (H)	Sandstone Vryheid(M)	Gelykvlagte, Rydalvale (M-L)	Natal Sand Sourveld(M)	Dry Upland(H)	(M)
W216	258	1635-950 222(L)	501-600 (M)	Sandstone Vryheid(M)	Farningham, Doveton(L)	Piet Retief Sourveld(M)	Dry Upland(H)	(M)
W217	188	1142-920 222(L)	601-700 (H)	Sandstone Vryheid(M)	Farningham, Doveton(L)	Natal Sand Sourveld(M)	Dry Upland(H)	(M)
W224	220	1598-780 818(H)	401-500 (M)	Dolerite; Granite(L)	Cartref(H)	Highland Sourveld(M)	Dry Upland(H)	(M)
W225	355	1542-700 842(H)	501-600 (M)	Granite(L)	Williamson(M	Natal Sand Sourveld(M)	Dry Upland(H)	(M)
W241	340	1524-564 960(VH)	501-600 (M)	Dwyka Tillite(H)	LonglandsVasi (H)	Northern Tall Grassveld(H)	Dry Upland(H)	(H)
W242	415	1560-426 1134(VH)	501-600 (M)	Dwyka Tillite(H)	Oatsdale(M)	Northern Tall Grassveld(H)	Riverine Interior(H)	(M-H)
W243	210	1140-426 714(H)	601-700 (H)	Dwyka Tillite(H)	Williamson(M	Northern Tall Grassveld(H)	Dry Upland(H)	(H)
W244	205	1370-365 1005(VH)	601-700 (M)	Sandstone Vryheid(M)	Mispah(M)	North Eastern Mountain(M)	Mistbelt(L)	(M)
W231	165	1200-680 820(H)	401-500 (M)	Dwyka Tillite(H)	Mispah(M)	Northern Tall Grassveld(H)	Dry Upland(H)	(M)
W232	226	1400-480 920(H)	501-600 (M)	Dwyka Tillte(H)	Mispah(M)	Highland Sourveld(M)	Highland Submontane(M	(M)
W233	160	1160-440 720(H)	601-700 (H)	Dwyka Tillte(H)	Mispah(M)	Lowveld(H)	Riverine Interior(H)	(H)

Table 6.1: Biophysiographic characteristics of the Upper Former Natal

QUART. NO.	SIZE Km^2	RANGE ALTITUDE	EI_{30}	PREDOM. GEOLOGY	PREDOM. SOILS	VELD TYPES	BIOCLIMATIC REGIONS	RATINGS
W221	216	1530-950 580(H)	501-600 (M)	Sandstone Vryheid (M)	Williamson (M)	Natal Sand Sourveld(M)	Dry Upland(H)	(M)
W222	410	1580-920 660(H)	401-500 (M)	Dwyka Tillite(H)	Avalon,Bergville(M)	Natal Sand Sourveld(M)	Dry Upland(H)	(M)
W223	310	1526-840 686(H)	401-500 (M)	Dwyka Tillite(H)	Mispah(M)	Natal Sand Sourveld(M)	Dry Upland(H)	(M)

Table 6.2: Biophysiographic characteristics of the Upper Former KwaZulu

6.2.2 UPPER REACHES: FORMER KWAZULU

Overall, this region is moderately susceptible to erosion. All subcatchments have a moderate erosion potential. Their moderate erosivities (401 - 500), resistant geology (Dolerite and Granite) and moderately erodible soils (Mispah and Williamson) compensate for the influence of their high altitudinal ranges and unfavourable bioclimate (Dry Upland).

6.2.3 THE MIDDLE REACHES: FORMER KWAZULU

Overall, this region has high erosion potential. In general, subcatchments have a high erosion potential due to the presence of steeply tilted slopes (290 - 1127), high erosivities (601 - 700), the underlying susceptible Dwyka Tillite and the unfavourable bioclimatic conditions (Dry Upland and Riverine Interior Lowland). Only four subcatchments (W238, W246, W251, and W252) have a moderate erosion potential. Their soils (i.e, Mispah and Williamson) and geology (Vryheid Sandstone) are moderately susceptible to erosion. Although W238, W246 and W252 have high altitudinal ranges, their rainfall erosivity indexes are moderate (i.e, 501 - 600). W251 has both moderate altitudinal ranges (350 - 855) and erosivity indexes (501 - 600).

QUART. NO.	SIZE -Km^2	RANGE IN ALTITUDE	EI_{30}	PREDOM. GEOLOGY	PREDOM. SOILS	VELD TYPES	BIOCLIMATIC REGIONS	RATINGS
W226	340	1445-490 955(VH)	601-700 (H)	Dwyka Tillite(H)	Mispah(M)	Highland Sourveld(M)	Highland Submontane(M)	(H)
W234	175	1030-420 610(H)	501-600 (H)	Dwyka Tillte(H)	Mispah(M)	Northern Tall Grassveld(H)	Dry Upland(H)	(H)
W235	118	980-400 580(H)	601-700 (H)	Granite(L)	Mispah(M)	Lowveld(H)	Riverine Interior(H)	(H)
W236	225	1030-210 820(H)	601-700 (H)	Sandstone Natal(L)	Williamson(M)	Lowveld(H)	Riverine Interior(H)	(H)
W237	285	800-130 670(H)	701-800 (H)	Tillite of Dwyka(H)	Mispah(M)	Lowveld(H)	Riverine Interior(H)	(H)
W238	185	750-120 630(H)	701-800 (H)	Sandstone Natal(L)	Mispah (M)	Lowveld(H)	Lowland Upland(H)	(H)
W245	285	1127-290 837(H)	601-700 (H)	Shales Pietermaritzburg(H)	Farningham Balmoral(L)	Northern Tall Grassveld(H)	Moist Upland (M)	(H)
W246	260	792-230 562(H)	601-700 (H)	Sandstone Vryheid(M)	Farningham Balmoral(L)	Lowveld(H)	Lowland Upland(H)	(H)
W247	270	945-215 730(H)	601-700 (H)	Sandstone Vryheid (M)	Farningham Balmoral(L)	Lowveld(H)	Dry Upland (H)	(H)
W248	285	875-215 660(H)	601-700 (H)	Dwyka Tillite (H)	Mispah(M)	Lowveld(H)	Riverine Interior(H)	(H)
W251	255	855-350 505(M)	501-600 (M)	Sandstone Vryheid (M)	Trevanian Platt (L-M)	Zululand Thornveld(H)	Riverine Interior(H)	(M)
W252	265	750-120 630(H)	501-600 (M)	Sandstone Vryheid(M)	Mispah(M)	Zululand Thornveld(H)	Riverine Interior(H)	(M)
W253	125	780-170 610(H)	601-700 (H)	Sandstone Vryheid (M)	Williamson(M)	Lowveld(H)	Riverine Interior(H)	(H)
W254	135	690-170 520(H)	601-700 (H)	Sandstone Vryheid (M)	Williamson(M)	Lowveld(H)	Riverine Interior(H)	(H)
W255	305	780-120 660(H)	601-700 (H)	Sandstone Vryheid (M)	Williamson(M)	Lowveld(H)	Riverine Interior(H)	(H)

Table 6.3: Biophysiographic characteristics of the Middle Former KwaZulu

6.2.4 MIDDLE REACHES: GAME RESERVE

With the exception of subcatchment W256, the erosion hazard potential of subcatchments in the Game Reserve is moderate. This is due largely to the influence of moderately resistant Vryheid Sandstones, moderately erodible Mispah and Williamson soils, moderate slopes (50 - 365) and erosivity indexes (501 - 600). W256 is characterised by very high altitudinal ranges, high erosivities as well as unfavourable bioclimatic conditions (Riverine Interior). Scotney (1978) noted that severe erosion develops in this veld type under conditions of poor veld management and overstocking.

However, Venter (1988) and Watson (1990) found that the Natal Parks Board's conservation management policies were effective in restricting erosion in this region.

QUART. NO.	SIZE -Km^2	RANGE IN ALTITUDE	EI_{30}	PREDOM. GEOLOGY	PREDOM. SOILS	VELD TYPES	BIOCLIMATIC REGIONS	RATINGS
W239	140	365-85 280(L)	501-600 (M)	Sandstone Vryheid(M)	Mispah (M)	Lowveld(H)	Riverine Interior(H)	(M)
W256	190	620-60 560(H)	501-600 (M)	Sandstone Vryheid(M)	Valsrivier,Lindley (H-M)	Lowveld(H)	Riverine Interior(H)	(H)
W261	90	230-50 180(L)	501-600 (M)	Sandstone Vryheid(M)	Mispah(M)	Lowveld(H)	Riverine Interior(H)	(M)
W262	170	355-50 305(L)	701-800 (H	Sandstone Natal(L)	Mispah(M);	Lowveld(H)	Riverine Interior(H)	(M)

Table 6.4: Biophysiographic characteristics of the Game Reserve

6.2.5 LOWER REACHES: FORMER KWAZULU

Overall erosion potential in this region is rated as low. It is interesting to note that this is the only region in the catchment with a low erosion hazard potential. This is accounted for by the moderate altitudinal ranges (30-350), moderate erosivities (501-600), underlying resistant Basalts, the resistant Msinsini soils and the favourable Coastal Lowland bioclimate.

QUART. NO.	SIZE -Km^2	RANGE IN ALTITUDE	EI_{30}	PREDOM. GEOLOGY	PREDOM. SOILS	VELD TYPES	BIOCLIMATIC REGIONS	RATINGS
W263	185	350-30 320(M)	701-800 (H)	Basalt of Letaba(L)	Mispah(M)	Lowveld(H)	Riverine Interior(H)	(M)
W264	225	340-15 325(M)	601-700 (H)	Basalt of Letaba(L)	Msinsini(L)	Coastal Forest & Thornveld(L)	Coastal Lowland(L)	(L)
W265	240	270-18 252(M)	601-700 (H)	Basalt of Letaba(L)	Msinsini Mayo(L);	Lowveld(H)	Coastal Lowland(L)	(L)

Table 6.5: Biophysiographic characteristics of the Lower Former KwaZulu

6.2.6 LOWER REACHES FORMER NATAL

Overall this region is rated as having a moderate erosion potential. It is characterised by highly erodible Unconsolidated Superficial Deposits and soils (Fernwood and

Maputa), however, these factors are overshadowed by the influence of low altitudinal ranges (0 - 80), moderate erosivities (501 - 600), and the favourable Coastal Lowland bioclimate.

QUART. NO.	SIZE -Km^2	RANGE IN ALTITUDE	EI_{30}	PREDOM. GEOLOGY	PREDOM. SOILS	VELD TYPES	BIOCLIMATIC REGION	RATINGS
W266 & W267	505	80-0 80(L)	601-701 (H)	Unconsolidated Superficial Deposits(H)	Fernwood(H) Maputa(H)	Coastal Forest & Thornveld(L)	Coastal Lowland(L)	(M)

Table 6.6: Biophysiographic characteristics of the Lower Former Natal

The Natal Town and Regional Commission (1984) estimated that 67 % of the former KwaZulu areas in the catchment had a high erosion hazard potential (refer to section 4.9). While their measure of the former KwaZulu areas in the middle reaches of the catchment is reliable in that it concurs with the findings of this study that 60 % of this region had a high erosion hazard potential, their assessment is not valid for the former KwaZulu areas in the upper and lower reaches. This study found that 100 % and 67 % of these regions had moderate and low erosion hazard potential, respectively (refer to fig 6.1 and table 6.7).

	UPPER: FORMER NATAL	UPPER: FORMER KWAZULU	MIDDLE: FORMER KWAZULU	MIDDLE: GAME RESERVE	LOWER: FORMER KWAZULU	LOWER: COASTAL PLAIN
HIGH (%)	19	-	60%	25%	-	-
MODERATE (%)	81	100%	40%	75%	33	100%
LOW (%)	-	-	-	-	67	-

Table 6.7: Erosion hazard potential

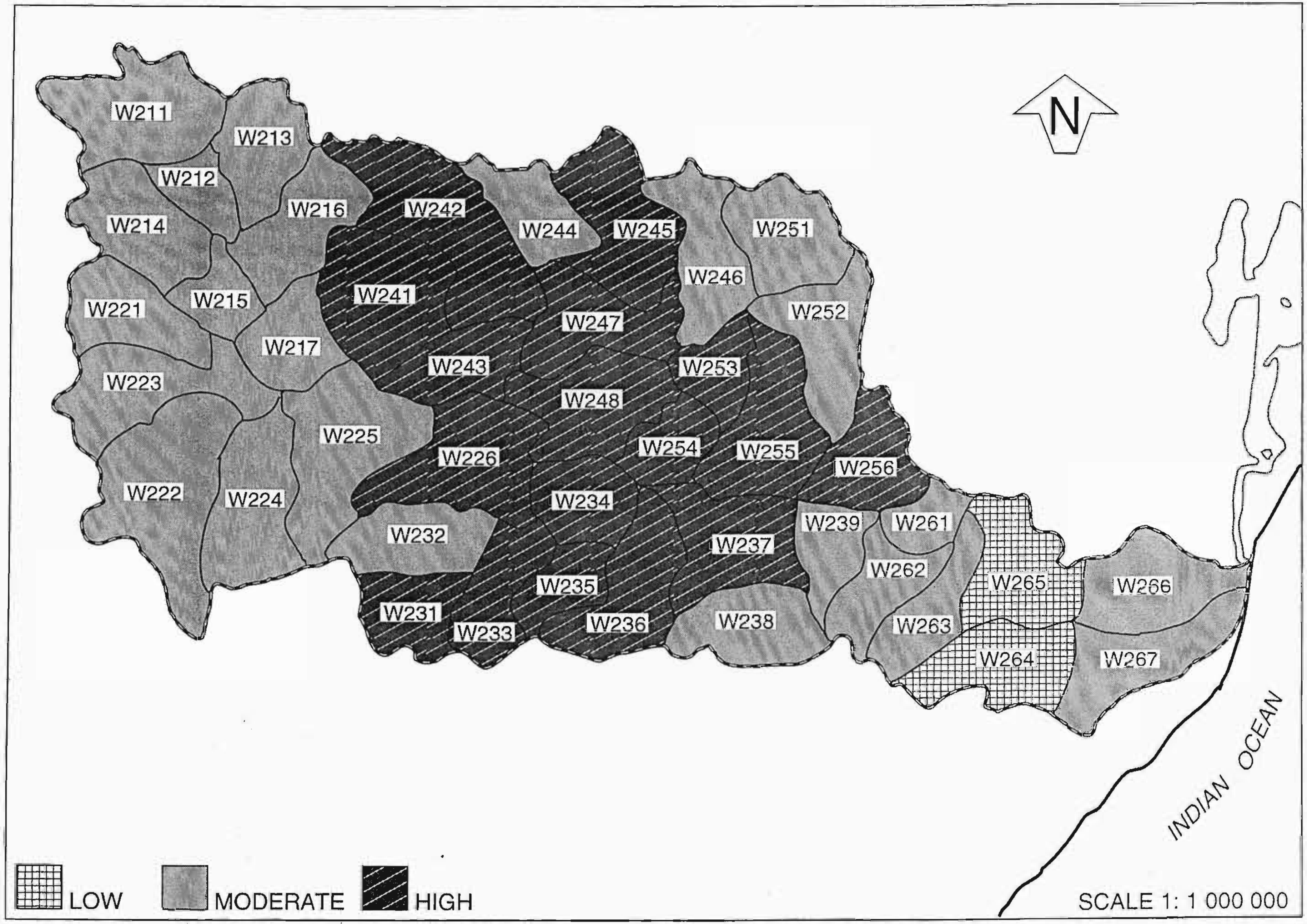


Figure 6.1: Erosion hazard potential of subcatchments

6.3 EROSION HAZARD POTENTIAL OF LANDTYPES

The overall susceptibility of the 16 landtypes to erosion was established and rated on the basis of the ratings of the erosion risk factors given by various authors. For example, SLEMSA (1976) and MacVicar (1984) for soils, Watson (1990), Liggitt (1988) and Botha (1992) for geology, Scotney (1978) and Liggitt (1988) for bioclimatic regions and veld types as detailed in 5.3.1, 5.3.2 and 5.3.3. Erosion risk factors were classified into three categories: high, moderate, and low (refer to Table 6.8). The most dominant rating category for each subcatchmet was choosen. Landtypes **Ca, Fa and Fb** emerged as the most susceptible to erosion. All three landtypes occur in unfavourable bioclimates (Dry Upland and Riverine Interior). Both Ca and Fb have very long slopes; Ca also has steep slopes and highly erodible soils. Fa and Fb are underlain by the highly susceptible Dwyka Tillite. **Ad and Db** were rated moderate to highly susceptible to erosion because of the balanced influence of biophysiographic factors that have a high and moderate effect on erosion risk. While both have long slopes and an unfavourable bioclimate (Riverine Interior), their slopes are gentle and their Northern Tall Grassveld type affords good soil cover. **Ab, Ac, Bb, Bd, Dc, and Ib** were rated moderately susceptible due to their gentle slopes, soils of low erodibility, and underlying resistant Dolerites and moderate Vryheid Sandstones. **Ba, Ea, Ha, Hb and Ia** have a low erosion potential and are all characterised by moderate to short gentle slopes. Ha, Hb and Ia have good bioclimatic and veld type conditions which compensate for the influence of their highly erodible soils and underlying susceptible geology. Ba and Ea both have resistant soils (Farningham, Doveton and Msinsini) and geology (Dolerite).

	SLOPE LENGTH	SLOPE ANGLE	SOILS	GEOLOGY	VELDTYPES	BIOCLIMATE (REGION)	RATING
AB	751-1000 (M)	8,9-17,6 (M)	FARNINGHAM, BALMORAL(L)	DOLERITE (L)	LOWVELD (H)	RIVERINE INTERIOR(H)	M
AC	2001-3000 (VH)	8,9-17,6 (M)	FARNINGHAM, BALMORAL(L)	DOLERITE (L)	NORTHERN TALL GRASSVELD(L)	RIVERINE INTERIOR(H)	M
AD	1001-1500 (H)	8,9-17,6 (M)	OATSDALE(M)	SHALE PIETERMARI -TZBURG(H)	NORTHERN TALL GRASSVELD(L)	RIVERINE INTERIOR (H)	M-H
BA	51-100 (VL)	8,9-17,6 (M)	FARNINGHAM DOVETON(L)	DOLERITE (L)	NORTHERN TALL GRASSVELD(L)	DRY UPLAND (H)	VL
BB	1501-2000 (VH)	8,9-17,6 (M)	AVALON(M) SOUTHWOULD (L)	VRYHEID SANDSTONE (M)	NATAL SAND SOURVELD(M)	DRY UPLAND (H)	M
BD	501-750 (M)	8,9-17,6 (M)	SOETMELK(M)	VRYHEID SANDSTONE (M)	NATAL SAND SOURVELD(M)	DRY UPLAND (H)	M
CA	2001-3000 (VH)	17,7-34,4 (H)	LONGLANDS VASI(H)	VRYHEID SANDSTONE (M)	NATAL SAND SOURVELD(M)	DRY UPLAND (H)	H
DB	1001-1500 (H)	8,9-17,6 (M)	HARTEBEES STERKSPRUIT (H)	VRYHEID SANDSTONE (M)	NORTHERN TALL GRASSVELD(L)	RIVERINE INTERIOR (H)	M-H
DC	501-751 (M)	17,7-34,4 (H)	GELYKVLAGTE RYDALVALE (M)	VRYHEID SANDSTONE (M)	NATAL SAND SOURVELD(M)	DRY UPLAND (H)	M
EA	501-751 (M)	8,9-17,6 (M)	MSINSINI(VL)	DOLERITE (L)	NORTHERN TALL GRASSVELD(L)	DRY UPLAND (H)	M
FA	501-751 (M)	> 34,5 (VH)	MISPAH (M)	DWYKA TILLITE (H)	LOWVELD(H)	RIVERINE INTERIOR (H)	H
FB	1501-2000(VH)	8,9-17,6 (M)	MISPAH (M)	DWYKA TILLITE (H)	LOWVELD(H)	RIVERINE INTERIOR (H)	H
HA	751-1000 (M)	< 3,5 (L)	FERNWOOD, MAPUTA(H)	UNCONSOLI DATED DEPOSITS(H)	COASTAL FOREST AND THORNVELD(L)	COAST LOWLAND(L)	L
HB	251-500 (M)	< 3,5 (VL)	DUNDEE(H)	ALLUVIUM (H)	COASTAL FOREST AND THORNVELD(L)	COAST LOWLAND(L)	L
IA	251-500 (M)	3,6-8,8 (L)	FERNWOOD(H)	UNCONSOLI DATED DEPOSITS(H)	COASTAL FOREST AND THORNVELD(L)	COAST LOWLAND(L)	L
IB	251-500 (M)	> 34,5 (VH)	SHORROCKS(M) MAKATINI(L)	DOLERITE (L)	HIGHVELD SOURVELD(M)	DRY UPLAND (H)	M

TABLE 6.8: Erosion hazard potential of landtypes

6.4 DISTRIBUTION OF GULLIES

6.4.1 DISTRIBUTION OF GULLIES IN QUATERNARY SUBCATCHMENTS.

While a quarter of the Mfolozi's 43 subcatchments had high to very high gully densities, overall they were not well represented i.e, 9, 20 and 46 percent of the subcatchments had moderate, low and very low densities, respectively (refer fig. 6.2)

Upper Former Natal: Six of the subcatchments in this region had very high gully densities, i.e, W231, W232, W241, W242, W243 and W244. Only one had moderate densities. Low and very low densities were equally represented in the remaining eight.

Upper Former KwaZulu: Gully densities throughout this region were low.

Middle Former KwaZulu: Five of this region's subcatchments had high gully densities, i.e, W226, W234, W245, W247, and W248. Moderate, low and very low densities were found in 3, 2 and 6 of its subcatchments, respectively.

Middle Game Reserve, Lower Former KwaZulu and Lower Former Natal: Gully densities throughout these regions were found to be very low.

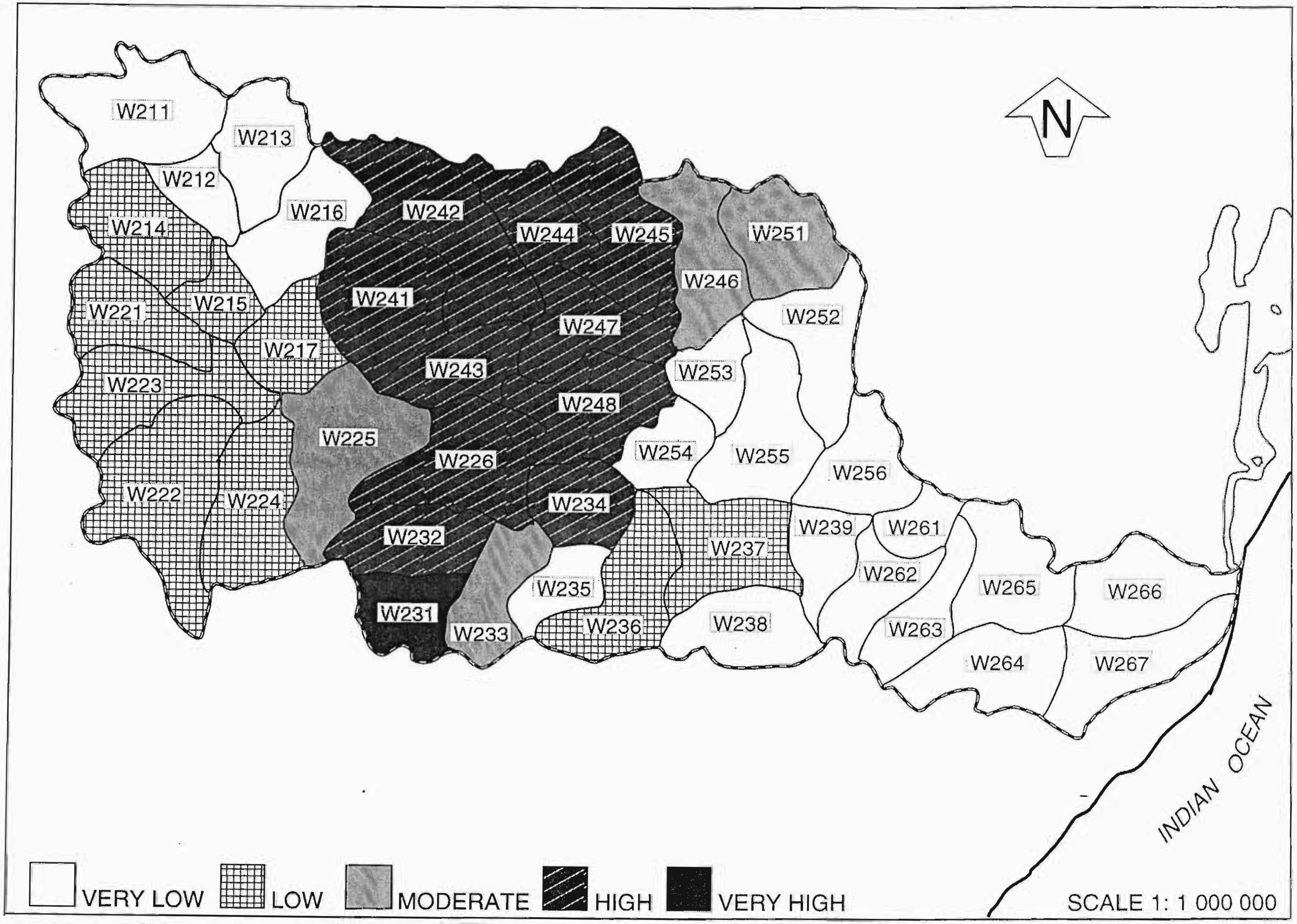
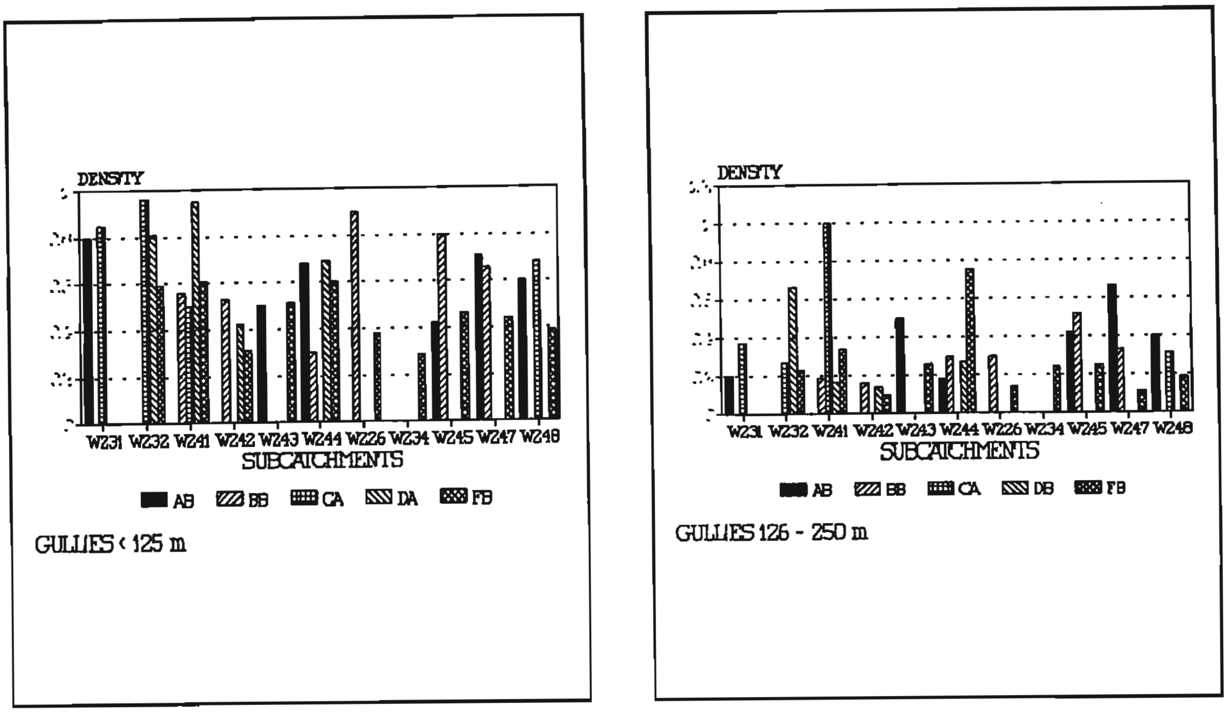


Figure 6.2: Distribution of gullies in subcatchments

An average of 54 % of the variability in the distribution of all four gully length classes could be accounted for by the variables of influence considered in this study using Forward Stepwise Multiple Regression Analysis (refer table 6.5). While substrate and vegetal cover variables exerted a substantial influence on gullies of all lengths, the influence of the topographic variables was greater in the longer gullies. The soils on which most of these gullies occur are very shallow moderately to highly erodible Mispah and Williamson soils (refer to sections 6.2.1 and 6.2.3). All eleven of the most severely gullied subcatchments are covered by Northern Tall Grassveld in which grass is the predominant cover. It is interesting to note that this finding concurs with Le Roux's (1981) observation that grassland is more resistant to sheet erosion and more susceptible to gully erosion. The Principle Component Analysis also grouped these four gully length classes together (refer to table 5 in appendix) signifying that there is no process related basis for categorizing them into the length classes employed on Looser's (1988; 1992) map and indicating that their distribution is influenced by basically the same factors.

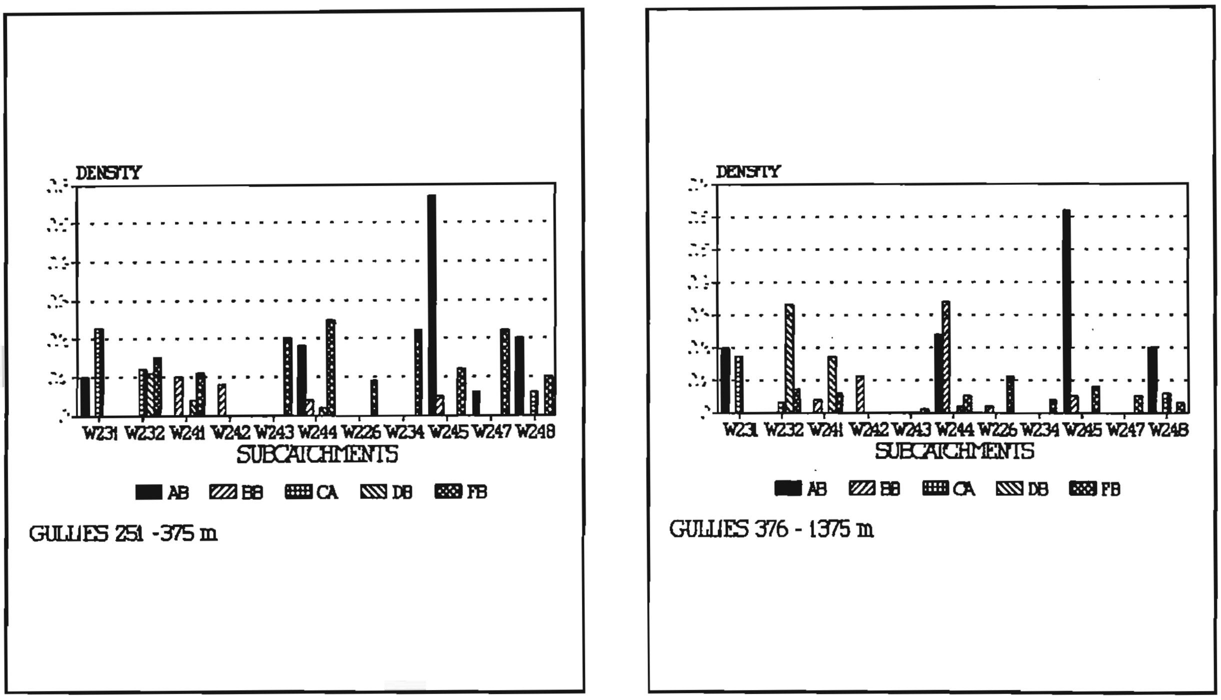
6.4.2 DISTRIBUTION OF GULLY EROSION IN LANDTYPES

Gullies were best represented in Landtypes Ab, Bb, Ca, Db, and Fb (refer to fig. 6.3). Despite being moderately susceptible to erosion, landtypes Ab, Bb, and Db have high gully densities. These three landtypes are characterised by moderate to very long slopes and unfavourable veld (i.e, Northern Tall Grassveld) and bioclimatic conditions (Dry Upland). All these factors appear to have regulated the distribution of gullies in these landtypes (refer to table 4 in appendix). The distribution of gullies in Ca appears to be predominately regulated by very long, steep slopes covered by very highly erodible sandy loam soils (Longlands and Vasi). Landtype Fb is covered by very long slopes, shallow moderately to highly erodible soils (Mispah), geology (Dwyka Tillite) that is highly susceptible to erosion, and unfavourable veld (Lowveld) and bioclimatic



GULLIES < 125 m

GULLIES 126 - 250 m



GULLIES 251 -375 m

GULLIES 376 - 1375 m

Figure 6.3: Distribution of gullies in Landtypes

(Riverine Interior) conditions. Although, this landtype is significantly associated with numerous variables, their coefficients are not strong enough to support speculation (refer to table 4 appendix).

6.5 DISTRIBUTION OF UNCONFINED EROSION

6.5.1 DISTRIBUTION OF UNCONFINED EROSION IN SUBCATCHMENTS

While almost a quarter of the Mfolozi catchment's 43 subcatchments had high to very high densities of unconfined erosion, overall they were not well represented i.e, 18, 14 and 46 percent of the subcatchments had moderate, low and very low densities, respectively (refer to fig. 6.4).

Upper Former Natal: A very small area of this region was covered by unconfined erosion. Only one subcatchment (W233) in this region had a high density of unconfined erosion. Moderate, low and very low densities were found in 4, 3 and 8 of its subcatchments, respectively.

Upper Former KwaZulu: Unconfined erosion throughout this region was very low.

Middle Former KwaZulu: Nine of this region's subcatchments had high to very high densities of sheet erosion (i.e, W233, W234, W245, W246, W247, W248, W251, W252, W253, W254, and W255). Moderate and low densities were found in 4 and 2 of its subcatchments, respectively.

Middle Game Reserve: With the exception of subcatchment W256 which had low density, unconfined erosion densities in this region were very low.

Lower Former KwaZulu and Lower Former Natal: Unconfined erosion densities throughout these regions were very low.

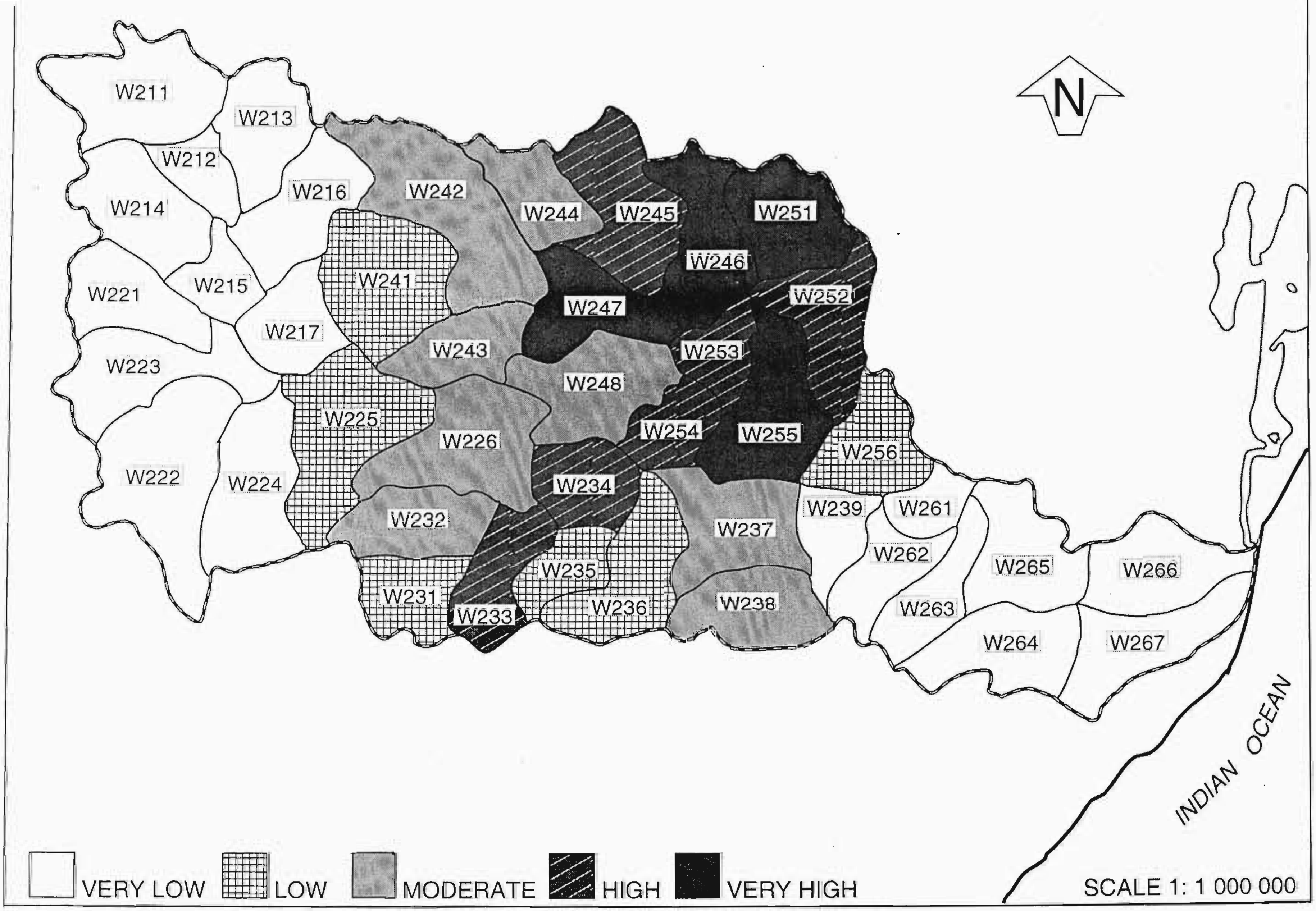


Figure 6.4: Distribution of unconfined erosion in subcatchments

As shown in Table 6.5, slope length, veldtypes, bioclimatic regions and landuse accounted for 40% of the variability in the distribution of sheet/rill erosion and bare loose material. However, the relationship between unconfined erosion and slope length was negative. i.e, as slope length increases, the incidence of unconfined erosion decreases. As noted in section 3.6.3, i.e, where unconfined erosion predominates, soil loss generally increases with increasing slope length and this is generally attributed to the increased volume of surface flow. However, this study found the opposite. This finding suggests that the slopes in the study area had a high degree of surface roughness which by encouraging infiltration would decrease runoff. The findings of this study that unconfined erosion decreases as seral development advances concurs with those of Snyman *et al* (1985) and Venter (1988). Eight of these ten most eroded subcatchments occur within the Riverine Interior, rated by Scotney (1978) to be amongst the most severely eroded (refer section 3.6.4). Studies by Rowntree (1988) on equilibrium concepts associated with vegetation change and soil erosion in semi-arid areas of the Karoo, and by Cobban and Weaver (1993) on gully features in the Tsolwana Game Reserve in the former Ciskei, show that there is a relationship between sheet/rill erosion and gully erosion. Rowntree (1988) showed that phases of activity of sheet/rill erosion alternate with gully erosion as a mechanism to maintain equilibrium between erosion and deposition. Cobban and Weaver (1993) showed that sediment removed by upslope sheet erosion processes was deposited in gullies at the foot of the slope, and when this process reached a threshold, gully erosion was triggered and removed the material originally derived from sheet erosion. Contrary to the findings of these studies, this study did not find a relationship between sheet/rill erosion and gully erosion. As noted in table 5 in the appendix, Principle Component Analysis represented unconfined erosion as a separate, independent entity that does not necessarily depend on other erosion features to occur in a particular area. For example, in this study, subcatchments and landtypes that are severely gully eroded are seldom those that are severely sheet/rill eroded (refer to fig. 6.2 and 6.4). As shown in Table 6.5, the reason why these two erosion forms are not interrelated is that landuse was not an important factor in influencing the gullies whereas it exerted a significant influence on unconfined erosion. As noted by Botha (1992) the gullies are obviously predominately natural features.

6.5.2 DISTRIBUTION OF UNCONFINED EROSION IN LANDTYPES

Unconfined erosion was found to be well represented on landtypes Ab, Fa, and Fb (refer to fig. 6.5). Landtypes Fa and Fb are dominated by moderately erodible shallow soils (Mispah), highly susceptible geology (Dwyka Tillite) and unfavourable bioclimatic (Riverine Interior) conditions. All these factors are significantly correlated to unconfined erosion even though the correlations are very small (refer to Table 4 in appendix). Although the dominant features for landtype Ab suggest it is the least susceptible to erosion, the distribution of unconfined erosion in it appears to be regulated by loam clay soils (Farningham and Balmoral) and thornveld which according to Le Roux (1981) is susceptible to sheet erosion.

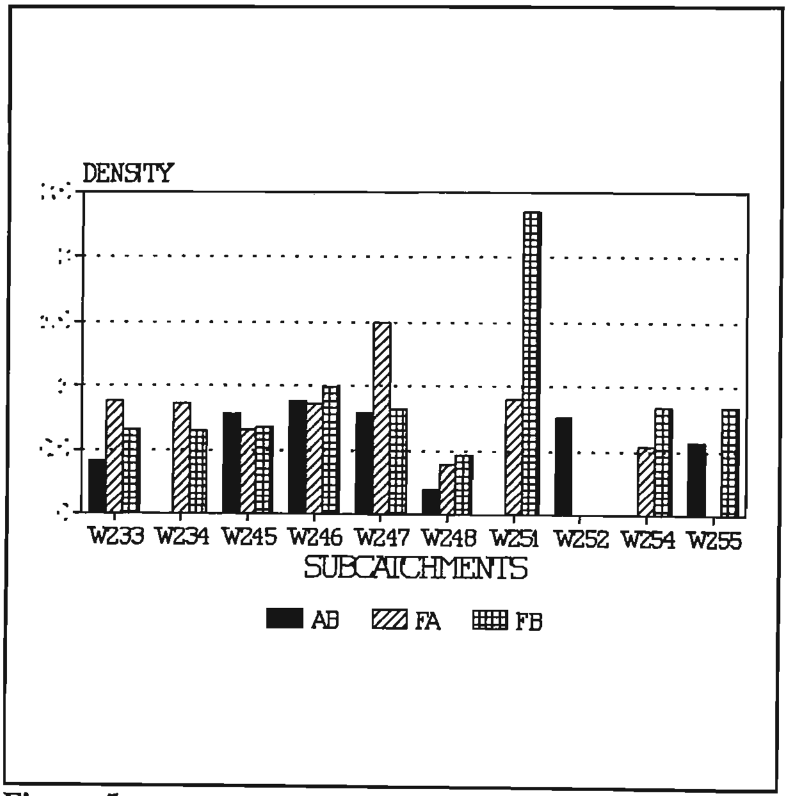


Figure 5.

Figure 6.5: Distribution of unconfined erosion in landtypes

6.6 DISTRIBUTION OF BADLANDS

6.6.1 DISTRIBUTION OF BADLANDS IN SUBCATCHMENTS

While 12% of the Mfolozi's 43 subcatchments had high to very high badlands coverage (refer 5.3), overall they were not well represented i.e, 4, 10 and 74 % of the subcatchment had moderate, low and very low coverage, respectively (refer fig. 6.6)

Upper Former Natal: Three subcatchments in this region had a high areal extent of badlands, i.e, W214, W215, and W224 (refer to fig. 6.6). Their areal extent was moderate, low and very low in 1 (i.e W213), 2 (W216 and W225) and 8 (W211, W212, W217, W231, W232, W233, W241, and W242) of its subcatchments, respectively.

Upper Former KwaZulu: With the exception of W221, badlands were well represented in this region.

Middle Former KwaZulu: Badlands throughout this region were poor to very poorly represented.

Middle Game Reserve, Lower Former KwaZulu and Lower Former Natal: Badlands throughout this regions were very poorly represented.

It is unfortunate that the Multiple Regression Analysis failed to reveal the factors that could have influenced the distribution of these erosion features. The fact that they were measured (i.e., the proportion of landtype and subcatchment areas affected) in a different way to all the other erosion categories (i.e, density within landtypes and subcatchments) may be the reason why an error message was generated on each of the several attempts to process the badland data set. However, it can be assumed that bioclimatic factors together with topography could have had an influence on the distribution of these features since all the above mentioned subcatchments are situated in the same bioclimatic region (Dry Upland) and with the exception of W215, have high altitudinal ranges (refer to table 6.2.1 and 6.2.2).

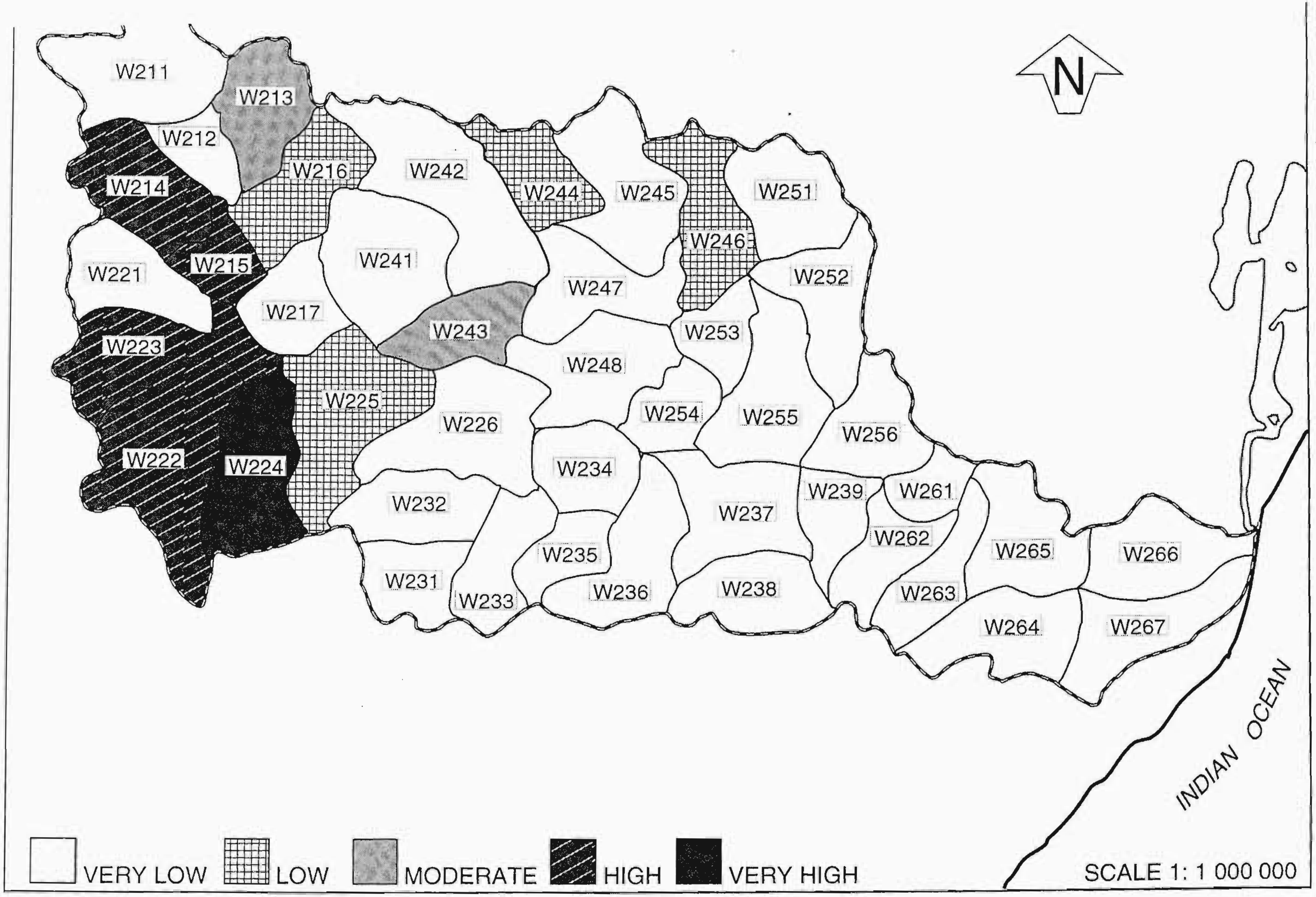


Figure 6.6: Distribution of badlands in subcatchments

6.6.2 DISTRIBUTION OF BADLANDS IN LANDTYPES

Badlands are dominant in landtypes Bb, Ca and Dc (refer to fig. 6.7). Of these three landtypes Ca is the most susceptible to erosion (refer to Table 6.2). In this landtype, badlands are best correlated with steep slopes and highly erodible sandy loam soils (Longlands and Vasi). Bb is characterised by very long gentle slopes with unfavourable dry bioclimatic conditions. Dc is characterised by steeply tilted slopes and dry bioclimatic conditions. Both landtypes Bb and Dc are significantly correlated with several factors, but, the coefficients are very small for speculation (refer to table 4 in appendix).

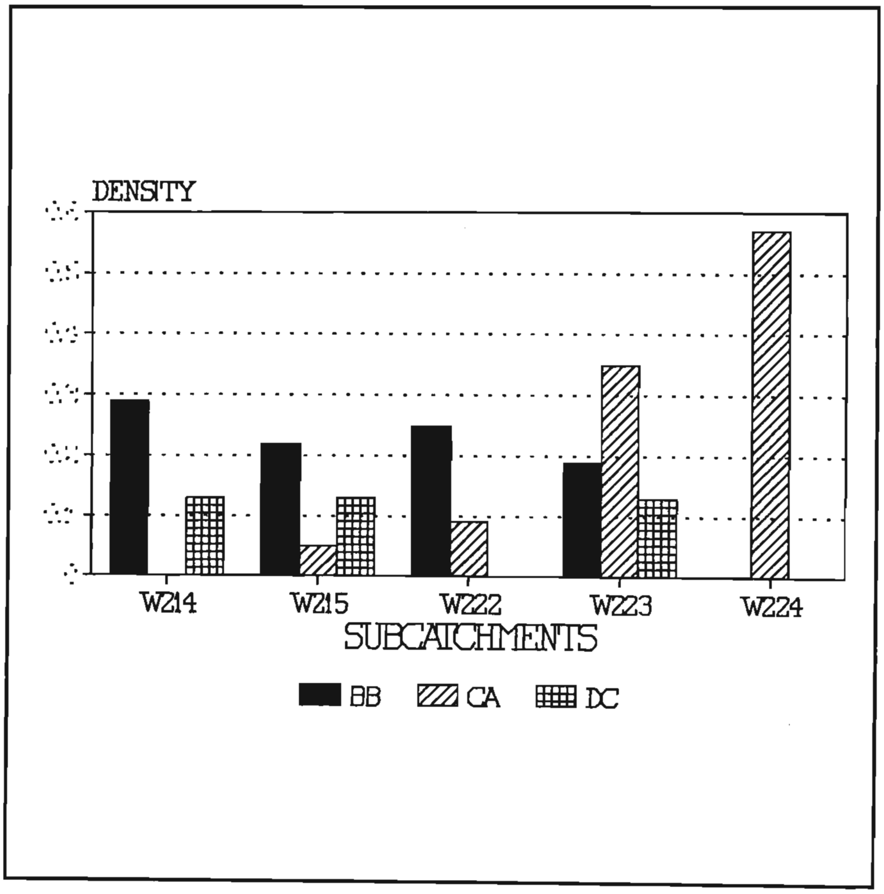


Figure 6.7: Distribution of badlands in landtypes

6.7 DISTRIBUTION OF MASS WASTING PROCESS

6.7.1 DISTRIBUTION OF MASS WASTING PROCESS IN SUBCATCHMENTS

While 7 % of the Mfolozi's 43 subcatchments had high to very high mass wasting densities, overall they were not well represented i.e, 16, 14 and 63 percent of the subcatchment had moderate, low and very low densities, respectively (refer fig. 6.8)

Upper Former Natal: Three of the subcatchments in this region had very high mass wasting densities, i.e, W212, W213 and W242. Moderate, low and very low densities were found in 4, 3 and 5 of its subcatchments, respectively.

Upper Former KwaZulu: With the exception one subcatchment (W224), mass wasting processes were poorly represented in this region.

Middle Former KwaZulu: With the exception of W247 and W226 (both having moderate mass wasting densities), mass wasting processes were poorly represented in this region.

Middle Game Reserve, Lower Former KwaZulu and Lower Former Natal: Mass wasting processes throughout these regions were found to be low.

As shown in Table 6.5, two variables i.e., terrain unit and veldtypes, accounted for 42% of variability in the distribution of terracettes, slipped and slumped slopes. Mass wasting processes were best represented on the convex, midslope positions where their incidence was obviously promoted by the coincidence of increase acuteness of the angle of repose of the shear plane and the increased mass on the plane associated with water transmitted from upslope as detailed in Selby (1982). In this study mass wasting processes preferentially occurred in a grass dominated community (The Northern Tall Grassveld). According to Watson (1988) in comparison to communities of more woody sere, shallow rooting grasses are less effective in binding the soil and contributing to its shear strength. It is important to note that the wide range of variables considered could only account for less than half of these features. The scale at which the landuse variable data was entered, that is, one type for a whole subcatchment, may not have been sensitive enough to pick up the influence of landuse at the more localised scale of these features. Kovacs *et al*'s (1985) report detailing damage to the catchment in the wake of Cyclone Domoina clearly shows that landslides and mudflows were associated with slope profiles that had been altered in road construction.

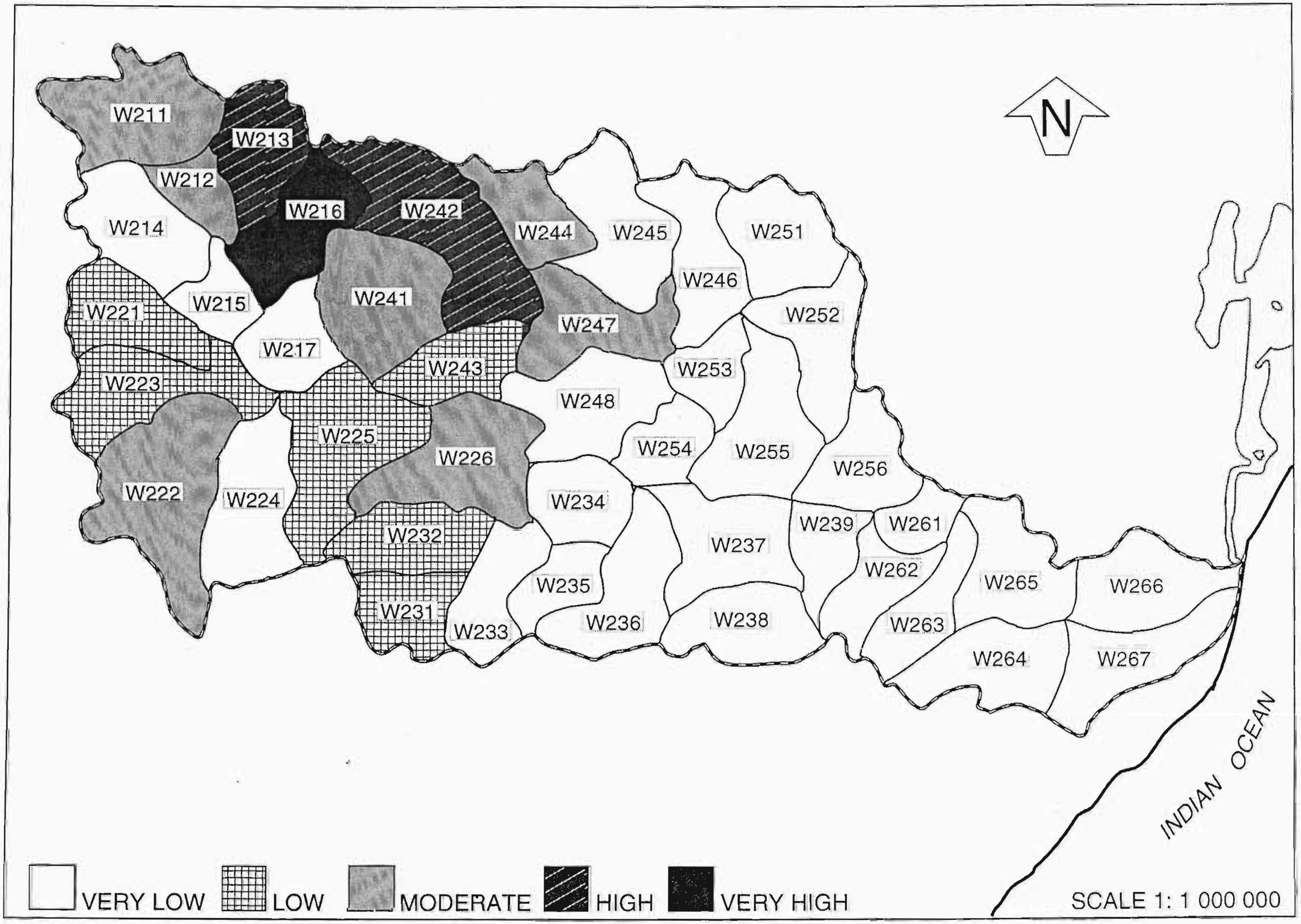


Figure 6.8: Distribution of mass wasting in subcatchments

6.7.2 DISTRIBUTION OF MASS WASTING IN LANDTYPES

Mass wasting is best represented in landtypes Ac, Bb, and Fa (refer to fig. 6.9). Both landtype Ac and Bb are covered with very long, gentle slopes, low to moderately erodible loam clay (Farningham and Balmoral) and sandy soils (Avalon and Southwould) and unfavourable bioclimatic conditions (Dry Upland and Riverine Interior). All these factors are correlated with the distribution mass wasting processes in landtype Ac (refer to table 4 in appendix). In Bb, moderate Natal Sourvelds and Vryheid Sandstones appear to account for the distribution of mass wasting. The distribution of these erosion features in Fa appear to be regulated by very steep slopes.

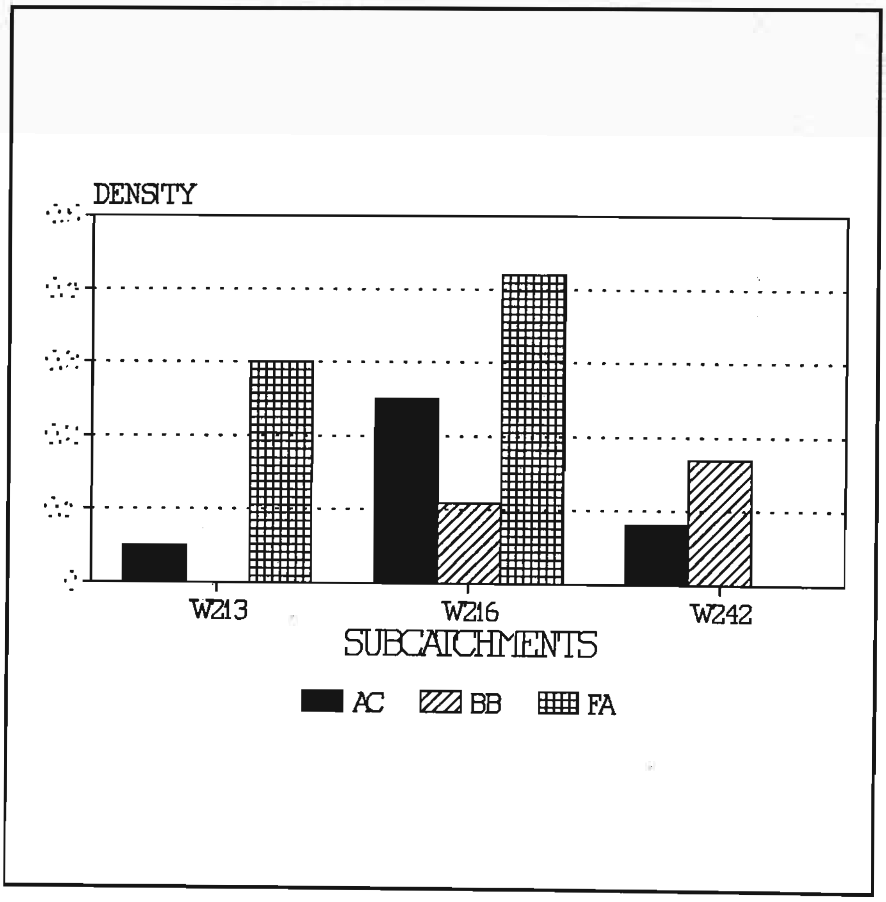


Figure 6.9: Distribution of mass wasting in landtypes

6.8 DISTRIBUTION OF RELIEF FORMS

6.8.1 DISTRIBUTION OF RELIEF FORMS IN SUBCATCHMENTS

While relief forms cannot be classified as potential sediment sources, they can restrict landuse practices in a particular area. For example, it is difficult or even impossible to settle or to practice agriculture on areas with more than 10 m vertical drop. Also the roughness hillocks and outcrops can restrict landuse of a particular area. Although these features were not well represented in the catchment, high densities were recorded in quaternary subcatchments W225 and W222.

6.8.2 DISTRIBUTION OF RELIEF FORMS IN LANDTYPES

In general, these relief forms are not well represented but they are found in landtype Ca, Fb, Fa, Ab, and Dc. High densities values were found in landtype Ca, Fb and Ab (refer to fig. 6.10). These three landtypes are likely to be found on Vryheid Sandstone, Dwyka Tillite and Dolerite, respectively. Both Ca and Fb have very long slopes and moderate to high altitudinal ranges. Ab is characterised by medium slopes and moderate altitudinal ranges.

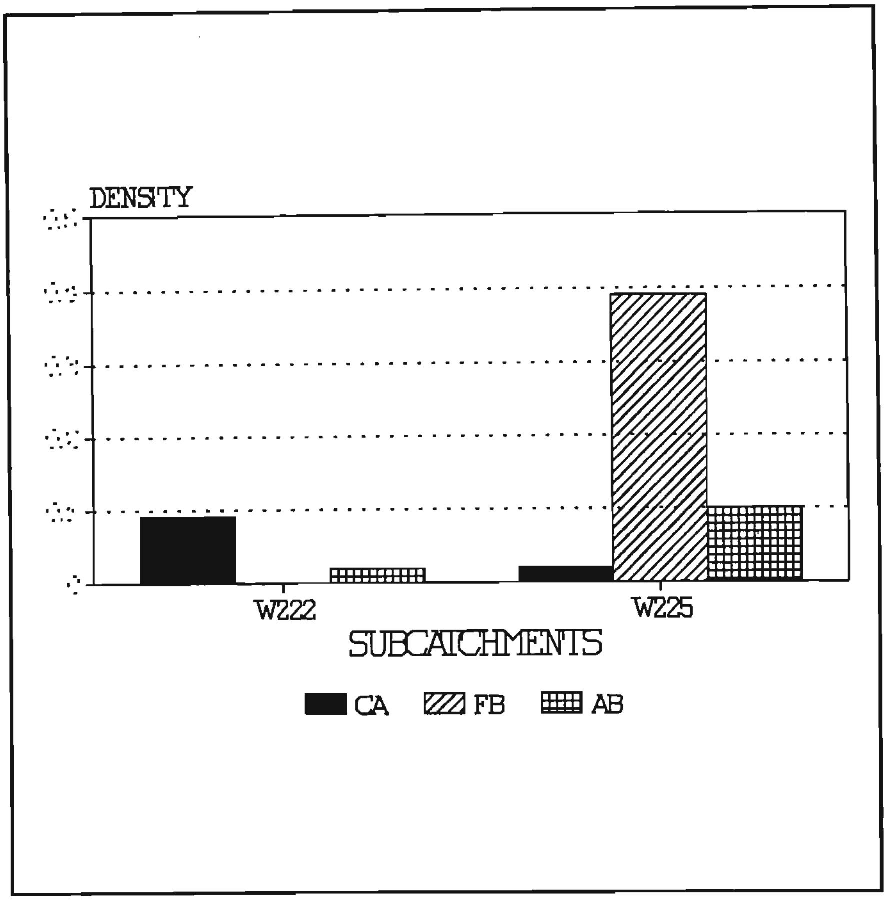


Figure 6.10: Distribution of relief forms in landtypes

6.9 DISTRIBUTION OF OVERALL EROSION

6.9.1 DISTRIBUTION OF OVERALL EROSION IN SUBCATCHMENTS.

Table 6.3 and Figure 6.11 summarise the distribution of all erosion type categories considered in the study in the subcatchments within the different land use regions. While 33 % of the Mfolozi's 43 subcatchments had severe to very severe erosion, overall erosion was not well represented, i.e, 16, 18 and 33 percent of the subcatchments had moderate, low and very densities, respectively. This differs from the overview anticipated from several reports on the catchment that it is already severely eroded over substantial areas (refer 4.9), and from the overview anticipated from the erosion potential map of the catchment, that many subcatchments, Middle Former KwaZulu in particular, have a high natural predisposal to erosion (refer fig. 6.1).

Upper Former Natal: Overall erosion in this region was found to be very much higher than anticipated. That is, although only four subcatchments (comprising 19 % of the total area) were rated highly susceptible to erosion (table 6.1), severe and very severe erosion was found in 44 % of the area (i.e, seven subcatchments - W231, W232, W233, W241, W242, W243 and W244). This severe to very severe erosion is no doubt substantially influenced by the high altitudinal ranges and the underlying Dwyka Tillite common in six of the seven subcatchments. All seven had high to very high gully densities (refer to section 6.3.1).

Upper Former KwaZulu: Erosion in this region was found to be much lower than anticipated. That is, despite it been rated moderately susceptible, erosion throughout the region was low. However, badlands were found to be well represented in the region (refer to fig. 6.6), with two out of three subcatchments recording high areal coverage by badlands.

Middle Former KwaZulu: The overall erosion in this region was found to be lower than anticipated. That is, although 60 % of this region was rated highly susceptible to erosion (refer to fig. 6.1), severe to very severe erosion was found in 46 % of the area. The five very highly eroded subcatchments were W234, W245, W246, W247, & W251. These five subcatchments have in common high altitudinal ranges which have obviously contributed to very high erosion densities. Despite these high altitudinal ranges (210-1127), very high erosion in these subcatchments is no doubt also due to different factors. For example, in W234, underlying Dwyka Tillite and unfavourable bioclimatic conditions (Riverine Interior) have also contributed to very high erosion. The other two subcatchments (W226 and W248) were highly eroded. Both have high altitudinal ranges (490-1445 & 215-855) , unfavourable veld (Lowveld) and bioclimatic conditions (Riverine Interior) and a highly susceptible underlying geology (Dwyka Tillite). In four of the seven highly and very highly eroded subcatchments (W234, W245, W247 and W248) both gully and unconfined erosion were well represented. In the other three the erosion was mostly due to unconfined processes. These findings support Liggitt (1988), Liggitt and Fincham (1989) and Looser (1985)'s findings. That is, in their study areas in these subcatchments they found that erosion was severe (refer to 4.9).

Middle Game Reserve: Overall erosion throughout this region was low, which was not anticipated since 75 and 25 % of it was rated moderately and highly susceptible, respectively (refer to 6.2). This findings support Venter's (1988) and Watson's (1990) findings that the Natal Parks Board's conservation management policies were effective in restricting erosion (refer to 6.2.4).

Lower Former KwaZulu: Overall erosion throughout this region was found to be low. This was expected since 67 % of it was rated as having low erosion potential (refer to 6.2). Watson (1990) and Looser (1985) studies in these subcatchments also found that erosion in these subcatchments was low (refer to 4.9)

Lower Former Natal: Overall erosion in this region was much lower than anticipated. That is, densities throughout it were low although it had been rated moderately susceptible. These subcatchments are either under sugar or conservation (refer to 4.8.4). The fact that actual erosion is lower than potential erosion signifies that this land is well managed.

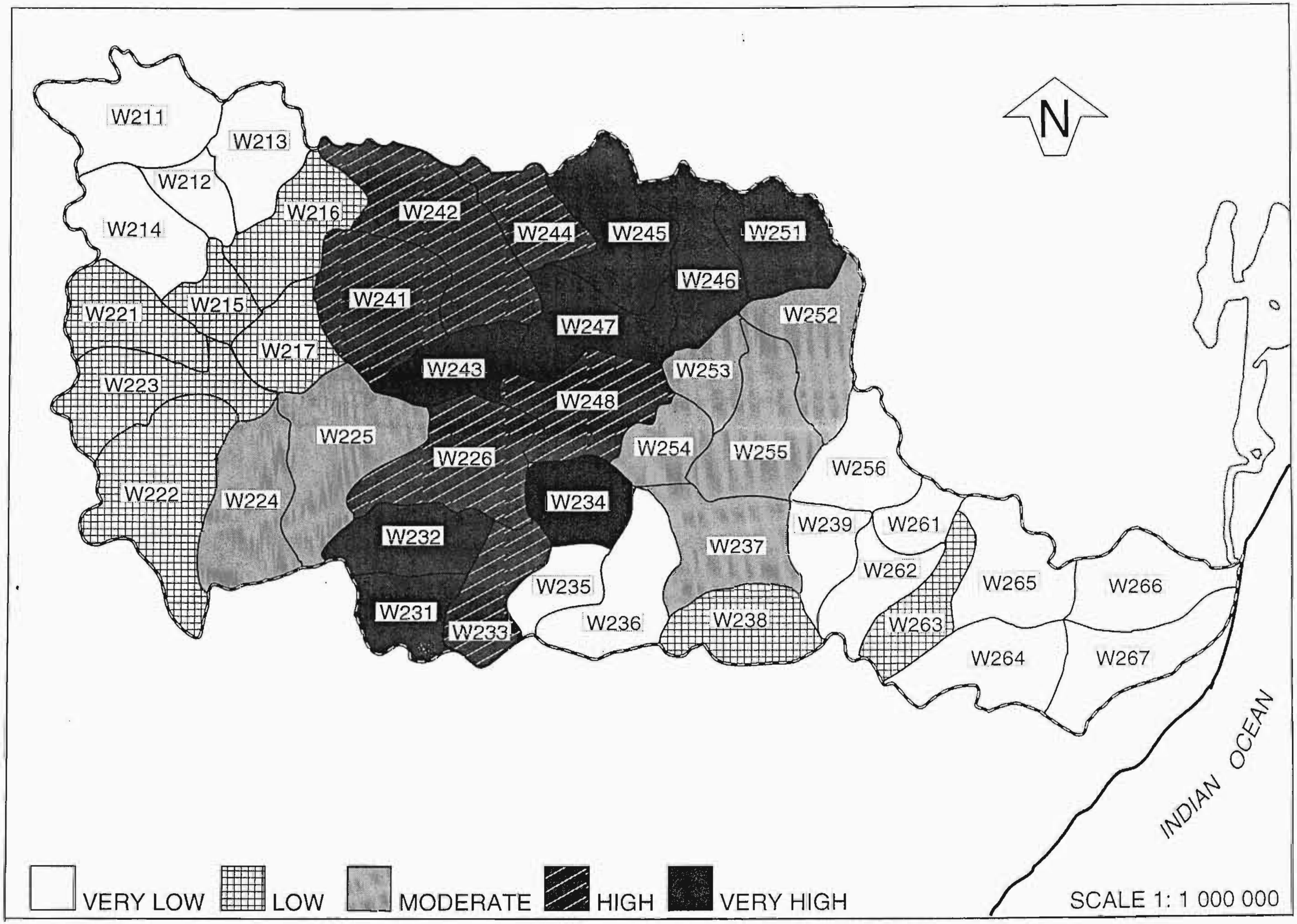


Figure 6.11: Distribution of overall erosion in subcatchments

	UPPER: FORMER NATAL	UPPER: FORMER KWAZULU	MIDDLE: FORMER KWAZULU	MIDDLE: GAME RESERVE	LOWER: FORMER KWAZULU	LOWER: COASTAL PLAIN
VERY HIGH (%)	19		33			
HIGH (%)	25		13			
MODERATE (%)	12		33			
LOW (%)	19	100	8	100	100	100
VERY LOW (%)	25		13			

Table 6.9: Distribution of overall erosion in subcatchment (%)

6.9.2 DISTRIBUTION OF OVERALL EROSION IN LANDTYPES

The eight landtypes in which the highest overall density of potential sediment sources was recorded were established and analyzed further. The landtypes are: **Ab, Ac, Bb, Ca, Db, Dc, Fa, and Fb** (refer to Table 6.4 for the distribution of erosion features in these landtypes). More detailed tables of the densities of erosion features in these landtypes, together with significant correlations between their biophysiographic variables and erosion classes are shown in appendix Tables 3.1 - 3.6 and 4, respectively. Landtypes Ac, Bb, Ca and Fb have very long slopes, moderate altitudinal ranges (with the exception of Ca), low to moderately erodible soils (Farningham, Balmoral, Avalon, Southwould, and Mispah) and highly susceptible Dry Upland and Riverine Interior bioclimates. Ab, Db, Dc, and Fa are characterised by medium slopes, moderate altitudinal ranges, moderately susceptible Vryheid Sandstone (with the exception of Ab and Fa which are underlain by Dolerite and highly susceptible Dwyka Tillite, respectively), and the highly susceptible Riverine Interior bioclimate.

LAND TYPES	GULLIES	UNCONFINED	BADLANDS	MASS WASTING	RELIEF FORMS
Ab	X	X			X
Ac					
Bb	X		X	X	
Ca	X		X		X
Db	X				
Dc			X		
Fa		X		X	
Fb	X	X			X

Table 6.10: Distribution of erosion features in landtypes

EROSION FEATURES	VARIABLES OF INFLUENCE		R^2
GULLIES 1	Terrain Units	(-0.11)	0.51
	Soils	(0,43)	
	Veld Types	(0,47)	
GULLIES 2	Slope Length	(-0,55)	0.52
	Soils	(0.30)	
	Geology	(0,14)	
	Veldtype	(0,44)	
	Precipitation	(0,49)	
GULLIES 3	Slope Length	(-0,28)	0.54
	Soils	(0,34)	
	Veldtypes	(0,65)	
GULLIES 4-11	Terrain Unit	(0,19)	0.58
	Slope Length	(0,41)	
	Slope Shape	(0,68)	
	Geology	(0,18)	
	Veldtype	(0,27)	
	Bioclimate	(0,48)	
	Precipitation	(0,77)	
ANTHROPOGENICALLY INFLUENCED DUMPS	Slope Angle	(-1,07)	0.20
	Soils	(0,43)	
	Veldtypes	(0.33)	
	Bioclimate	(0,62)	
UNCONFINED EROSION	Slope Length	(-0,50)	0.40
	Veldtypes	(-0,24)	
	Bioclimatic	(0,87)	
	Landuse	(0,41)	
MASS WASTING	Terrain unit	(-0,20)	0.42
	Veldtypes	(0,74)	

Table 6.11: Variables influencing the distribution of erosion

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1 INTRODUCTION

The main aim of this study was to identify areas in the Mfolozi catchment that are either potentially highly susceptible to erosion or already severely eroded. Such areas should not be allocated to people lacking the technical or financial means to implement appropriate soil conservation measures under the Land Reform Programme. In this chapter, the major findings described and discussed in the previous chapter are summarised and their implications noted. Recommendations regarding subcatchments and landtypes suitable and not suitable for inclusion in the Land Reform Programme, as well as those regarding more general considerations are also made in this chapter.

7.2 MAJOR FINDINGS AND IMPLICATIONS

1. Previous studies (as detailed in sections 3.1 and 4.9) suggest that extensive, severely eroded areas were well represented in the catchment. This study revealed that such areas comprise only 33 % of the catchment. Estimates of the Mfolozi river's mean annual sediment yield cited in section 4.9.1 are comparatively high. This study's finding that erosion is neither as severe nor as extensive as previously depicted suggests that Watson (1990; 1993) may be correct in her assertion that sediment eroded from the catchment may be making less of a contribution to this yield than that liberated into the river channels as a consequence of the wetland destruction described by Begg (1988).

2. Previous studies suggest that extensive, severely eroded areas were well represented in the catchment's former KwaZulu areas (refer to 4.9). This study revealed that erosion in the former KwaZulu areas in the upper and the lower reaches of the catchment was in fact less well represented than in the adjacent former Natal areas in these regions. The middle reaches of the catchment have a higher erosion risk potential than either the upper or lower reaches. Only former KwaZulu and conservation landuses were present in the middle reaches, and this study's finding that erosion was better represented in the former, substantiates Venter's (1988) and Watson's (1990) conclusion that the management policies implemented by the Natal Parks Board in the Hluhluwe-Umfolozi Park are generally effective in arresting serious soil erosion.

3. Previous studies have attributed soil erosion in the catchment principally to overstocking and poor cultivation practices in the former KwaZulu areas. This study has clearly revealed that even under conditions of serious overcrowding (refer to section 2.3.3), the traditional subsistence use of communal lands in regions which do not have a high risk potential, is less destructive to the soil resource than commercial mechanised agricultural practises. However, as noted in section 6.4.1, in high erosion risk potential areas, traditional landuse practices do have a significant influence on unconfined erosion.

4. Botha (1992) provided evidence showing that most major gullies in the catchment were regulated by climatic variations and predate any significant anthropogenic influence. This study's finding that (unlike the situation for the other erosion categories considered) landuse did not play a significant role in explaining the variation in the distribution of gullies (refer to 6.3.1), substantiates his conclusions.

7.3 RECOMMENDATIONS

7.3.1 Subcatchments recommended for reallocation

Seven subcatchments (i.e, W231, W232, W233, W241, W242, W243 and W244) in the Upper Former Natal were severely eroded. In addition to being highly susceptible to erosion, most of these subcathments have more than two erosion features (including gullies, mass movements and unconfined erosion) well represented within them. None of these subcatchments are not recommended for allocation in the Land Reform Programme.

Despite it being rated moderately susceptible, erosion throughout the Upper Former KwaZulu was low. However, badlands were found to be well represented in the region (refer to fig. 6.6), with two out of three subcatchments recording high areal coverage by badlands. These subcatchments can be recommended for reallocation provided landtypes that contain these features are excluded. These landtypes includes Bb, Ca, and Dc.

Overall, the Middle Former KwaZulu was rated highly susceptible to erosion (refer to fig. 6.1). Actual erosion in this region was found in 46 % of the area. This suggests that most of these region is not suitable for reallocation in the Land Reform Programme. If possible, no subcatchments in this region should be considered for reallocation, but rather be given extensive conservation measures.

Although not highly eroded, parts of this Middle Game Reserve have a high natural predisposal to erosion. Lack of erosion in this region indicates that management is indeed effective. It is likely that landuse change may exacerbate erosion in this region, as such, this region is not recommended for reallocation.

In addition to having a moderate to low erosion risk potential, actual erosion in the lower former KwaZulu and the Lower Former Natal is very low. Both these regions are recommended for reallocation.

7.3.2 Landtypes that are not recommended

Although eight landtypes (i.e, Ab, Ac, Bb, Ca, Db, Dc, Fa, and Fb) were identified as highly eroded, only four (i.e, Ab, Bb, Ca and Fb) (refer to fig 6.4) were found to be severely eroded as more than two erosion features were well represented in them. Two of these landtypes, that is Ca and Fb are also highly susceptible to erosion. There are also landtypes that are moderately to highly susceptible to erosion (Ad and Db), but as yet do not have much erosion represented in them (refer to table 6.4). Where possible, allocation of all these landtypes should be avoided in the Land Reform Programme, especially where people intend to follow agriculture as a means of survival.

CATCH MENTS	EROSION HAZARD	GULLIES	UNCONFINED	BAD LANDS	MASS MOVEMENTS	RELIEF FORMS	COMMENTS
Upp.For Natal							
W211	M	VL	VL	VL	M	VL	RECOMMENDED*
W212	M	VL	VL	VL	M	VL	RECOMMENDED*
W213	M	VL	VL	M	H	VL	RECOMMENDED*
W214	M	L	VL	H	VL	VL	RECOMMENDED*
W215	M	L	VL	H	VL	VL	RECOMMENDED*
W216	M	VL	VL	L	VH	VL	RECOMMENDED*
W217	M	L	VL	VL	VL	VL	RECOMMENDED*
W224	M	L	VL	VH	VL	VL	RECOMMENDED*
W225	M	M	L	L	L	H	RECOMMENDED*
W231	H	VH	L	VL	L	VL	NOT RECOMMENDED
W232	M-H	H	M	VL	L	VL	NOT RECOMMENDED
W233	H	M	H	VL	VL	VL	NOT RECOMMENDED
W241	H	H	L	VL	M	VL	NOT RECOMMENDED
W242	H	H	M	VL	H	VL	NOT RECOMMENDED
W243	H	H	M	M	L	VL	NOT RECOMMENDED
W244	M	H	M	L	M	VL	NOT RECOMMENDED
Upp.For KwaZulu							
W221	M	L	VL	VL	L	VL	RECOMMENDED*
W222	M	L	VL	H	M	H	RECOMMENDED*
W223	M	L	VL	H	L	VL	RECOMMENDED*
Midd.For KwaZulu							
W226	H	H	M	VL	M	VL	NOT RECOMMENDED
W234	H	H	H	VL	VL	VL	NOT RECOMMENDED
W235	H	VL	L	VL	VL	VL	NOT RECOMMENDED
W236	H	L	L	VL	VL	VL	NOT RECOMMENDED
W237	H	L	M	VL	VL	VL	NOT RECOMMENDED

W238	M	VL	M	VL	VL	VL	NOT RECOMMENDED
W245	H	H	H	L	VL	VL	NOT RECOMMENDED
W246	M	M	VH	VL	VL	VL	NOT RECOMMENDED
W247	H	H	VH	VL	M	VL	NOT RECOMMENDED
W248	H	H	M	VL	VL	VL	NOT RECOMMENDED
W251	M	M	VH	VL	VL	VL	NOT RECOMMENDED
W252	M	VL	H	VL	VL	VL	NOT RECOMMENDED
W253	H	VL	H	VL	VL	VL	NOT RECOMMENDED
W254	H	VL	H	VL	VL	VL	NOT RECOMMENDED
W255	H	VL	VH	VL	VL	VL	NOT RECOMMENDED
Game Reserve							
W239	M	VL	VL	VL	VL	VL	NOT RECOMMENDED#
W256	H	VL	L	VL	VL	VL	NOT RECOMMENDED#
W261	M	VL	VL	VL	VL	VL	NOT RECOMMENDED#
W262	M	VL	VL	VL	VL	VL	NOT RECOMMENDED#
Low.For KwaZulu							
W263	M	VL	VL	VL	VL	VL	RECOMMENDED
W264	L	VL	VL	VL	VL	VL	RECOMMENDED
W265	L	VL	VL	VL	VL	VL	RECOMMENDED
Low.For Natal							
W266	M	VL	VL	VL	VL	VL	RECOMMENDED
W267	M	VL	VL	VL	VL	VL	RECOMMENDED

Table 7.1: Recommended subcatchments

** ALTHOUGH RECOMMENDED, ALLOCATION OF THE MOST SEVERELY ERODED AND MOST HIGHLY SUSCEPTIBLE LANDTYPES HIGHLIGHTED IN SECTION 7.3.2 SHOULD BE AVOIDED.*

 # ALTHOUGH NOT RECOMMENDED, AREAS OUTSIDE THE GAME RESERVE WITHIN THESE SUBCATCHMENTS CAN BE REALLOCATED.

7.3.3 Overall Recommendation

1. It is important to note that erosion features do not have the same influence on the lives of all people (refer to 3.2, 3.3 and 3.4). Due to lack of sufficient literature about people's perception on how erosion features influence them, this study was unable to weigh the influence of these features. More research needs to be carried out on this topic. In addition to assisting in the weighing of the effect of various erosion features, this kind of research will also contribute in giving local communities a chance to take part in the decision making.

2. In addition to being highly susceptible to erosion, many former KwaZulu areas have been overcrowded due to apartheid policies. Instead of focusing on the social circumstances which led to soil erosion in the first place, many researchers have blamed traditional landuse as the main cause of severe erosion. These kinds of misconceptions often lead development planners to ignore the contribution and the effort made by traditional subsistence farmers in regulating soil loss in the country. As also concluded by Garland, Robinson, and Pile (1994), it is indeed necessary for planners to show appreciation of and encourage local communities to participate in their own developments.

3. Although most gullies in the catchment are evidently natural and possibly even stable features, previous research in the catchment (refer to 3.6.5) has shown that roads have contributed to gully initiation. As people will be moving to new areas, new roads and footpaths will be necessary. Strict soil conservation principles should therefore be adhered to in future road design, construction and maintenance.

4. The major activities in Former KwaZulu areas are subsistence and small scale farming (refer to 4.8.2). These activities failed to improve lives of rural people in the past. There is a need for a landuse assessment study in this area, so that people may be involved in other employment activities (e.g. mining, tourism, and industries).

It is beyond the scope of this study and the researcher's limited experience to suggest which kind of erosion is better compared to the others. However, the intention was to provide a basic document for development planners to know what to expect when allocating areas according to the Reconstruction and Development Programme's Land Reform Programme. Despite the scale and the complexity of erosion problem in the study area, the researcher managed to identify both the subcatchments and the landtypes that are highly susceptible to erosion as well as those that are highly eroded.

The political situation in the region seems to be gradually stabilising. This provides favourable conditions for the Land Reform Programme to take of. While the final decision about areas that should be reallocated in the Land Reform Programme lies in the hands of politicians, developers and planners, it is hoped that conclusions and recommendations of this study will make a meaningful contribution towards the success of this programme in the Mfolozi catchment.

BIBLIOGRAPHY

Acocks, J.P.H., 1953: Veld Types of South Africa. **Mem. Bot. Surv. S. Afr.**, 28, Government Printer South Africa.

Acocks, J.P.H., 1988: Veld Types of South Africa. **Mem. Bot. Surv. S. Afr.**, 47, Government Printer South Africa.

Afra News, June 1990: **Natal rural freehold communities reprieval campaign.**

Afra News, April 1991: **Back to the land campaign, the reoccupation of Charlestown, Criemen and Roosboom.**

Afra News, September, 1992: **Editorial Comments.**

Afra News, March, 1993: **Editorial Comments.**

Afra News, May, 1994a: **Land claims court legislation.**

Afra News, May, 1994b: **Rural local government challenge.**

Alexander, J., 1991: The unsettled land: The politics of land redistribution in Matebeleland 1980 - 1990, **Journ. of Southern Africa,**

ANC (undated), **ANC Agricultural Policy**, publication, Johannesburg.

ANC, 1994: **Reconstruction and Development Programme,** Johannesburg.

Baillie, I.C., 1985: Comment on the palaeoenvironmental interpretation of colluvial sediment and paleosols of the later, pleistocene hypothermal in Southern Africa, **Palaeoclimatology, paleogeography and paleoecology**, 52. 159-161.

Beckedahl, H.R., 1977: Subsurface erosion near the Oliviershoek Pass, Drakensberg, **S. Afr. Geogr. Journ.**, 59,2.

Begg, G.W., 1988: **The wetlands of Natal (Part 2) - The distribution, extent and status,** Natal Town and Regional Planning Commission, Pietermaritzburg, 71: 1-272.

Berjak, M., Fincham, R.J., Liggitt, B. and Watson, H.K., 1986: Temporal and spatial dimensions of gully erosion in the Northern Natal, South Africa. **International Archives of Photogrammetry and Remote Sensing,** 26, 283-293.

Blaikie, P., 1985: **Political economy of soil erosion in developing countries,** Longman Scientific Tech., New York.

Blaikie, P. and Brookfield, H., 1987: **Land degradation and society,** Routledge, New York.

Botha, G.A., 1992: **The geology and palaeopedology of late quaternary colluvial**

sediments in northern Natal, Univ. of Natal, Pietermaritzburg, Unpublished PhD Thesis.

Bracher, P.R., 1985: **Monitoring of cross-sectional changes in the Mfolozi river,** Flood Studies, T.N.3., Dept. Water Affairs, Pretoria.

Bracher P.R. and Kovacs, Z.P., 1985: **Cross-section changes in the Mfolozi River**, Dept. Water Aff., Pretoria.

Braune, E. and Looser, U., 1989: **Costs impacts of sediments in South African rivers,** Proc. Baltimore Symposium, May 1989, 131-141.

Brinkcate, T. and Hanvey, P., 1996: **People's perception and attitudes towards soil erosion: Case Study of the Madabe Area near Saulspoort,** Unpublished Report, Univ. of the Witwatersrand.

Budlender, G, 1992: The right to equitable access to land, **South African Journal of Human Rights,** 8, 3, 294-304.

Bundy, C., 1979: **The rise and fall of the South African peasantry**, HEB, London.

Bundy, C., 1991: Land, Law and Power in rural South Africa, **Matlhasedi** Nov/Dec 1991.

Christopher, A.J., 1969: **A study of colonial land settlement,** Univ. of Natal, Unpublished Thesis.

Claasens, A, 1990: Land Policy: Seeking a common framework in local struggles, **SASH**, 10-15.

Claasens, A., 1991: Who owns South Africa? Can the repeal of the land Acts De-racialise land ownership in South africa?, **Journal of Human Rights Trusts,** 66-77.

Cobban D.A, and Weaver A. Van B., 1993: A preliminary investigation of the gully features in the Tsolwana Game Reserve, Ciskei, Southern Africa, **S. Afr. Geogr. Journ.,** 75, 14-21.

Coleman, J.M., 1976: **Deltas - Processes of deposition and modes for exploration**, Cont. Educ. Publ. Comp., 102 pp.

Cooke, R.U, and Doornkamp, J.C, 1978: **Geomorphology and environmental management - An introduction,** Claredon Press, Oxford.

Cooper, D., 1984: The Zululand floods of 1984 - a personal view, **Africa Wildlife,** 38, 3, 101-102.

Combrie Greig, J., 1984: The impact of Tropical Cyclone "Domoina", **African Wildlife**, 38, 3: 91-97.

Crosby, C.T., McPhee, P.J., and Smithen, A.A., 1983: Introduction of the Universal Soil Loss Equation in the Republic of South Africa, **Am. Soc. Agric. Eng.,** Paper No. 832072, 1-15.

Dardis, G.F., Beckedalh, H,R., Bowyer-Bower T.A.S., and Hanvey, P. M., 1988: Soil erosion forms in southern Africa, in Dardis, G.F. and Moon, B.P., (eds), 1988: **Geomorphological studies in southern Africa,** Balkema Rotterdam, 187-213.

Davies, J. C., 1973: **Statistics and data analysis in geology,** John Wiley and Sons, New York.

Deitrich, W.E, Wilson, C.J. and Reneau, S.L, 1986: Hallows, colluvium and landslides in soil mouthed landscape in Abrahams A.D. (ed), 1980, **Hillslope Processes,** Allen and Unwin, Boston, 361-388.

De Klerk, M, 1990: Market-based options for Land Reform, **Transformation,** 12, 53-87.

De Klerk, M., 1991: **A harvest in discontent**, IDASA, 53-87.

Department of Agriculture and Fisheries, (Natal Region) 1981: **Agricultural development programme**, Pietermaritzburg.

De Ploey, J., 1981: The effects of some factors of erosion, **Mem. Inst. Geol.**, U.Louvain XXXI, 171-181.

Dolny, H., 1989: Land reform in South Africa, **Erosa** discussion paper, October 1989.

Dolny, H, 1990: Agriculture: Conflicts of interests in a mixed economy, **Transformation** 12, 1990.

Dunne, T., Wahome, E. and Aubry, B., 1981: **An ordinal - scale classification of water erosion,** Technical Rep. Ser., Kenya Rangeland Ecological Monitoring Unit.

Elswaify, S.A. and Cooley, K.R., 1980: Soil losses from sugarcane and pineapple lands in Hawaii, in De Boodt, M. and Gabriels, D., (eds) 1980: **Assessment of erosion,** John Wiley and Sons, New York, 327-340.

Elwell, H.A., and Stocking, M.A., 1976: Vegetation cover to estimate soil erosion hazard in Rhodesia, **Geoderma,** 15, 6-70.

Erskine J.M 1982: **Agriculture in Natal\Kwazulu: Development Potential, Rural studies series,** Mon, 1, INR, University of Natal, Pietermaritzburg.

Erskine, J.M, 1985: Growing population, misuse of natural resources and agricultural production in the african rural areas of South Africa, in **Proc. XIX Int. Conf. Agric. Economists**, Malaga, 1-6.

Faniran and Areola, 1978: **Essentials for soil study with special reference to Tropical Areas,** Heinemann, London.

Fisher, R.A. and Yates, F., 1963: **Statistical tables for biological, agricultural and medical research,** Oliver and Boyd, London.

Fitzpatrick, R.W., 1978: **Occurrence and properties of iron and titanium oxides on soils along the eastern seaboard of South Africa,** Unpublished PhD. Thesis, UNP.

Francis, E. and Williams, G., 1993: **The land question,** CJAS/RCEA 27: 3.

Friedmann, M., 1991: **Is a feminist development appropriate and possible in South Africa,** INR, UNP - Paper presented at the first Women and Gender Conference, UND, January 1991, Unpublished.

Garland, G.G., 1987: **Erosion risk from footpaths and vegetation burning in the Central Drakensberg,** Natal Town and Regional Planning Supplementary Report, 20

Garland G.G, Robinson J.R, and Pile K.G., 1994: **Policy, perception and soil conservation - a case study from Cornfields, Natal,** Human Needs, Resources and Environment Report, HSRC, August 1994.

Gcabashe, M. and Mabin, A., 199O: Preparing to negotiate the land question, **Transformation,** 11, 58-74.

Gosling, M., 1984: Cyclone "Domoina". The Natal Parks Board counts the costs, **Africa Wildlife,** 38, 3, 97-101.

Hanekom, D., 1993: The State must intervene, in **Afra News**, 21, 6-8.

Heede, , 1971: **Characteristics and processes of soil piping in gullies,** USDA Forest service Research Paper, 68, Rocky Mountain Forest and Range Experiment Station, Fort Collins.

Holy, M., 1980: **Erosion and environment**, Pergamon Press, Oxford.

Hudson, N. W., 1971: **Soil conservation,** Batsford, New York.

Hudson, C.A., 1987: **A Regional application of Slemsa in the Cathedral Peak Area of the Drakensberg** - Unpublished M.Sc. Thesis, Dept. of Environmental and Geographical Sciences, UCT.

Humphrey, B.C.H., 1983: **Land erosion potential assessment - A Reappraisal,** Univ. of Natal Durban, Unpublished Report.

IDRC/ANC/COSATU/SACP/SANCO Mission, 1994: **Environment, reconstruction and development in the new South Africa,** Aug. Report on Environmental Policy, 1-140.

Kent, L.E., 1980: **Stratigraphy of South Africa - part 1,** Handbook 8, Dept. Geol. Surv. Pretoria.

Khosa, M.M, 1994: Whose land is it anyway? Geographical and Environmental Sciences UND, **Indicator S.A,** 12, 1 Summer 1994.

Knapp, 1979: **Soil processes,** George Allen and Unwin, London.

Kirby, M.J., 1980: Modelling water erosion processes, in Kirby, M.J. and Morgan, R.P.C., (eds) 1980: **Soil Erosion,** John Wiley and Sons, Chichester, 183-216.

Kovacs, Z.P., Du Plessis, D.B., Bracher, P.R., Dunn, P. and Mallory G.C.L., 1985: **Documentation of the 1984 Domoina Floods**, T.R. 122, Dept. of Water Affs., Pretoria, 1-46.

Kriel, J.P., 1983: The occurrence of potential beneficial use of water in South Africa, **R.S.A., 2000,** 5, 1, 27-30.

Lal, R, 1977: Analysis of factors affecting rainfall erosivity and soil erodibility, in Greenland, D.J and Lal, R,(eds.) 1977: **Soil Conservation and Management in Humid Tropics,** John Wiley and Sons, Chichester, 93-97.

Lal, R., 1985: Soil erosion and sediment transport research in Tropical Africa, Journ. **Hydrological Sciences Journal**, 30, 2, 6, 239-250.

Land Type Survey Staff, 1986: Land Type Map 2730 Vryheid, **Mem. Agric. Nat. Resour. S. Afr.**, 7, Pretoria.

Land Type Survey Staff, 1986: Land Type Map 2830 Richards Bay, **Mem. Agric. Nat. Resour. S. Afr.**, 11, Pretoria.

Le Roux, J.S., 1981: **Interaction between climate, vegetation and runoff in the Karoo. In: Maaren H (ed) Workshop on the effect of rural landuse and catchment management resources,** Tech. Rep. 113, 90-106, Dept. of Water Affairs, Pretoria.

Liggitt, B., 1988: **An investigation into soil erosion in the Mfolozi catchment,** Unpublished M Sc. Thesis, Univ. of Natal, Pietermaritzburg.

Liggitt, B. and Fincham, R., 1989: Gully erosion - the neglected dimension in soil erosion research. **S. Afr. Journ. Sci.**, 85, 1: 18-20.

Looser, J.U., 1985: **Sediment problems in the Mfolozi Catchment - assessment of research requirements,** Dept. Water Aff., Pretoria, 1-20.

Looser, J.U., 1989: Methods to determine the origin and delivery of sediment in the Mfolozi catchment, **Proc. Forth S. Afr. Nat. Hydro. Symp.,** Pretoria, 347-354.

Looser, J.U., 1988: Die Geomorphogische karte als erosionsbezogene wasserwirtschaftliche planungsgrundlage - ein Metholodischer ansatz fur ein mittelgrosses einzugsgebiet in Natal, Sud Afrika, (The Geomorphological map as a base for erosion based hydrological planning - a methodological approach for medium sized catchment in Natal, South Africa), **Geomethodica,** 13, 117-144.

Looser, J.U., 1992: **The Geomorphological map of the Mfolozi catchment,** Unpublished, Commissioned by the Institute of Water Quality Research, Pretoria.

Maud, R.R., 1978: Geomorphology of KwaZulu Natal, **Proceedings Wildlife Society Symposium,** Durban, 9-15.

Mayende, 1993: Agrarian reform in South Africa, in Hallowes, D., (ed) **Hidden Faces, Environment, Development and Justice: South Africa and the Global context,** Natal Witness Printers, Pietermaritzburg.

MacVicar, C.N., 1984: Identification of soils of the sugar industry, **Experiment Station Bulletin.,** 19, S. Afr. Sugar Association, Mount Edgecombe, 1-41.

Marcus, T., 1991: Palace coup on the land, the government's land reform package up against the need for fundamental change, **Indicator S.A.,** 4.

Marcus, T., 1994: Land Reform in rural reconstructing programmes: Comparative policy approaches and experiences as from developing world, **Development Southern Africa** Vol 11 No 4 November 1994.

Mbongwa, M.M, 1990: **The Political Economy of Post 1960 Dispossession in South Africa: An Assessment in Land Reform and Agricultural Development,** Paper presented at the Newick Park Initiative, UK.

McAllister, P.A., 1988: The impact of relocation in a Transkei "betterment" area, in Cross, C. and Haines, R., (eds) 1988: **Towards Freehold Options for land and development in South Africa's black rural areas,** Juta, 112-121.

McAllister, P.A., 1989: The impact of relocation in the Transkei - a case study from Willowvale district, **Journal of Southern African Studies,** 15, 2, 346-368.

Morgan, R.P.C., 1979: **Soil Erosion,** Longman, London.

Morgan, R.P.C., 1986: **Soil Erosion and Conservation,** Longman, London.

Natal Town and Regional Planning Commission, 1984: **Towards a Plan for the Mfolozi catchment - An Overview,** Pietermaritzburg.

Okigbo, B.N., 1977: Farming systems and soil erosion in West Africa, in Greenland, D.J. and Lal,R., (eds.) 1977, **Soil Conservation and management in the humid tropics,** John Wiley and Sons, Chichester, 151-163.

Olson, T.C. and Wischmeier, W.H., 1963: Soil Erodibility evaluation for soils on the runoff and erosion stations, **Proc. Soil Sci. Soc.** America, 27, 590-592.

Palmer, R., 1990: Land Reform in Zimbabwe, 1980-1990, **African Affairs.**

Partridge, T.C. and Maud, R.R., 1987: Geomorphic evolution of Southern Africa since the Mesozoic, **S. African Journ. Geol.**, 90, 2, 179-208.

Phillips, J., 1973: **The agricultural and related development of the Tugela Basin and its influent surrounds,** Natal Town and regional Planning Commission, Pietermaritzburg, 19, 1-299.

Pitman, W.C., Middleton, B.J. and Midgley, D.C., 1981: **Surface water resources of South africa; Parts 1 and 2. Rep. 9/81,** IV, Dept. Water Affairs, Pretoria.

Platford, G.G, 1982: The determination of some soil erodibility factors using a rainfall simulator, **Proc. S. Afr. Sugar Technol. Assoc.,** June, 1-4

Ramokgopa, R., 1993: The environmental impact of betterment schemes on rural areas -Case study: Botlokwa, Unpubl. BA(HONS) Thesis, University of Durban Westville.

Randall, L.A., 1993: **The use of satellite data and geographic information systems for mapping sediment production areas: Part 1: Spectroradiometry and satellite data interpretation,** Dept. of Water Aff. and Forestry, Hydrological Research Institute N/W200/00/EQ/2193, 3/0203.

Rapp, A., 1975: Soil erosion and Sedimentation in Tanzania and Lesotho, **Ambio** 4, 4, 154-163.

Renard K.G., and Foster, G.R., 1983: Soil Conservation: Principles of Erosion by Water, Dryland Agric. - **Agron. Mon,** 23, Madison, USA.

Robertson, M., 1989: Land Reform: South African Options, **Columbia Human Rights Law Review**, 21, 193-209.

Roose, E.J, 1976: Use of the USLE to predict erosion in West Africa, in Greenland, D.J and Lal, R,(eds.): **Soil Erosion, Prediction and Control,** Special Pub. 21, Soil Conservation Service of America, Purdue, 60-74.

Roose, E.J., 1977: Application of universal soil loss equation of Wischmeier and Smith in West Africa, in Greenland and Lal (eds), 1977: **Soil conservation and management in Humid Tropics,** John Wiley and Sons, Chichester, 93-97.

Rooseboom, A., Verster, E., Zietsman, H. L., Lotriet, H. H., 1992: **The development of New sediment yield map of Southern Africa,** Water Research Commission (WRC) Report No/297/2/92 by Sigma Beta Consulting Engineers.

Rowntree K.M., 1988: Equilibrium concepts, vegetation change and soil erosion in semi-arid areas: Some considerations for Karoo, in Dardis G.F. and Moon B.P. (eds) 1988: **Geomorphological studies in Southern Africa,** Balkema, Rotterdam.

SARCCUS, 1981: **A System for the classification of soil erosion in the SARCCUS region,** Dept. Agric. Rep., Pretoria, 1.

Sangweni, S, 1993: Affirmative action: land reform option, **Afra News** 20, 16-18.

Schieber, M., 1983: **Bodenorosion in Sudafrika,** Geissener Geog, Schriften Heft 51, Selbst. verlag des Goeg. Inst., U. Justus-Liebig, 131-133.

Scotney, D.M., 1978: Soil erosion in Natal, **Proceedings Wildlife Society of South Africa Symposium,** Durban, 16-39.

Selby, 1982: **Hillslope materials and processes,** Oxford University Press, Oxford.

Shaw, G. and Wheeler, D., 1985: **Statistical techniques in geographical analysis,** John Wiley and Sons, Chichester.

Skweyiya, Z., 1990: Opening Access: With a purely market-based Approach, **Transformation,** 12.

SLEMSA, 1976: Soil Loss Estimator for Southern Africa, **Natal Agric. Res. Bull.,** 7, Dept of Agric., Pietermaritzburg.

Smith, D.M, 1994: **Geography and social justice,** Oxford, Burkwell.

Sorrenson, M.P.K., 1967: **Land reform in Kikuyi country: a study in government policy,** Oxford University Press, London.

Anon, 1993: **South African Interim Constitution,** Government Publication, Pretoria.

Statham, I, 1979: **Earth surface processes,** Oxford, University Press, Oxford.

Stocking, M.A., 1988: Assessing vegetation cover and management effects, in Anon., (ed.) 1988: **Soil erosion research methods,** Soil and Water Cons. Soc., Ankeny, 163-185.

Stocking, M.A, and Elwell, H.A, 1976: Vegetation and erosion: a review, **Scottish Geographical Magazine**, 92, 1.

Summerfield, 1991: **Global geomorphology, an introduction to the study of landforms,** Longman Scientific and Technical, N.Y.

Tiffen, M., Mortimore, M. and Gichuki, F., 1994: **More people less erosion: environmental recovery in Kenya,** John Wiley and Sons, Chichester.

Toy, T.J., 1977: **Erosion - research techniques, erodibility and sediment delivery,** Geo. Abstracts, Norwich.

Unterhalter, E., 1987: **Forced removal, the division, segregation and control of the people of South Africa,** IDAF, London.

Van Heerden, I.L. and Swart, D.H., 1985: Fluvial processes in the Mfolozi Flats and the consequences for St. Lucia Estuary, **Proc. Second S. Afr. Nat. Hydro. Symposium,** September 1985, Pietermaritzburg, 202-219.

Venter, J., 1988: **Soil loss and runoff in the Mfolozi Game Reserve and the implications for game reserve management,** Unpubl. PhD. Thesis, Univ. of Natal, Pietermaritzburg.

Watson, H.K., 1988: Terracettes in the Natal Drakensberg, South Africa, in Dardis G.F. and Moon, B.P., (eds) 1988: **Geomorphological studies in Southern Africa,** Balkema, Rotterdam

Watson, H.K., 1990: **A comparative study of soil erosion in the Umfolozi Game Reserve and adjacent KwaZulu area from 1937 to 1983**, Unpublished PhD. Thesis, Univ. of Durban Westville.

Watson, H.K., 1993: An assessment of the validity of the general perception of soil erosion in the Mfolozi catchment, South Africa, **Geookodynamik**, 14, 1/2, 75-84.

Watson, H.K., 1996: Short and Long term influence on soil erosion of settlement by peasant farmers in KwaZulu Natal, **S. Afr. Geogr. Journ.**, 78 (in press).

Watson, H.K. and Poulter, A., 1987 : **Erodability of soils at Cathedral Peak in the Natal Drakensburg,** Paper presented at forestry research Institute Symp. on 50 years of research in mountains catchments in South Africa, Stellenbosch, Nov., 1-5.

Watson, H.K., Ramokgopa, R and Looser, J.U., 1996: The distribution of erosion in the Mfolozi Drainage Basin - implications for sediment yield control, Proc. Intern. Ass. of Hydro. Sci., **International Symp. on Erosion and Sediment yield: Global and Regional Perspective,** 15 - 19 July, Exeter, UK.

Weaver, A. Van B., 1988: Changes in landuse and soil erosion in South Africa and Ciskeian portions of the yellowwoods drainage basin between 1975 and 1984, **Earth Science Reviews**, 25, 501 - 507.

Weaver, A. Van B., 1989: Soil erosion rates in Roxeni Basin, Ciskei, **South African Georgr. Journ,** 71, 1, 32-37.

Weaver, A. Van B. and Hughes, D.A., 1985: The estimation of rainfall erosivity values for Ciskei, **Proc. Tall Timber Fire Ecology Conf.,** 11, 121-145

Westmann, W.E., 1985: **Ecology, impact assessment, and environmental planning**, John Wiley and Sons, USA.

Whitlow, J.R., 1988: **Land degradation in Zimbabwe, a geographical study,** Rep. Dept. of Natural Resources, 1-62.

William, D.C, 1992: Measuring the impact of land reform in Nigeria, **Journal of Modern African Studies 30,** 4, 587-608.

Wiersum, K.F., 1985: Effects of various vegetation layers of an *Acacia auriculiformis* forest plantation and surface erosion in Java, Indonesia, in El-Swaify, S.A., Mouldenhauer, W.C. and Lo, A., (eds) 1985, **Soil erosion and conservation,** Soil Sci. Soc. Am., 79-89.

Wischmeier, W.H., 1959: A rainfall erosion index for Universal Soil Loss Equation, **Proc. Soil Sci. Soc. of America,** 23, 246-249.

Wishmeier, W.H., Johnson, C.B. and Cross, B.V., 1971: A soil erodibility nomograph for farmland and construction sites, **Journal Soil and Water Conservation,** Sept. - Oct., 189-193.

Xulu, B.S. 1992: **A critical analysis of the South African land question**, Unpubl. BA (HONS) Thesis, University Of Zululand.

APPENDIX

1. Distribution of subcatchments and landtypes in regions

QUART. NO.	SIZE Km^2	LANDTYPES	SIZE (Km$^{2)}$
W211	275	AB	41
		AC	170
		BA	20
		BB	2
		CA	20
		DB	5
		FA	10
		FB	29
W212	127	AC	74
		BA	6
		BB	2
		CA	14
		FB	31
W213	240	AC	193
		CA	2
		FA	39
		FB	6
W214	280	AC	17
		BA	2
		BB	51
		CA	58
		DB	12
		DC	86
		EA	12
		FB	41
W215	130	AC	1
		BB	25
		BD	23
		CA	34
		DC	40
		EA	1
		FB	2

W216	258	AC	124
		BA	4
		BB	107
		BD	8
		CA	1
		DC	1
		FA	7
		FB	6
W217	188	BB	8
		BD	9
		CA	45
		EA	31
		FB	22
W224	220	BD	3
		CA	139
		EA	26
		FA	3
		FB	21
		IB	38
W225	355	AB	5
		CA	139
		EA	150
		FA	18
		FB	54
		IB	18
W241	340	BA	24
		BB	161
		BD	10
		CA	2
		DB	23
		EA	34
		FA	2
		FB	63

W242	415	AB	1
		AC	89
		AD	22
		BA	40
		BB	134
		BD	8
		CA	28
		DB	7
		DC	7
		FA	53
		FB	29
		IB	5
W243	210	AB	2
		AC	38
		BD	84
		CA	1
		EA	14
		FA	9
		FB	64
W244	205	AB	16
		AC	18
		BB	63
		DB	36
		FA	41
		FB	20
		IB	7
W231	165	AB	10
		CA	89
		DB	51
		FA	37
		FB	5
		IB	4
W232	226	AB	12
		CA	51
		DB	9
		FA	44
		FB	88
		IB	22

W233	160	AB	12
		AC	38
		BB	240
		CA	16
		EA	45
		FA	12
		FB	

Table 1.1: Aerial coverage of subcatchments and landtypes in the Upper Former Natal

QUART. NO.	SIZE (Km^2)	LANDTYPES	SIZE (Km^2)
W221	216	BB	3
		CA	9
		DB	24
		DC	93
		FB	5
W222	410	AB	7
		BB	117
		CA	190
		DB	11
		DC	10
		EA	10
		FA	6
		FB	60
		IB	10
W223	310	BB	26
		BD	9
		CA	158
		DC	47
		EA	29
		FA	5
		FB	21
		IB	19

Table 1.2: Aerial coverage of subcatchments and landtypes in the Upper Former KwaZulu

QUART. NO.	SIZE-Km^2	LANDTYPES	SIZE(Km^2)
W226	340	AC	5
		BD	11
		EA	25
		FA	32
		FB	262
		IB	10
W234	175	AC	4
		FA	110
		FB	61
W235	118	AC	19
		BB	3
		FA	86
		FB	13
W236	225	AC	5
		FA	161
		FB	49
		IB	10
W237	285	AB	13
		FA	90
		FB	189
W238	185	AC	10
		EA	7
		FA	141
		FB	382
W245	285	AB	20
		AC	104
		BB	17
		CA	19
		FA	12
		FB	108
W246	260	AB	25
		AC	8
		CA	3
		FA	45
		FB	106

W247	270	AB	15
		AC	109
		BB	3
		DC	11
		FA	5
		FB	89
W248	285	AB	5
		AC	15
		BD	3
		CA	16
		EA	3
		FA	73
		FB	68
W251	255	AC	26
		FA	52
		FB	158
W252	265	AB	13
		DB	122
		FA	43
		FB	93
W253	125	AC	21
		FA	4
		FB	89
W254	135	AB	14
		EA	38
		FA	37
		FB	40
W255	305	AB	7
		DB	28
		EA	31
		FA	22
		FB	214

Table 1.3: Aerial coverage of subcatchments and landtypes in the Middle Former KwaZulu

QUART. NO.	SIZE- Km^2	LANDTYPES	SIZE (Km^2)
W239	140	DB FA FB	27 14 101
W256	190	AB DB FA FB	3 22 27 136
W261	90	FB	105
W262	170	FA FB	13 135

Table 1.4: Aerial coverage of subcatchments and landtypes in the Game Reserve

QUART. NO.	SIZE- Km^2	LANDTYPES	SIZE (Km^2)
W263	185	DB EA FA FB	11 3 7 163
W264	225	DB EA FB	11 115 110
W265	240	DC EA FB IA	2 10 81 27

Table 1.5: Aerial coverage of subcatchments and landtypes in the Lower Former KwaZulu

QUART. NO.	SIZE-Km^2	LANDTYPES	SIZE (Km^2)
W266	505	DC	15
		EA	13
		HA	87
		HB	21
		IA	80
W267		AB	11
		AC	5
		DC	6
		EA	29
		FB	9
		HA	143
		HB	69
		IA	7

Table 1.6: Aerial coverage of subcatchments and landtypes in the Lower Former Natal

2. Densities of different erosion features in subcatchments

	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	RELIEF	ANT DUMPS	TOTAL	SEVE RITY
W211	0,01	0,01	0,03	0,01	0	0	0,05	0	0,01	0,12	VL
W212	0,06	0,06	0,01	0,01	0	0	0,8	0,02	0	0,24	L
W213	0,02	0,04	0.03	0,02	0,00	0	0,1	0,02	0,01	0,24	L
W214	0,09	0,08	0,05	0,09	0	0,18	0,01	0	0	0,40	M
W215	0,11	0,05	0,09	0,12	0	0,32	0	0,01	0	0,70	H
W216	0,01	0,03	0,03	0,09	0,11	0,01	0,17	0,05	0	0,58	H
W217	0,25	0,05	0,06	0,16	0,05	0,08	0	0	0	0,64	H
W224	0,24	0,09	0,04	0,08	0	0,38	0,00	0,01	0	0,86	VH
W225	0,47	0,22	0,06	0,05	0,20	0,01	0,02	0,07	0	1,12	VH
W231	0,84	0,30	0,17	0,22	0,36	0	0,02	0	0	1,92	VH
W232	0,70	0,27	0,14	0,09	0,58	0	0,02	0	0	1,80	VH
W233	0,35	0,14	0,08	0,09	0,68	0	0	0	0	1,33	VH
W241	0,53	0,24	0,11	0,07	0,29	0,07	0,07	0,01	0,11	1,50	VH
W242	O,39	0,15	0,06	0,05	0,45	0	0,12	0,02	0	1,34	VH
W243	0,44	0,34	0,15	0,06	0,48	0,19	0,02	0	0	1,69	VH
W244	0,47	0,28	0,07	0,15	0,39	0	0,05	0,07		1,49	VH

Table 2.1: Erosion densities of Upper Former Natal

	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	RELIEF	DUMPS	TOTAL	SEVE RITY
W221	0,17	0,05	0,06	0,11	0,16	0,06	0,03	0,10	0	O,65	H
W222	0,11	0,13	0,07	0,09	0	0,2	0,05	0,05	0	O,71	VH
W223	0,07	0,05	0,04	0,08	0,09	0,30	0	0	0	0,65	H

Table 2.2: Erosion densities in the Upper Former KwaZulu

	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	RELIEF	DUMPS	TOTAL	SEVE RITY
W226	0,44	0,18	0,14	0,12	0,03	0	0,06	0,01	0	1,26	VH
W234	0,30	0,31	0,28	0,10	0,77	0	0	0	0	1,77	VH
W235	0,11	0,03	0	0	0,25	0	0	0	0	0,39	M
W236	0,26	0,13	0	0	0,34	0	0	0	0	0,37	M
W237	0,21	0,08	0,02	0,02	0,59	0	0	0	0	0,92	VH
W238	0,04	0,01	0	O	0,62	0	0	0	0	0,67	H
W245	0,42	0,27	0,15	0,18	0,73	0	0	0	0	1,77	VH
W246	0,25	0,21	0,09	0,13	1,08	0.01	0	0	0	1,79	VH
W247	0,52	0,33	0,13	0,09	0,87	0	0,07	0,01	0	1,97	VH
W248	0,36	0,16	0,10	0,05	0,45	0	0	0	0	1,14	VH
W251	0,30	0,13	0,12	0,01	0,84	0	0	0	0	1,62	VH
W252	0,08	0,04	0,02	0,01	0,71	0	0	0	0	0,87	VH
W253	0,06	0,03	0,03	0,01	0,77	0	0	0	0	0,89	VH
W254	0,25	0,09	0,01	0	0,71	0	0	0	0	1,05	VH
W255	0,07	0,03	0,01	0,01	0,93	0	0	0	0	1.06	VH

Table 2.3: Erosion densities in the Middle Former KwaZulu

	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	ANT DUMP	RELIEF	TOTAL	SEVE RITY
W239	0,01	0.01	0	0	0,14	0	0	0	0,02	0,24	M
W256	0,04	0,01	0,01	0	0,28	0	0	0	0	0,35	M
W261	0,15	0	0	0	0,12	0	0	0	0	0,28	M
W262	0,05	0	0	0	0,11	0	0	0	0	0,16	M

Table 2.4: Erosion densities in the Middle Game Reserve

	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	DUMPS	RELIEF	TOTAL	SEVERITY
W263	0	0	0	0	0,14	0	0	0	0	0,14	L
W264	0	0,01	0	0	0	0	0	0	0	0,01	VL
W265	0	0	0	0	0	0	0	0	0	0	VL

Table 2.5: Erosion densities in the Lower Former KwaZulu

	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	DUMPS	RELIEF	TOTAL	SEVE RITY
W266	0	0	0	0	0	0	0	0	0,01	0,01	VL
W267	0	0	0	0	0	0	0,01	0	0	0,01	VL

Table 2.6: Erosion densities in the Lower Former Natal

3. Densities of different erosion features in highly eroded landtypes

	LAND TYPE	G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	RELIEF	DUMPS	TOTAL
W215	BB	0,25	0,12	0,28	0,08	0	0,25	0	0	0	0,98
	BD	0,17	0,04	0	0,21	0	0,21	0	0	0	0,63
W217	CA	0,31	0,02	0	0,14	0,15	0,33	0	0	0	0,95
	FB	0,4	0	0,18	0,22	0	0	0	0	0	0,8
	BB	0,25	0,08	0,07	0,16	0	0	0	0	0	0,56
W224	CA	0,25	0,12	0,03	0,1	0	0,57	0,02	0	0	1,09
	EA	0,07	0,03	0,03	0,03	0	0,8	0	0	0	0,96
W225	FB	0,88	0,57	0,12	0,16	0,44	0	0,47	0,39	0	3,03
	CA	0,52	0,19	0,05	0,03	0,07	0,04	0	0,02	0	0,92
	IB	0,4	0,11	0,05	0	0,16	0	0	0	0	0,72
W231	CA	0,85	0,37	0,23	0,17	0,55	0	0,04	0	0	2,21
	AB	0,8	O,2	0,1	0,2	0,2	0	0	0	0	1,5
	FA	0,27	0,35	0,16	0,36	0,18	0	0	0	0	1,32
	IB	0,5	0,25	0,25	0	0,15	0	0	0	0	1,15
	DB	0,75	0	0	0,12	0	0	0	0	0	0,87
W232	CA	0,96	0,27	0,12	0,03	0,95	0	0,05	0	0	2,38
	DB	0,81	0,66	0,11	0,33	0	0	0	0	0	1,91
	FA	0,88	0,4	0,11	0,13	0,09	0	0	0	0	1,61
	FB	0,59	0,23	0,15	0,07	0,53	0	0	0	0	1,57
	IB	0,27	0,09	0,22	0,04	0,22	0	0	0	0	0,84
W233	EA	0,25	0,25	0,13	0,18	0,88	0	0	0	0	1,69
	AC	0,36	0,15	0,1	0,24	0,63	0	0	0	0	1,48
	AB	0,25	0,33	0,16	0	0,41	0	0	0	0	1,15
	FA	0,24	0,02	0,04	0,02	0,88	0	0	0	0	1,01
	FB	0,25	0	0,16	0	0,66	0	0	0	0	1,07
	CA	0,82	0,17	0	O,02	0,3	0	0	0	0	1,07
W241	CA	0,5	1	0	0	1	0,5	0	0	0	3
	BD	0,5	0,2	0,3	0,1	0,8	0	0	0	0	1,9
	EA	0,7	0,32	0,23	0,05	0,32	0	0	0	0	1,72
	DB	0,95	0,17	0,04	0,17	0,34	0	0,01	0	0	1,68
	FB	0,61	0,34	0,11	0,06	0,38	0	0	0	0	1,5
	BA	0,41	0,2	0,88	0	0,41	0	0,3	0	0	1,4
	BB	0,56	0,19	0,1	0,04	0,14	0,06	0,09	0,04	0,04	1,26
	FA	0,33	0,25	0	0,08	0,5	0	0	0	0	1,16
W242	BD	0,91	0,1	0,2	0	0,9	0	0	0	0	2,11
	DB	0,42	0,14	0	0	0,28	0	0,25	0	0	1,09
	IB	0,8	0,2	0,2	0	0,8	0	0	0	0	2
	AD	0,4	0,36	0,09	0	0,81	0	0	0	0	1,66
	AC	0,19	0,13	0,05	0,05	0,4	0	0,08	0,02	0,5	1,42
	BB	0,53	0,16	0,08	0,11	0,37	0	0,17	0	0	1,42
	DC	1	0,14	0,28	0	0	0	0	0	0	1,42
	FA	0,45	0,2	0	0	0,77	0	0	0	0,01	1,43
	FB	0,31	0,1	0	0	0,34	0	0,06	0	0	0,81
W243	BD	0,44	0,44	0,15	0,1	0,41	0,33	0,07	0	0	1,94
	AC	0,39	0,39	0,13	0,02	0,8	0	0	0	0	1,73
	AB	0,5	0,5	0	0	0,5	0	0	0	0	1,5
	FB	0,51	0,26	0,2	0,01	0,23	O,2	0	0	0	1,41
	FA	0,22	0,11	0,11	0,11	0,55	0	0	0	0	1,1
W244	FB	0,6	0,75	0,25	0,05	0,95	0	0	0	0	2,6
	DB	0,69	0,27	0,05	0,02	0,75	0	0,13	0	0	1,91
	AB	0,68	0,18	0,18	0,24	0,56	0	0	0	0	1,84
	BB	0,3	0,3	0,04	0,34	0	0	0,03	0.2	0	1,21
	FA	0,31	0,15	0,02	0	0,53	0	0,07	0	0	1,08

Table 3.1: Erosion densities of erosion features in landtypes in the Upper Former Natal

		G1	G2	G3	G4-11	UCON	BADLANDS	MASS	RELIEF	ANTH	TOTAL
W221	DB	0,25	0,08	0,04	0,08	0,08	0,33	0,16	0,04		1,06
	DC	0,14	0,03	0,04	0,12	0,25	0,06	0,03	0,01		0,68
W222	FA	0,33	0,16	0,16	0,66				0,08		1,39
	CA	0,12	0,12	0,08	0,1		0,09	0,11	0,05		0,67
	FB	0,06	0,05	0,1	0,01		0,38		0,01		0,61
	IB	0,1	0,3			0,2					0,60
W223	FA	0,8	0,8	0,4	0,8	0,85	0,4				4,05
	CA	0,5	0,25	0,25	0,57		0,35				1,92
	IB	0,1	0,05	0,05	0,05	0,1					1,25
	EA	0,1	0,4	0,1	0,2		0,4				1,2
	FB	0,09		0,04	0,09		0,9				1,12
	BB	0,15	0,03	0,07	0,27	0,15	0,19				0,86

Table 3.2: Erosion densities of erosion features in landtypes in the Upper Former KwaZulu

		G1	G2	G3	G4-11	UNCON	BADLANDS	MASS	RELIEF	ANTH	TOTAL
W226	BD	0,9	0,5	0,3	0	0,6	0	0	0	0	2,3
	EA	0,64	0,4	0,32	0,16	0,28	0	0	0	0	1,8
	FA	0,5	0,31	0,25	0,12	0,18	0	0	0	0	1,36
	IB	0,4	0,26	0,06	0,66	0,4	0	0	0	0	1,18
	AC	0,6	0	0	0	0,6	0	0	0	0	1,2
	FB	0,38	0,14	0,09	0,11	0,2	0	0,08	0	0	1
W234	FA	0,31	0,36	0,31	0,12	0,86	0	0	0	0	1,96
	FB	0,29	0,24	0,22	0,04	0,65	0	0	0	0	1,44
W237	AB	0,53	0,3	0,07	0,07	0,15	0	0	0	0	1,12
	FB	0,2	0,04	0,02	0,01	0,67	0	0	0	0	0,94
	FA	0,23	0,12	0	0,02	0,47	0	0	0	0	0,84
W238	FA	0,04	0,01			0,72					0,77
	AC					0,6					0,6
W245	AB	0.42	0,42	0,57	0,62	0,78					2,81
	BB	0,8	0,52	0,23	0,05	0,9					2,5
	AB	0,9				0,9					1,8
	AC	0,33	0,24	0,13	0,23	0,77					1,7
	FB	0,46	0,25	0,12	0,08	0,68					1,59
	FA	0,08	0,33	0,08		0,66					1,15
W246	AB	0,36	0,32	0,2	0,48	0,88					2,24
	AC	0,22	0,18	0,1	0,19	0,88	0,05				1,62
	FB	0,29	0,2	0,04	0,03	0,99					1,55
	FA	0,44	0,11	0,06	0,07	0,86					1,54
	CA					0,91					0,91
W247	FA	0,71	0,26	0,06	0,15	1,5					2,68
	BB	0,66	0,33	0,33		0,98		0,03			2,3
	AB	0,71	0,66	0,06		0,79					2,22
	DC	0,72	0,36	0,04		0,9					2,02
	FB	0,44	0,33	0,22	0,05	0,82					1,86
	AC	0,36	0,3	0,09	0,09	0,51					1,38
W248	CA	0,68	0,31	0,18	0,06	0,93					2,16
	AB	0,6	0,4	0,2	0,2	0,2					1,6
	FB	0,39	0,19	0,1	0,03	0,47					1,18
	AC	0,46	0,06	0,26	0,2	0,06					1,04
	FA	0,39	0,19	0,1	0,03	0,39					0,7
W251	FB	0,7	0,31	0,37	0,67	2,35					4,4
	AC	0,5	0,26	0,07	0,14	0,65					1,54
	FA	0,32	0,13	0,09	0,10	0,9					1,62
W252	FB	0,16	0,01	0,01	0,01						1,13
	DB	0,06	0,04	0,04	0,03						0,85
	AB					0,76					0,76
W253	FB	0,27	0,05			1					1,32
	AC	0,19	0,04	0,09		0,61					0,93
W255	EA	0,03	0,06	0,03		0,96					1,08
	FB	0,09	0,02	0,01		0,84					0,96
	AB					0,57					0,57
W254	EA	0,25	0,14	0,02		0,88					1,29
	FB	0,08	0,05	0,01		0,84					0,98
	FA	0,08	0,05	0,01		0,54					0,86

Table 3.3: Erosion densities of erosion features in landtypes in the Middle Former KwaZulu

		SLOPE LENGTH	SLOPE SHAPE	SLOPE ANGLE	SOILS	GEOLOGY	VELDTYPE	BIOCLIMATE
AB	GULLY1				-0,24	0,36	-0,22	
	GULLY2	0,21	0,27	0,3	-0,32			
	GULLY3	0,24	-0,25		-0,33		-0,22	0,33
	GULLY4	0,20	0,20		-0,23		-0,19	0,53
	UNCON.		0,23		0,46	-0,32	0,43	
	MASS		-0,21	0,41				
	BADL.	0,35	-0,32		-0,25			
	MINED.							
	RELIEF				-0,25	0,50		
AC	GULLY1	-0,32		-0,5	-0,20			
	GULLY2	-0,38		-0,45				
	GULLY3			-0,61	-0,22			
	GULLY4			-0,55				0,39
	UNCON							-0,42
	MASS		-0,39	0,32				-0,32
	BADLAN							0,76
	DUMPS	-0,33				0,97		0,34
	RELIEF							
BB	GULLY1	0,02				0,68	0,30	0,37
	GULLY2				0,35	0,79		0,56
	GULLY3				0,34			
	GULLY4				0,23			
	UNCON	-0,2				0,85		0,61
	MASS				-0,22	0,21	0,72	0,40
	BADL		-0,43	-0,269	-0,19	-0,23		
	DUMPS							
	RELIEF	0,34			-0,23	-0,26		
CA	GULLY1	0,49			0,58			
	GULLY2		0,31					
	GULLY3		0,30		-0,22	0,19		
	GULLY4			0,64	-0,31			
	UNCON	-0,19		0,72	-0,30			
	MASS				-0,42			
	BADL			0,62	-0,22			
	DUMPS							
	RELIEF				0,24			
DB	GULLY1	-0,29						0,35
	GULLY2					-0,22		
	GULLY3					-0,25		
	GULLY4	-0,28		-0,28				
	UNCON		0,31	0,28	-0,33	0,49	0,45	0,46
	MASS			-0,22			0,27	
	BADL	0,32		-0,63	0.90	0,24		
	DUMPS							
	RELIEF			-0,35	0,34			
DC	GULLY1	0,35			-0,51	-0,22	0,76	0,82
	GULLY2	0,69	0,47		-0,19	0,35		
	GULLY3		-0,35	-0,33	-0,55	0,49	0,82	0,88
	GULLY4	0,26	-0,63	-0,35	0,51	-0,21		
	UNCON	0,51			0,93		-0,23	0,27
	MASS	0,27	-0,44				0,19	
	BADL	0,30		-0,60	0,37	0,98		-0,19
	DUMPS							
	RELIEF			-0,32	-0,39	1,00		

FA	GULLY1	-0,28	-0,21					
	GULLY2							
	GULLY3							
	GULLY4							
	UNCON	-0,41	-0,52		0,23			0,29
	MASS	0,45	0,33	-0,54				
	BADL					0,30		0,29
	DUMPS						0,80	
	RELIEF							
FB	GULLY1		0,43		-0,30	-0,24	0,22	
	GULLY2				-0,21	-0,20		
	GULLY3				-0,22			
	GULLY4							
	UNCON		0,21		-0,25	-0,25		
	MASS			0,24				
	BADL							
	DUMPS							
	RELIEF			0,27	0,23			

Table 4: Significant correlations of erosion features and biophysiographic factors in landtypes

PRINCIPLE COMPONENT ANALYSIS

I		II		III		IV	
Slope Shape Slope Angle Bioclimate Slope Length Soils Precipitation	0.9 0.86 0.87 0.83 0.79 0.79	Gullies 1 Gullies 2 Gullies 3 Gullies 4-11	0.87 0.90 0.88 0.75	Anthropogenically Influenced Dumps	0.92	Mass Wasting	0.92
V		VI		VII			
Terrain Unit	0.9	Geology	0.84	Unconfined Erosion	0.88		

Table 5: Loadings of Rotated Eigenvectors (PCA)