What are the costs of land degradation to communal livestock farmers in South Africa?

The case of the Herschel District, Eastern Cape

Susanne Vetter

April 2003

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ABSTRACT

For several decades, there has been growing concern about the state of communally grazed rangelands in South Africa and other parts of the continent, and the sustainability of communal farming practices has been questioned. In the past, the perception that overgrazing causes land degradation has led to the implementation of betterment planning, forced destocking and other government interventions in the former homeland areas of South Africa. A more recent approach to communal rangelands argues that this traditional view has ignored communal farmers' objectives, which are to maximise stock numbers rather than offtake in the form of sales and slaughter, and challenges the view that communal rangelands are necessarily degraded. Long-term livestock records in many former homeland districts of South Africa have shown no appreciable long-term decline in animal numbers. This has led several influential researchers and policy makers to conclude that no loss in productivity has occurred and that these systems are sustainable in fulfilling the objectives of the land users.

The aim of this study is to assess the costs of degradation in terms of land users' objectives using a case study in a communal rangeland area in South Africa. The Herschel District in the North-Eastern Cape is considered to be one of the most severely degraded areas in the country, as measured by vegetation changes, reduced plant cover, invasion by unpalatable shrubs and soil erosion. Livestock records however show that total stock numbers have not declined over the last hundred years. District borders have not changed during that period, and the livestock census data are generally held to be reliable and consistent over the years. Does this mean that, in terms of land users' objectives, no degradation has occurred?

To answer this, the following key questions are addressed:

1. What are the objectives of livestock owners in Herschel?
2. Does degradation go back as far as the livestock records – and how has it changed over that period?
3. How have livestock owners in Herschel maintained high stock numbers?

The objectives of livestock owners in Herschel differ between livestock species. The most important function of cattle is as a store of wealth and a form of insurance for times when cash is required. People also keep cattle for slaughter on traditional occasions such as funerals and weddings, milk, ploughing and lobola (dowry). The most important benefits

are thus realised from live animals, not offtake. Sheep are primarily kept for wool production, slaughter and sale, and goats are kept for slaughter and sale. The benefits of small stock are thus derived from offtake rather than maximum number. However, under the communal land use system where all residents have free access to the grazing land, stock owners maximise stock numbers to achieve maximum offtake. Total stock numbers in the district thus reflect the maximum possible and not a regulated stocking rate with an aim to production.

To determine the present status of soils and vegetation in Herschel, I analysed transect data which show that Herschel has lower average basal cover, more erosion and distinctly different grass composition than surrounding commercial farming districts. Geology and slope play a secondary role in influencing grass composition and cover. At higher altitudes, Herschel is characterised by higher cover of Karoo shrubs. Steeper slopes and lower incident solar radiation are correlated with increased shrub cover.

I used the literature, interviews with people in Herschel and aerial photographs dating back to 1950 to reconstruct changes in soil erosion in Herschel. The literature suggests that the first signs of decline were observed in the late 19th century, and by the 1920s, the district was found to be degraded with low agricultural productivity. From then on, Herschel is repeatedly described as a worst case scenario in South Africa, but it is difficult from the literature to deduce changes in degradation levels over time. Interview data indicate that degradation has increased in living memory, and it is a common perception that betterment planning, which was implemented between 1961 and 1963, led to dramatic increases in soil erosion as a result of land use change and a lack of sense of ownership after people were forcibly moved into villages. The aerial photographs show that erosion was already severe and widespread in 1950, that erosion levels differ between areas, and that erosion has increased considerably since 1950.

Given that farmers endeavour to maximise stock numbers, and that stock numbers have not declined while degradation has increased substantially, the question remains of how these high stock numbers have been maintained. Interview data with livestock owners in four study areas indicate that farmers have changed their resource use and inputs over time. Grazing patterns have changed from seasonal transhumance to occupation of all grazing areas year round. While total stock numbers have remained the same, stock composition has changed: cattle numbers have remained the same, but a decline in sheep numbers has been accompanied by an increase in goat numbers. Buying livestock from outside the district to maintain herds and replace drought losses is becoming increasingly common in Herschel, as are the cultivation and purchase of feed inputs and provision of veterinary medicines. Although stock numbers have stayed the same, the condition, growth rates and reproductive output of livestock has decreased. There is also evidence that crop production has declined.

To determine to what degree ecological factors and feed inputs play a role in maintaining stock numbers, I performed a multiple regression analysis using stocking rates (of cattle, sheep, goats and total LSU) in 1974, the 1980s and 1997 as response variables. Independent variables were rainfall, geology, slope, altitude and temperature which are related to ecological carrying capacity, and human population density and the percentage of the area consisting of arable land which are related to inputs such as feed. The regression results show that human population densities become increasingly strong, and ecological factors increasingly weak, predictors of cattle and sheep densities. These results suggest that livestock numbers are increasingly being maintained through the provision of feed and other inputs.

In conclusion, the assumption that livestock farmers primarily aim to maximise stock numbers is too simplistic and does not take real objectives into account. In practice, stock owners have been maximising animal numbers. Over the time period that these stock numbers have been maintained, soil erosion has spread and intensified substantially, though this varies within the district. There is evidence that productivity has declined and that stock numbers are increasingly maintained by inputs such as feed. The costs of degradation are thus twofold. Firstly, it is becoming increasingly expensive for stock owners to maintain less productive stock. Secondly, there are clearly environmental costs such as severe soil loss, and the fact that stocking rates remain high during and after droughts poses increased risks for further degradation.

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CONTENTS

1. INTRODUCTION

For most of this century, there has been concern about the state of communally grazed rangelands in Africa and other parts of the world. Communal rangelands are commonly viewed as overstocked, overgrazed, degraded and unproductive (e.g. Lamprey 1983, Sinclair and Fryxell 1985), and this has resulted in interventions aimed at reducing numbers of livestock in an attempt to halt degradation. More recently, this way of viewing communal grazing systems has come under considerable criticism regarding its economic and ecological assumptions, and the idea that communal rangelands are necessarily degraded is now widely challenged (e.g. Sandford 1983, Homewood and Rodgers 1987, Ellis and Swift 1988, Behnke and Scoones 1993, Behnke and Abel 1996, Sullivan and Rohde 2002).

Communal rangelands and their associated residential areas make up 13% of the land surface of South Africa and support a quarter of the country's population and half the country's livestock (Scogings et al. 1999). Land reform and restoration of land to people forcibly removed during the colonial and apartheid periods is resulting in more land coming under communal tenure of some form, and thus the issue of sustainability and degradation in communal rangelands is receiving renewed attention in South Africa.

Much of the work examining degradation and productivity of communal rangelands has been based on comparisons between communal and commercial farming areas (e.g. Venter, Liggit et al. 1989, Fabricius and Burger 1997, Todd et al. 1998, Ward et al. 1998, Todd and Hoffman 1999). This is useful for purposes of assessing how communal land use affects various properties of a system such as biodiversity and species richness (e.g. Shackleton 1998, Todd et al. 1998, Todd and Hoffman 1999), plant composition, cover and productivity (e.g. Kelly and Walker 1976, McKenzie 1982, Forbes and Trollope 1991, Evans et al. 1997, Parsons et al. 1997, Palmer et al. 1998), soil erosion (Weaver 1988a, Garland and Broderick 1992, Kakembo 1997, Hoffman et al. 1999), rain use efficiency (Ward and Ngairorue 2000), animal performance (Masika et al. 1998) and total economic value of products and services (Shackleton 1993, Shackleton et al. 2000). However, there are some limitations to this approach, which several of the authors of the studies cited above acknowledge. Firstly, it implies that commercial farming is conducted in a sustainable manner and forms an ideal benchmark against which other types of land use should be measured, which is not necessarily the case. More importantly, such comparisons do not take into account the different objectives and constraints of the communal farming systems, which need to be understood when assessing and recommending land use practices. If sustainable and productive ways of managing land use within communal tenure systems are to be identified, comparisons within or between communal systems (e.g. de Bruyn 1998, Goqwana 1998) are more meaningful.

Range scientists, development agents and policy makers are increasingly urged to assess degradation and sustainability in terms of land users' objectives. In a situation where large numbers of people live in poverty, it is fair to argue that priority must be given to sustainability of livelihoods over pure conservation objectives. In the light of policy changes and agricultural and land reform in South Africa, this study aims to assess the costs of apparent environmental degradation in terms of livestock owners' objectives in a case study of a communal farming district.

1.1 Background: the debate about degradation and sustainability in communal rangelands

1.1.1 Equilibrium or non-equilibrium? Dealing with temporal and spatial variability in rangelands

The traditional approach to range management is based on the assumption that a dynamic equilibrium exists between grazing animals and their forage resource, and that there is constant feedback between the two. Every environment has a certain carrying capacity, which is determined by rainfall, soils and other biophysical characteristics of the area, which determine the potential primary production (Bell 1982, Fritz and Duncan 1994). The actual carrying capacity in an area is determined by veld condition, a term referring to functional attributes of the vegetation such as its potential for forage production and resistance to soil erosion (Trollope et al. 1990). Veld condition is a function of grass composition, biomass and basal cover and is seen as a stage in plant succession which can be manipulated predictably with stocking rate (Dyksterhuis 1949, Smith 1988, Trollope 1990). No, or very light, grazing allows the vegetation to reach its climax stage, whereas heavy grazing pushes it back to a pioneer stage dominated by generally low-quality grass and forb species typical of disturbed environments. Veld management aims to maintain the vegetation in a maximally productive climax or subclimax stage (Whittaker 1953), depending on vegetation type, by adjusting stocking rates, rotational grazing and resting, and applying appropriate burning regimes (Foran et al. 1978, Trollope 1990). Rainfall in different years also affects grass production and composition (O'Connor 1985, 1994) and thus influences carrying capacity at different times.

A fundamental assumption of the equilibrium view is that pastoral systems are inherently stable, but are destabilized by overgrazing, a term used for the continuous utilization of rangelands at stocking rates exceeding the carrying capacity of the veld without periodic resting. Overgrazing leads to vegetation changes such as the replacement of palatable grasses with less palatable plant species, bush encroachment, lower standing biomass and reduced basal cover (Dyksterhuis 1949, Tainton and Hardy 1999). These in turn result in accelerated soil erosion, as well as a decrease in forage quality and availability, and ultimately an irreversible decline in animal production unless stocking rates are reduced. Overgrazing is thought to be inevitable in communal pastoral systems because people keep more livestock than they need for a variety of reasons (Lamprey 1983), and because of the problems inherent in communal ownership of the resource, where individual benefit is maximised at the expense of the communal resource (Hardin 1968).

Planning and management of African communal rangelands have generally followed the equilibrium model and the assumption that these systems are overstocked and degraded. This has led to government interventions such as destocking schemes, conversion of communal areas into individually managed "economic units" and settling of nomadic pastoralists into group ranches (Sandford 1983, Ellis and Swift 1988, Archer et al. 1989, Rohde et al. 1999,). In South Africa, betterment planning involved resettling people into planned villages, rezoning arable land, converting land unsuitable for cultivation to grazing land and fencing off grazing camps for rotational grazing. The main focus of these interventions has been on preserving natural resources, with the additional intention of increasing livestock production and offtake. These schemes have met with widespread resistance, not least because they ignored the objectives, aspirations and socio-economic conditions of the communal farmers. Interventions often seemed to create or exacerbate, rather than solve, degradation problems and left many people economically worse off than before (Desmond 1969, Ellis and Swift 1988, Hoffman et al. 1999).

The rangeland nonequilibrium paradigm developed in the 1980s in response to a growing concern that interventions aimed at stabilizing spatially and temporally variable rangelands were inappropriate and damaging to pastoralist livelihoods (Sandford 1982, 1983). At the same time, there was an increasing recognition in ecology outside rangeland systems that equilibrium concepts were not able to describe the dynamics of many ecological systems (Wiens 1977 and 1984, DeAngelis and Waterhouse 1987) and that nonequilibrium systems needed a fundamentally different paradigm. Ellis and Swift (1988) and Westoby et al. (1989) applied nonequilibrium concepts to rangeland systems and pointed out that a fundamental misunderstanding of their ecological dynamics was leading to inappropriate and failed interventions. While these authors acknowledge that equilibrium and nonequilibrium dynamics are extremes along a continuum and that a range of conditions exists in-between, the equilibrium ideas of stability and predictability have always been the most pervasive in ecology and range management (Ellis and Swift 1988).

Ellis and Swift (1988), based on research in the Turkana District of northern Kenya, argue that the equilibrium assumptions underpinning conventional range management are inappropriate in areas that experience low and highly variable rainfall. In these systems, the main driving force determining forage availability every year is not grazing intensity, but rainfall. Due to the extremely short duration of the growing season, the high frequency of droughts, and the great inter- and intra-annual variation of rainfall, the effective carrying capacity (and hence animal numbers) fluctuates considerably between years. Two-year droughts, which are accompanied by severe mortalities, also occur regularly. Herd size builds up gradually in the years following a drought, during which time the vegetation is relatively lightly grazed. An important implication of this is that, in such systems, degradation due to overgrazing is theoretically impossible, since animals seldom if ever reach densities at which they could affect the vegetation.

This rangeland paradigm came into the limelight with the publication of the book "Range ecology at disequilibrium" edited by Behnke et al. (1993). The editors drew together contributions from researchers in ecology, agriculture, development and the social sciences to make the point that variability in rangelands needed to be explicitly understood and incorporated into management and development. This was further stressed in the book "Living with Uncertainty" (edited by Scoones 1994) where authors focus on management and policy implications of temporal and spatial heterogeneity. These two publications drew much attention from researchers, policy makers and development agents, and stimulated an intense debate, accompanied by a whole new body of research, aimed at either refuting or confirming the new paradigm and its application in different contexts.

Much of the heat of the debate was generated by the two paradigms' different predictions for degradation of semi-arid rangelands. The nonequilibrium assertion that degradation is far less common than predicted by the equilibrium concept under true nonequilibrium conditions has been embraced by many policy makers to the point where concerns about degradation and the need to avert it were dismissed (e.g. Dikeni et al. 1996). This provoked much criticism from ecologists concerned about the ecological consequences of uncritically adopting the nonequilibrium paradigm, for example in areas which they felt were not predominantly experiencing nonequilibrium dynamics (e.g. Illius and O'Connor 1999 and 2000, Cowling 2000). Areas where nonequilibrium concepts would be inappropriate include subhumid rangelands with a relatively predictable climate, but also semi-arid, climatically variable areas where the mobility of pastoralists has been severely restricted, or systems where the provision of seasonally scare resources such as feed and water is reducing the temporal variation in animal growth even though rainfall and plant growth are low in drought years. Illius and O'Connor (1999) specifically challenge the notion that fundamentally different dynamics are at work in nonequilibrium systems, and suggest that livestock are in equilibrium with their dry season resource and that this allows degradation of these key resource areas to occur.

The idea that semi-arid, drought-prone rangelands do not degrade relies on the assumption that substantial mortalities occur during droughts and livestock populations take several years to reach pre-drought levels (Ellis and Swift 1988, Behnke and Scoones 1993). Supplementary feeding can increase drought survivorship and reduce the time before livestock can breed after drought stress. Buying in of livestock (and especially breeding stock) can speed up the recovery of the herd to its pre-drought size. In South African communal areas, most livestock owners have cash incomes from migrant labour, local employment, remittances and/or pensions (Cousins 1998), making purchases of feed and stock possible. For example, data presented by Tapson (1993) show remarkably constant stock numbers over a 25-year period, even during and after the severe drought of the early 1980s, in direct contrast to the assertion that die-offs during droughts and long recovery periods are preventing degradation.

Traditionally, pastoralists employ a variety of strategies to cope with the variability of their environment (Sandford 1983, Ellis and Swift 1988). Commercial farmers generally maintain low enough stocking rates to ensure sufficient forage in years with low rainfall. However, it is argued that management based on constant and conservative stocking rates would be inappropriate and costly to farmers in climatically variable systems, as they would be unable to make use of all the available forage in wet years, and would still overstock in very dry years (Sandford 1982; Behnke and Scoones 1993). The opportunity cost of conservative stocking rates increases with increasing rainfall variability and more conservative stocking rates (Sandford 1982, Stafford Smith 1996).

Pastoralists try to minimize drought risks by keeping high numbers of animals, and while they risk substantial losses during a severe drought, this ensures that at least some part of the herd survives after a drought. The bigger the herd belonging to an individual in the communal system, the greater is the number likely to survive, and larger herds thus provide greater security during droughts. Instead of aiming to keep animal numbers constant, pastoralists allow herd size to track rainfall (Sandford 1983 and 1994, Toulmin 1994).

Spatial heterogeneity is also utilised in grazing systems where resource availability and rainfall are not evenly distributed across the landscape (Sandford 1983, Ellis and Swift 1988, Scoones 1995). Pastoralists in arid areas are usually fairly mobile and will move their animals to the best available grazing, covering different areas over the course of the year and between years. Such movements may be in the form of transhumance, which follows a more or less predictable pattern between wet and dry season resources, or more opportunistic movement tracking less predictable patterns of productivity, often caused by patchy rainfall patterns (Coughenour 1991, Bayer and Waters-Bayer 1994). Neighbouring communities often have arrangements for reciprocal grazing rights that pastoralists can make use of in bad years. These movement patterns are thought to enable farmers to maintain high stocking rates even in dry years without putting continuous pressure on the grazing resource throughout the year (Coughenour 1991, Ellis et al. 1993, Stafford Smith 1996). In commercial farming systems, rotational resting fulfils the same function (Coughenour 1991), and this land use system was found to allow the maintenance of high stocking rates without deterioration of the vegetation in semi-arid South African savannas (Matthews 1956, Trollope 1984).

Most rangelands also contain small, highly productive areas that make a disproportionately large contribution to the area's total forage production. Examples are riverine areas, which support green grass growth throughout most of the year, or croplands where animals can graze on crop residues in the dry season. Such "key resource areas" are thought to play a vital role in carrying animals through the dry season bottleneck, and may be responsible for maintaining total animal numbers considerably higher than the predicted carrying capacities, which are based on a homogeneous landscape (Scoones 1993, 1995). In areas where semi-arid areas border on wetter areas where crop production is possible, nomadic pastoralists and settled agriculturalists may have mutually beneficial arrangements where livestock use crop residues in the dry season, allowing the crop farmer to make use of manure. Where such relationships break down, the total number of livestock that can be kept may be considerably reduced as exploitation of the drier areas by pastoralists relies on mobility and access to crop residues in the dry season (Bayer and Waters-Bayer 1994).

Appropriate management in these highly variable systems should aim at supporting flexible responses to droughts, such as pre-empting drought mortality by marketing surplus animals, and offering opportunities to re-stock by buying in animals (Sandford 1983, Toulmin 1994, Behnke and Abel 1996). Ellis and Swift (1988) and Ellis et al. (1993) also stress that to persist through droughts, pastoralists need to be able to expand their operations into areas not normally used for grazing, and to gain access to outside resources. Opportunistic strategies are being recognised as better alternatives to constant, conservative stocking rates, even in commercial systems (Danckwerts et al. 1993). However, the economic efficiency and environmental sustainability of tight tracking strategies, particularly those which rely on buying stock after droughts, are still debated (e.g. Sandford 1994, Illius et al. 1998, Campbell et al. 2000).

While the debate between followers of the disequilibrium theory and those with a more traditional approach has not been resolved, it is increasingly realised that no one rule will describe every system, and that non-equilibrium and equilibrium concepts are extremes along a continuum (e.g. Wiens 1984, Ellis et al. 1993, Stafford Smith 1996). Recent studies (e.g. Ward et al. 1998, Fernandez-Gimenez and Allen-Diaz 1999, Ward et al. 2000, Desta and Coppock 2002) found different responses to intensive grazing in rangelands with different mean annual rainfall and different levels of rainfall variability. The response of the more arid rangelands with more variable rainfall was found to be consistent with non-equilibrium predictions and showed little evidence of grazing induced changes when compared to ungrazed or lightly grazed areas. The more mesic areas, with rainfall coefficients of variation (C.V.) of less than 30%, showed grazing induced changes such as bush encroachment and changes in grass composition. This is consistent with the prediction (Ellis et al. 1993, Ellis 1994) that non-equilibrium dynamics predominate in areas where rainfall C.V. exceeds 33%.

Research needs to focus on identifying which dynamics dominate in which systems and under what circumstances, so that appropriate management strategies can be developed. Many of the economic and ecological arguments made by the "disequilibrium" school of thought have been incorporated into working papers for agricultural policy in South Africa (Cousins 1996, Dikeni et al. 1996). The suitability of these models to the South African context, from an ecological and economic point of view, needs to be critically evaluated before implementing them in South Africa.

1.1.2 What are appropriate criteria for assessing degradation in communal rangelands?

The commercial model is based on farmers' aims to maximise saleable offtake from the herd, and its recommended stocking rates are commonly based on growth curves that maximise meat yield. Unlike commercial farmers, communal farmers are not primarily beef producers; they keep different species of livestock for a number of purposes, such as slaughter, milk production, sale, draught power, manure and a store of wealth. Meat consumption is often a minor component of the benefits derived from cattle, and milk tends to be a far more important product (Coughenour et al. 1985, Tapson 1990). Many authors (e.g. Sandford 1983, Behnke and Abel 1996) argue that these multiple aims are best achieved with bigger herds, even if reproductive rates and the condition of individual animals are compromised. The aim of communal farmers is thus generally accepted to be to maximise total animal numbers.

The Jones and Sandland (1974) model (Figure 1.1), which is based on the theory of logistic population growth and is supported by data from controlled grazing trials, illustrates the relationship between stocking rates and weight gain of cattle. From the graph, we can see that production per animal remains constant, and production per hectare increases linearly, below a certain stocking rate (maximum nutrition, MN). Up to this stocking rate, animals do not compete for grazing. Increasing stocking rates beyond this point result in a linear decrease of production per animal, while the production per hectare increases at a decreasing rate as the contribution of each additional animal is offset by the decreasing weight gain per animal as competition increases.

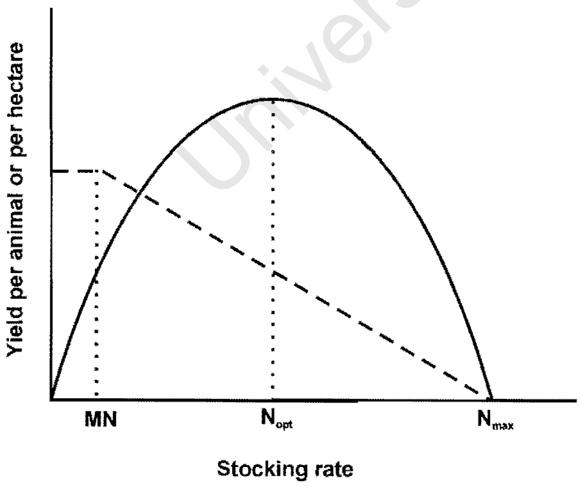

Figure 1.1. Relationship between beef yield per animal (dashed line) and per hectare (solid line) with stocking rate (animals per hectare). After Jones and Sandland (1974).

Yield per hectare is maximised at the "economic carrying capacity" (N_{opt}), beyond which the addition of more animals leads to a decrease of production per hectare. At the "ecological carrying capacity" (N_{max}), births equal deaths, and there is zero weight gain. According to the model, these two carrying capacities differ by a factor of about two. This may explain why stocking rates in South African communal areas are on average 1.85 times higher than in commercial farming districts (Hoffman et al. 1999).

Maximum yield and ecological carrying capacity may in fact be higher in multi-purpose farming systems with a mix of livestock species since the yield curves for milk and fibre decline at higher stocking rates than those for meat, and animals are able to provide draught power and live value even while they are losing weight (Wilson and MacLeod 1991, Behnke and Abel 1996). The total yield of livestock products in a mixed subsistence system with high stocking rates may thus exceed the total yield from a commercial operation (Shackleton 1993, Behnke and Abel 1996). Also, the model was developed under controlled conditions on homogeneous cultivated pasture and fails to take into account the spatial heterogeneity and temporal variation in forage quantity and quality found in real pastoral systems.

Livestock farming systems across Africa range from pure nomadic pastoralism and integrated agropastoral systems to people in cities keeping a few livestock to supplement their wages or other income, and from highly commercialized to pure subsistence systems. In South Africa, people in the former homelands combine wages, remittances and informal sector earnings in the cities with agriculture and livestock keeping, pensions and disability grants and other sources of income (Cousins 1998). In many cases, livestock production contributes only a fraction of a household's income. For example, Bembridge (1984) found that in three areas surveyed in Transkei, only between one and ten per cent of household income was derived from farming activities including cropping. The former homelands' small size and high population densities allow only a minority of wealthy farmers to have enough livestock to potentially make a living, but even small numbers of livestock can contribute some cash income, products and services to their owners (Tapson 1990, Shackleton 1993, Shackleton et al. 2000). Livestock also serve as an important safety net in old age or times of unemployment.

If policy making is to take into account the need for ensuring environmental sustainability while meeting the objectives of the land users, it seems appropriate to define range degradation as "the long lasting or permanent loss of an economic good, in this case an irreversible decline in livestock production" (Behnke and Scoones 1993). It has been argued that in terms of the above definition, there is little evidence to show that degradation has taken place in South African communal rangelands and that interventions such as destocking have been premature and remain unjustified (Shackleton 1993, Tapson 1993, Dikeni et al. 1996). In particular, the observation that livestock numbers in many homeland areas have not declined over several decades while the land was thought to be degrading at alarming rates, together with the assumption that traditional African livestock farmers aim to maximise animal numbers rather than production or offtake, has led several researchers and policy makers to argue that there has been no loss in the productive potential of the land. Wilson and MacLeod (1991) emphasize that degradation of a grazing system can be neither measured in terms of vegetation composition by itself nor simply in terms of animal numbers. Instead, the relationship between stocking rate and animal productivity (as in Jones and Sandland 1974) is the factor that needs to be compared between areas or over time to detect long-term losses in secondary productivity.

1.2 The Herschel case

The Herschel District in the North-Eastern Cape of South Africa is a former homeland area, all of which (with the exception of arable and residential areas) is used for communal grazing. The Tomlinson Commission (Union of South Africa 1955) reported Herschel to be one of the most severely degraded areas in South Africa. Hill Kaplan Scott (1985) found Herschel to be the most eroded district of the Transkei, and today it is still ranked as one of the most badly eroded and degraded districts in the country by extension officers (Hoffman et al. 1999). Soil erosion, sparse grass cover and invasion by unpalatable Karoo shrubs are widespread and visible throughout the district (Figure 1.2).

Despite these high levels of rangeland degradation, livestock records dating back to the end of the 19th century reveal no overall decline of livestock numbers in the district (Figure 1.3). Stocking rates range from 0.2 livestock units[1] per hectare (LSU/ha) in the high-altitude administrative areas to more than 0.5 LSU/ha in the lowlands. Livestock densities increased during the 1990s, and in 1997, densities of up to 0.8 LSU/ha were recorded in some lowland areas.

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[1] One large stock units (LSU) is the metabolic equivalent of a 450 kg steer; for details on the calculation of stocking rates and the conversions used, see Chapter 7.

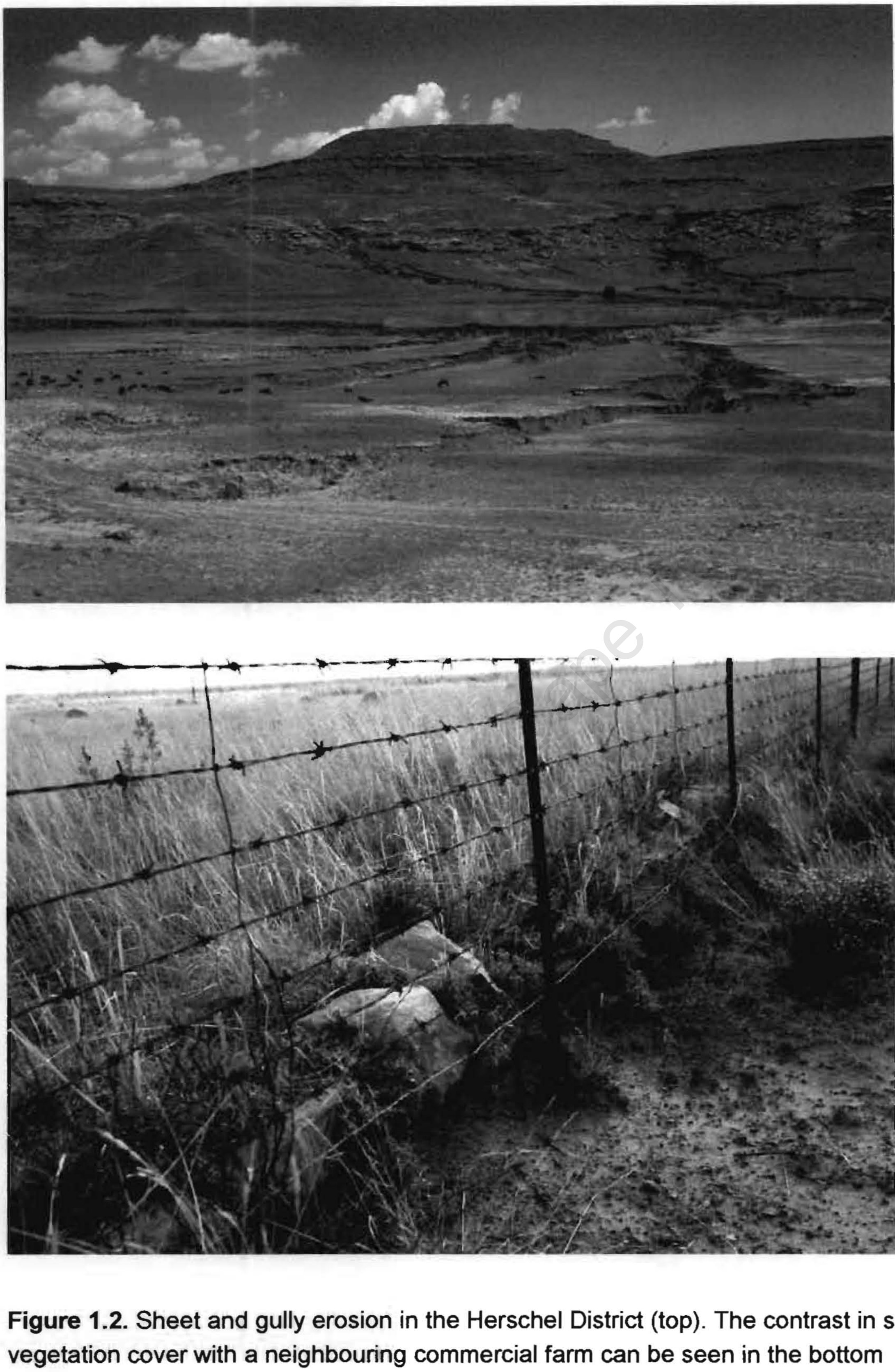

Figure 1.2. Sheet and gully erosion in the Herschel District (top). The contrast in soil and vegetation cover with a neighbouring commercial farm can be seen in the bottom photograph.

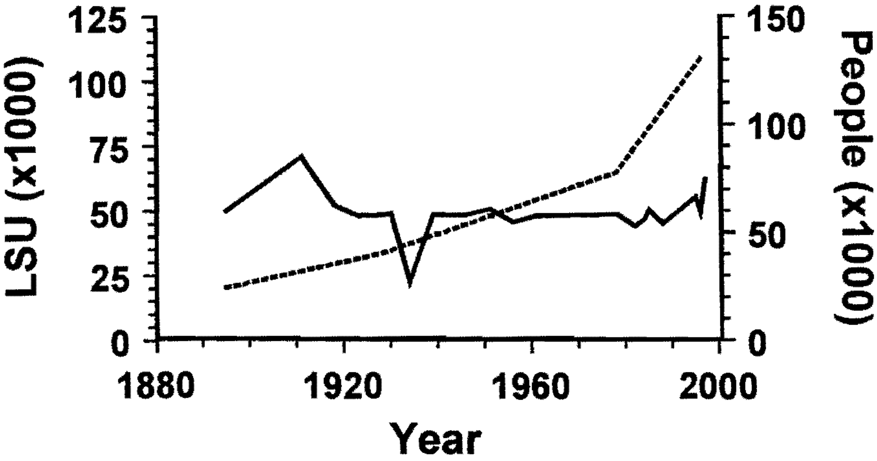

Figure 1.3. Total livestock (solid line) and human population (dotted line) in the Herschel District, 1895-1997 (Sources: Department of Agriculture, Statistics SA, Bundy 1979)

This cannot be explained by an expansion of the available grazing area, as the district boundaries have not changed, and grazing area has in fact been reduced over the years by the expansion of residential areas. This raises the question whether the productive potential of the land has been retained, or whether livestock numbers are being maintained by other means, such as feed inputs, purchases of livestock or changes in resource use, which carry a cost to communal livestock farmers. Other studies have used livestock numbers as evidence for declines in secondary production over time (Dean and Macdonald 1994), or a lack thereof (Scoones 1992, Tapson 1993). However, as Illius and O'Connor (1999) point out, these studies do not account for economic influences, changes in resource use or changes in reporting that may have influenced actual or recorded livestock numbers at different times.

There are some concerns about the reliability of livestock census data in the former Transkei and Ciskei areas (see Ainslie 2002 for a discussion). Livestock numbers were recorded during compulsory dipping against East Coast fever (a tick-borne disease which decimated cattle populations in the Eastern Cape in 1912/13) and sheep scab. Livestock owners, particularly those with large herds, often made attempts to evade the stock census, because the information was used by government officials as a basis for taxation or livestock culling. Some owners would do this by not taking a part of their herd to be dipped and counted at all, while others redistributed some of their animals to relatives so that smaller individual herds, but all the owner's livestock, were dipped and recorded (Beinart 1987). Some authors (e.g. Ainslie 2002, Kepe 2002) believe that the dip records in Transkei are more accurate than that of the Ciskei records. Herschel was transferred from Ciskei to Transkei government in 1976, when Transkei became independent. Despite these reservations, the official livestock census records are the only long-term source of livestock data available, and not all assessments of their reliability are as pessimistic as those cited above. Beinart (1984, 1992) judged the sheep and cattle census data in Transkei to be relatively well kept. Mike Coleman (Eastern Cape Department of Land Affairs, pers. comm.) argues that it was in practice very difficult to keep large "ghost herds" out of the public eye, that the veterinary staff in charge of dipping and keeping census records were well-trained and thorough, and that the margin of error in the livestock records was at least consistent over time.

1.3 Objectives of this study

The overall aim of this study is to assess the cost of environmental degradation in the Herschel District in terms of the land users' objectives. Central to this is an attempt to explain the paradox of how livestock numbers remain undiminished in a landscape rated as one of South Africa's most degraded. This study considers the following hypotheses to explain how stock numbers have been maintained in Herschel.

1. Erosion and vegetation change have altered certain properties of the ecosystem, but have not diminished the potential of the land for livestock production.

2. Degradation dates back 100 years, and the earliest livestock records already reflect a degraded landscape whose productive potential has remained relatively constant since then.

3. The land has declined in productive potential over the census period, and this is reflected in changing yields of livestock products such as meat, milk and wool. Livestock numbers have stayed the same, but the shape of the relationship between stocking rate and yield has changed, and while the earlier livestock numbers may have reflected stocking rates closer to the economic carrying capacity, N_{opt} (*sensu* Jones and Sandland

1974), the present livestock densities are close to, or even exceeding, the ecological carrying capacity[2], N_{max} (see Figure 1.1).

4. The productive potential of the land has declined and livestock numbers are maintained through changed resource use, buying livestock from outside the district to replace drought losses, and additional feed inputs.

An important feature of this research is that it attempts to uncover changes in the productive potential in a communal area over time, rather than basing an assessment of changes in productivity on a communal-commercial comparison. This presents a considerable challenge in piecing together various kinds of evidence over a period of several decades to infer past changes in production and productivity.

A further objective of this study is to understand the objectives of livestock owners in Herschel, in terms of which degradation is to be assessed. It is commonly assumed that communal farmers aim to maximise livestock numbers, and what data exist to support this are largely based on cattle production where uses such as draught power, manure and milk production as well as economic and social capital tend to play a more important role than sales and slaughter (Bembridge 1979, Tapson and Rose 1984, Tapson 1990, Tapson 1993, Campbell et al. 2000). The roles of small stock have been largely ignored or assumed to be similar to those of cattle.

A final aim of this work is to discuss the findings in the broader South African context and to make recommendations for the management of existing communal areas and land reform areas.

It should be noted here that the natural resource base of communal rangelands contributes other goods and services apart from livestock production (Cousins 1998, Shackleton et al. 2000), but these are not considered in this study. The objectives of livestock owners in Herschel may not necessarily reflect the objectives of all land users. However, according to a survey by Loxton Venn and Associates (1990), only a small

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[2] The term "ecological carrying capacity" as used here refers to the highest possible stocking rate, at which growth is zero. The term is not intended to imply a stocking rate which is necessarily ecologically sustainable. The long-term ecological sustainability of the stocking rates maintained in Herschel is tested in this study.

percentage of households does not own any livestock, and livestock keeping and cultivation are the main uses of land outside residential areas. Since the people with access to arable land are livestock owners, and most households own, or aspire to owning, at least some livestock, using livestock owners' objectives to assess degradation and its costs is considered to be reasonable.

1.4 Outline of the thesis

Chapter 2 is an introduction to the Herschel District, which provides biophysical, socio-economic and historical information.

Chapter 3 covers the present state of the vegetation and soils in the district and investigates the influence of land tenure and biophysical factors on grass composition, basal cover and shrub density. The soil and vegetation data are compared to the assessments of soil and vegetation degradation made by extension officers (Hoffman et al. 1999) to explore and evaluate the rating of Herschel as one of the country's most degraded districts.

Following on from this chapter, Chapter 4 focuses on soil erosion within Herschel, particularly where, why and when soil erosion has spread and intensified in Herschel. Its main aims are to establish how far back degradation dates, how it varies within Herschel, what variables correlate with high levels of soil erosion, and how the perceptions of the local people reflect the realities of degradation. Chapters 3 and 4 serve as a baseline from which the costs of degradation in Herschel can be assessed.

Chapter 5 explores the production objectives, farming strategies, production and herd dynamics for cattle, sheep and goats separately before discussing the livestock farming system in Herschel as a whole.

Chapter 6 examines ways in which high stocking rates have been maintained despite degradation, such as changes in resource use and livestock composition. This chapter also investigates evidence for declines in livestock productivity in relation to overstocking and degradation.

Chapter 7 uses correlates of stocking rates in the 23 administrative areas in the district to identify the factors which best explain differences in stocking rates in different areas within the Herschel district. The aim of this was to determine the relative importance of environmental factors and human inputs in maintaining high stocking rates. These relationships are investigated over three census periods between 1974 and 1997 to detect whether the factors maintaining livestock numbers change over this time. This chapter also examines the relative importance of rainfall and density-dependent interactions in regulating herd size and productivity in different years.

The concluding chapter, Chapter 8, discusses appropriate measures of degradation and the applicability of the nonequilibrium paradigm in South African communal rangelands, based on the results of this study. The chapter places the findings of this study in the broader South African context and concludes with some management recommendations.

2. STUDY AREA

2.1 Introduction

This chapter is an introduction to the Herschel district, where this study was carried out. While some analyses cover the whole district, field work and the mapping of soil erosion were conducted in four study areas which will be described in the last section. This chapter provides biophysical, socio-economic and historical information on the Herschel District.

2.2 Biophysical characteristics

2.2.1 Geographical location

The Herschel district of the Eastern Cape Province forms a triangle between Lesotho, the Free State and the Lady Grey and Barkly East districts of the Eastern Cape (Figure 2.1). Herschel extends from 30°19' to 30°42' S and from 27°00' to 27°56'E and is approximately 170 000 ha in extent. The Orange River separates Herschel from the Free State in the north-west while the Telle River, a tributary of the Orange River, forms the border between Herschel and Lesotho in the north-east. In the south, the peaks of the Witteberge (a southern branch of the Drakensberg running East to West) form the boundary between Herschel and the Lady Grey and Barkly East districts. Sterkspruit with a population of about 12 000 (Statistics South Africa 1998) is the largest town in Herschel and lies in the western half of the district along the main road between Zastron and Lady Grey.

2.2.2 Topography and drainage

Two different biophysical regions can be distinguished in Herschel, based on altitude, geology, soils, vegetation and climate. The relatively low-lying, hilly plains of the south-west and far north of the district give way to steep, high mountains in the south-east, with altitudes ranging from 1300 metres above sea level (m.a.s.l.) in the Orange River valley to peaks of up to 3000 m.a.s.l along the border with Barkly East and Lesotho. The whole district is drained by the Orange River and its tributaries, which have deeply dissected the landscape through headward erosion of rivers into the almost horizontal beds of sedimentary rock.

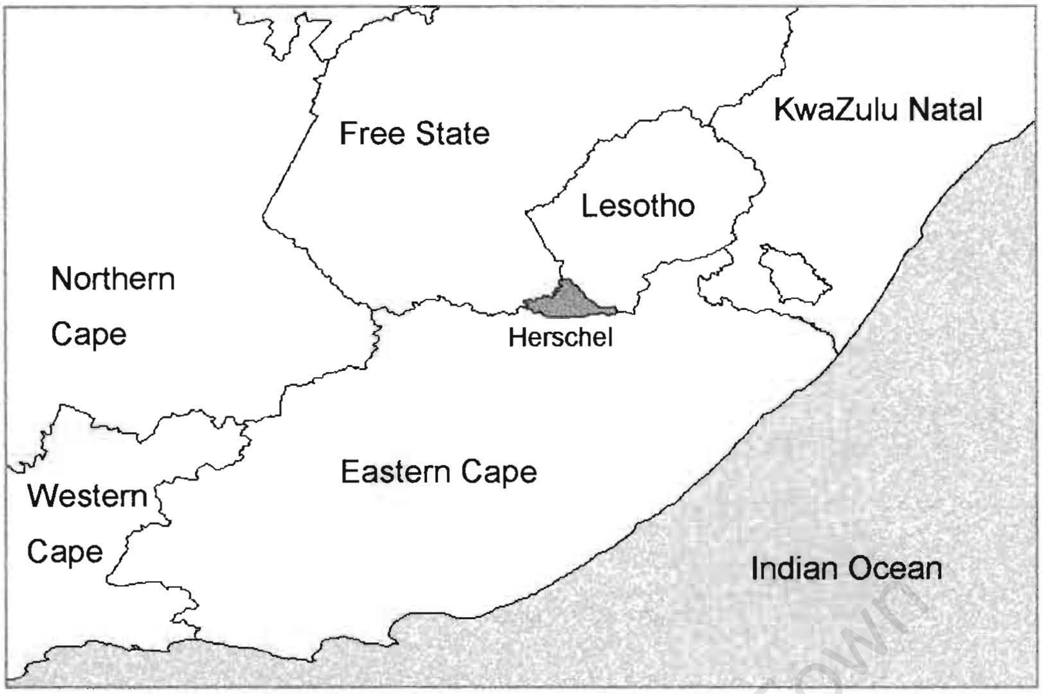

Figure 2.1. Location of the Herschel District in South Africa.

Four terrain morphology classes occur in Herschel (Schulze 1997, after Kruger 1983): low mountains with high relief in most of the centre of the district; high mountains with high relief in the south-east; undulating plains with few hills in the south-west and lowlands with low relief in the north. The former two terrain morphology types, which cover most of the district, are characterised by steep, long slopes and a high drainage density (2 - 3.5 km of streamlength per km^2). These characteristics generally lead to higher and faster discharge of runoff and thus increase the potential for accelerated soil erosion (Zachar 1982, Schulze 1997).

Much of the higher altitude terrain in the southern parts of Herschel is composed of the steep, north-facing slopes of the Witteberg mountains. On these sunny slopes, rates of evapotranspiration, freezing and thawing, organic matter decomposition and other soil processes tend to be accelerated due to higher temperatures (Zachar 1982). Studies quoted by Zachar (1982) show that soil erosion due to the above processes is more pronounced on sunlit, north-facing slopes than on shaded, south-facing ones. Shaded slopes have greater moisture and vegetation cover, which reduces their susceptibility to soil erosion processes.

2.2.3 Geology

The entire study area is underlain by sedimentary and volcanic rocks of the Karoo Supergroup, laid down in the Triassic and Jurassic periods respectively. The lowest and oldest stratum exposed in Herschel is a relatively small area of Tarkastad brownish-red and grey mudstone with sandstone, which is part of the Beaufort Group. Gritty sandstones, grey mudstones and shales of the Molteno Formation underlie most of the lower, gently sloping areas in the western parts of Herschel, with the overlying Elliot Formation brownish-red and grey mudstones and sandstones forming steep slopes in most of the northern and eastern parts of the district. At about 2000 m.a.s.l., Clarens sandstone forms a characteristic white band below the basalt plateau of the Drakensberg Formation. Dolerite sills are found throughout the study area, and alluvium deposited in the Quaternary fills several of the big valleys in Herschel. The different geological strata can be observed where rivers have incised the layers of rock to form steep valleys.

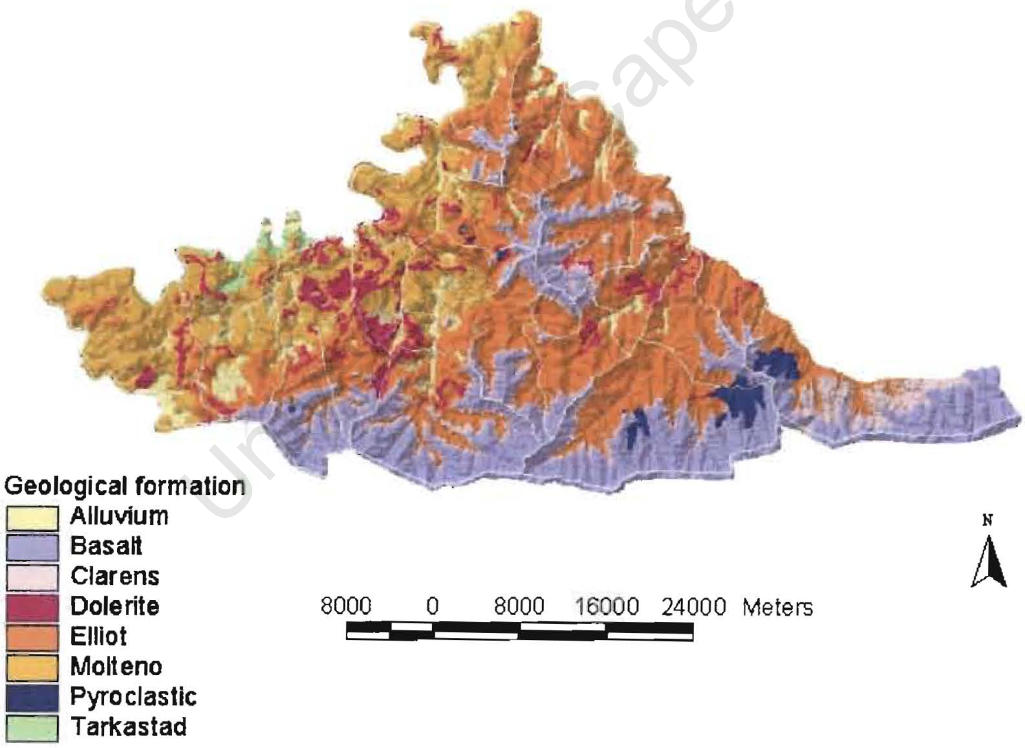

Figure 2.2. Geological formations and relief of the Herschel District. The figure also shows the boundaries of the 23 administrative areas (Source: Geological Survey 1980).

2.2.4 Soils

Most of the district is covered by sandy clay loam and sandy clay soils. Many of these are slowly or very slowly draining (Schulze 1997). Drainage rates are largely governed by the texture of the subsoil, and many of the soil forms found in Herschel are lithosols or duplex soils that have B horizons with low permeability overlain by more permeable A horizons. Four of the 84 Broad Homogeneous Soil Zones delimited by the Institute for Soil, Climate and Water (mapped in Schulze 1997) are represented in Herschel. Their characteristics are summarised in Table 2.1. The soil zones are distinguished on the basis of different pedogenetic processes which are influenced by factors such as terrain morphology, especially in its effect on internal and external drainage; biota including vegetation and soil organisms; parent material; age of the landscape and climate.

Soil zone 27, which covers most of the district, consists of relatively shallow soils derived from Karoo sediments and dolerite. Mayo, Bonheim and Milkwood soils with their fertile, well-structured and clay-rich melanic A horizons are derived from dolerite and are more resistant to soil erosion than the other soils which are derived from sediments (MacVicar et al. 1977). Soil zone 12 occurs on a flat, undulating landscape, which is bordered by the steep valley of the Orange River in the north of Herschel. The yellow-brown apedal, soft plinthic and gleycutanic B horizons indicate a seasonally waterlogged environment resulting from restrictive subsoils and impermeable underlying material. Soils of the Kroonstad and Estcourt forms are duplex soils with clay-rich subsoils under an E horizon and are highly erodible. The more saline Estcourt soils in particular are very unstable as the clay of the subsoil flocculates when soils are wet and crusts easily when dry (MacVicar et al. 1977). Soil zone 13 occurs in the steep high mountains in the south-east of the district, where the climate is cool and humid. The soils here are relatively well-drained and deep due to the advanced weathering of the basalt parent material. The natural fertility of all the soil forms represented in this soil zone is low because of leaching, but they are well-structured and have a high plant available water content. Soil zone 23 in Herschel encompasses several large floodplains with deep alluvial deposits. Highly erodible duplex soils of the Valsrivier and Sterkspruit forms cover about 60% of the area in this soil zone.

Table 2.1. Characteristics of the four soil zones represented in Herschel. Sources: Schulze (1997), MacVicar et al. (1977). Texture: Sa: sand, Cl: clay, Lm: loam. Percentages indicate the relative area occupied by the different classes.

Soil zone	Soil depth (cm)		Soil texture		Soil forms		Diagnostic horizons		
27	30-60	60%	SaClLm	60%	Hutton	20%	Orthic A	Red apedal B	
	60-100	30%	SaCl	40%	Swartland	20%	Orthic A	Pedocutanic B	Saprolite
					Bonheim	20%	Melanic A	Pedocutanic B	
					Mayo	10%	Melanic A	Lithocutanic B	
					Milkwood	10%	Melanic A	Hard rock	
					Mispah	10%	Orthic A	Hard rock	
12	45-100	80%	SaClLm	90%	Avalon	30%	Orthic A	Y/B apedal B	Soft plinthic B
	>100	20%	SaCl	10%	Estcourt	25%	Orthic A	E	Prismacutanic B
					Kroonstad	25%	Orthic A	E	Gleycutanic B
					Clovelly	10%	Orthic A	Y/B apedal B	
					Westleigh	10%	Orthic A	Soft plinthic B	
13	50-100	70%	SaCl	80%	Magwa	20%	Humic A	Y/B apedal B	
	>100	30%	SaClLm	10%	Inanda	20%	Humic A	Red apedal B	
			Cl	10%	Griffin	20%	Orthic A	Y/B apedal B	Red apedal B
					Clovelly	15%	Orthic A	Y/B apedal B	
					Hutton	15%	Orthic A	Red apedal B	
					Glenrosa	10%	Orthic A	Lithocutanic B	
23	40-100	70%	SaClLm	75%	Sterkspruit	35%	Orthic A	Prismacutanic B	
	100-400	30%	SaCl	25%	Glenrosa	15%	Orthic A	Lithocutanic B	
					Mispah	15%	Orthic A	Hard rock	
					Valsrivier	25%	Orthic A	Pedocutanic B	Unconsolidated
					Hutton	10%	Orthic A	Red apedal B	

2.2.5 Climate

The climate in Herschel ranges from sub-arid with warm summers and cool winters in the north-east to humid/sub-humid with mild summers and very cold winters in the south-east (Loxton Venn and Associates 1988). Due to variations in altitude and aspect, there is also considerable microclimatic variation throughout the district.

Rainfall

The average annual rainfall of about 500 mm in the relatively drier Orange River valley in the north-west of the district increases to over 1000 mm in the Witteberg mountains in the south-east (Els 1971). In Sterkspruit (altitude 1450 m.a.s.l.), average rain between 1944 and 1998 was 640 mm per annum. The coefficient of variation (C.V.) of the mean annual rainfall calculated over the same period was 28 %. This indicates a high degree of rainfall variability, though less than the 33% hypothesized to be the level above which non-equilibrium dynamics predominate (Ellis et al. 1993, Ellis 1994). Most rain falls in showers and thunderstorms during the summer months (October to March), with February and March being the wettest months (see Figure 2.3). Up to 193 mm of rain in one day has been measured at the Department of Agriculture office in Sterkspruit, and several records of around 50 mm of rain in a day exist there. The concentration of rain in such heavy showers, together with the steep slopes, sparse vegetation and restrictive soils which are all commonly found in Herschel, poses a considerable risk for accelerated soil erosion. Hail is sometimes associated with the thunderstorms and mainly occurs in early summer. Although these storms may be severe and can cause much damage, they usually cover a small area at a time (Els 1971). July and August are the driest months with less than 20 mm of rain per month.

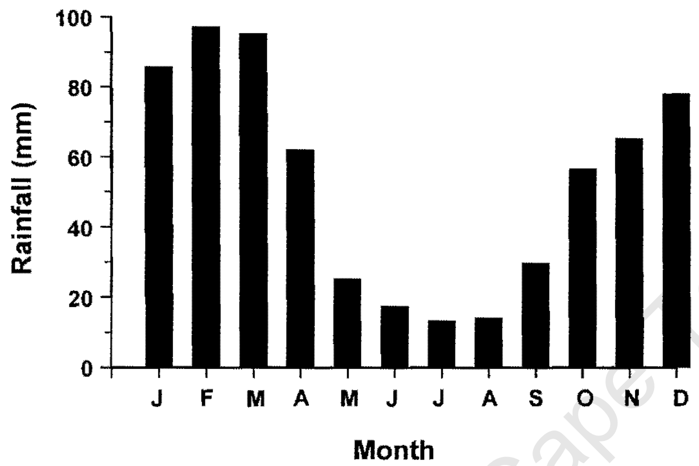

Figure 2.3. Mean monthly rainfall at Sterkspruit in the Herschel district for the period 1944-1998. Source: Records from Department of Agriculture office, Sterkspruit.

Annual rainfall varies considerably with a minimum of 238 mm in 1992 and a maximum of 1202 mm in 1976 having been recorded in Sterkspruit since 1944 (Figure 2.4). Data from Zastron (a nearby town in the Free State) and Funnystone (a farm near the border with Herschel in Barkly East in the higher rainfall zone) show that a drought in the early to mid-1930s was followed by a wetter period until the mid-1940s. A relatively wet period in the 1950s and early 1960s was followed by several low rainfall years in the mid-1960s. The late 1970s (1975-1980) were wet, followed by the drought of the early 1980s and reasonably wet years in the late 1980s and 1990-1991. During the early 1990s Herschel experienced the worst drought since 1940, lasting from 1992 until 1996, a year of average rainfall. The annual rainfall chronology in Figure 2.4 reveals no discernible increasing or decreasing trend in rainfall over the 54-year period covered by the data. Annual (January–December) and seasonal (July-June) rainfall are both normally distributed, and no significant relationship exists between year and either annual (r^2=0.0063) or seasonal (r^2=0.0052) rainfall total.

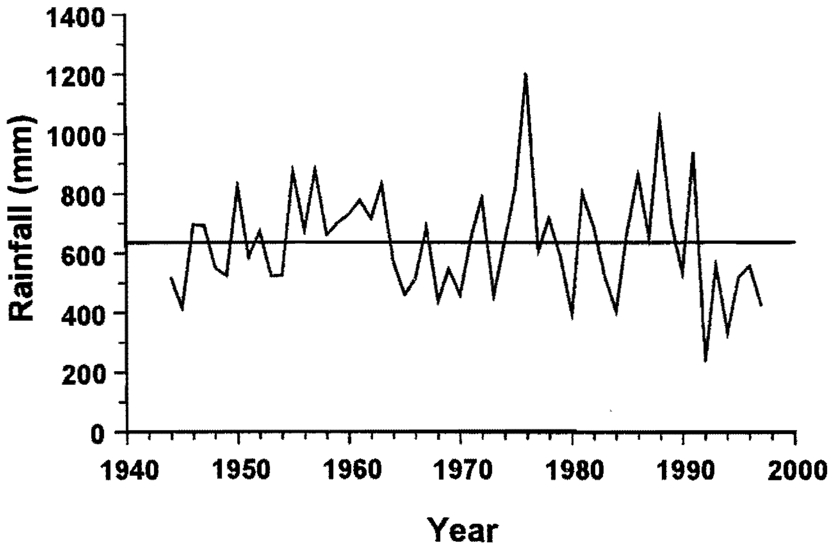

Figure 2.4. Annual rainfall chronology for Sterkspruit in the Herschel district for the period 1944-1998. Source: Records from Department of Agriculture office, Sterkspruit.

Temperature

A temperature gradient spans Herschel from the warmer Orange River valley to the high, cold peaks of the Witteberg mountains. All of Herschel experiences frost and sometimes snow in winter, though the duration of the frost period is longer in the south-east of the district. Table 2.2 summarises mean summer and winter temperatures, as well as the duration and severity of the frost period, for the warmest and coldest parts of Herschel. There is a great annual temperature range, with the difference between the average daily maximum temperature in summer and the average minimum temperature in winter being in the order of 30°C.

From the temperature data it is apparent that the growing season, particularly at higher altitudes, is very short. In the north and west of the district, the growing season is most likely to be determined by the availability of water (the moisture growing season is less than 175 days in the far north-west according to Schulze 1997), while in the high-altitude areas in the south-east, part of the 225-364 day long moisture growing season can usually not be exploited due to the severity of frosts and the long period during which they occur. Freezing and thawing due to frost and snow, especially in the higher areas, are important in influencing soil processes.

Table 2.2. Summer and winter temperatures (°C) and frost period in the warmest (Orange River valley) and coldest (Witteberg mountains) parts of the Herschel district. Source: Schulze (1997).

		Orange River valley	Witteberg mountains
January	**Mean maximum temperature**	28 - 30	< 20
	Mean minimum temperature	12 – 14	< 6
	Mean daily temperature	20 - 22	< 12
	Diurnal temperature range	14 - 15	11 - 12
July	**Mean maximum temperature**	16 - 18	< 10
	Mean minimum temperature	0 - 2	< -2
	Mean daily temperature	10 - 12	< 2
	Diurnal temperature range	16 - 17	10 - 11
Frost	**Average first day of frost**	May	March
	Average last day of frost	September	December
	Duration of frost period (days)	120 - 150	> 210
	Number of days of heavy frost	30 - 60	> 120

2.2.6 Vegetation

Two vegetation types occur in Herschel. Moist Cold Highveld Grassland is found in the lower-lying (up to about 2000 m.a.s.l.) parts of the district, and Afro Mountain Grassland in the high-altitude areas in the south and east of the district (vegetation types 40 and 45 of Low and Rebelo 1996). Within Herschel, the two vegetation types are synonymous with Acocks's (1988) Cymbopogon-Themeda veld (No. 48) and Themeda-Festuca Alpine veld (No. 58) respectively. The boundary between the two veld types corresponds closely to the transition between sedimentary rock and basalt, which occurs at around 2000 m.a.s.l. altitude.

According to Low and Rebelo (1996) and Acocks (1988), *Themeda triandra*, *Setaria sphacelata*, *Microchloa caffra*, *Elionurus muticus* and *Heteropogon contortus* are the most common grass species in Moist Cold Highveld Grassland, with a variety of *Eragrostis* species (*E. chloromelas*, *E. racemosa*, *E. capensis* and *E. plana*), *Cymbopogon plurinodis*, *Tristachya leucothrix*, *Brachiaria serrata*, and *Harpochloa falx* being other common grass species. In Herschel, *Aristida* species, *Eragrostis* species, *Microchloa caffra* and karroid shrubs such as *Pentzia globosa*, *Felicia filifolia*, *F. muricata* and *Chrysocoma ciliata* have become more widespread while *Themeda triandra* is rarely found (see Chapter 3). *Rhus erosa* shrubs are common on rocky lower slopes (O'Connor and Bredenkamp 1997).

The Afro Mountain Grassland vegetation type, a fire climax grassland, covers the Drakensberg and occurs at altitudes over 2000 m.a.s.l., mainly on Clarens sandstone and the basaltic plateau. *Themeda triandra* is a prominent species with *Elionurus muticus*, *Heteropogon contortus*, *Hyparrhenia hirta*, *H. pilosissima*, *Eragrostis* species (*E. chloromelas*, *E. racemosa*, *E. capensis* and *E. curvula*), *Andropogon appendiculatus*, *Trachypogon spicatus*, *Harpochloa falx* and *Aristida diffusa* (Acocks 1988, Low and Rebelo 1996). *Festuca* species such as *F. costata*, *F. caprina* and *F. scabra* and *Merxmuellera* species are less widespread but are nevertheless characteristic of this veld type. Scrub forest is found in sheltered ravines and on some south-facing slopes, with *Leucosidea sericea* being the most common woody element, which tends to encroach when the grass layer is degraded (O'Connor and Bredenkamp 1997). According to Acocks (1988), mismanagement also leads to an increase in *Merxmuellera disticha*, but most importantly to a conversion of grassveld to Karroid False Fynbos. This is characterised by fynbos species such as *Passerina montana* and *Erica caffra*, and Karoo species such as *Chrysocoma ciliata*, *Felicia filifolia*, *F. petiolata*, *Euryops* species, *Pentzia cooperi*, *Helichrysum* species, *Relhania pungens*, *Stoebe vulgaris* and others.

2.3 An overview of land use history

Herschel was inhabited by San people until it was settled in the 1830s by refugees of the *mfecane* and the frontier wars, primarily Hlubi, Tlokoa and Sotho (Beinart 1987). Under the Wesleyan Methodist Mission Society, the Wittebergen Native Reserve was established in the 1850s, which was incorporated into the Cape Colony and became the magisterial district of Herschel in 1870. By then the population had increased to around 20 000. According to Bundy (1979), the lack of any powerful traditional leadership in this diverse and largely refugee population allowed for agricultural and other innovation in the absence of opposition by chiefs. This, and the relative freedom from the traditional sanctions against the accumulation of personal wealth, attracted enterprising peasant farmers from elsewhere in the Cape.

From early settlement, land was communally used and managed. Arable plots were allocated to individual households by chiefs or headmen, but this did not confer individual ownership to these lands. In 1894, the Glen Grey Act was promulgated in the Cape Colony to promote individual tenure, the establishment of *bunga* or local councils and the collection of taxes. The Act also imposed a limit on the size and number of plot holdings per owner, which effectively prevented African commercial farming. Widespread resistance to this Act in Herschel and throughout the Cape (Beinart 1987) forced officials to reconsider, and land remained under communal tenure.

The Native Land Act of 1913 restricted Africans in South Africa to 8.9 million hectares, or 8% of the land area (this was later increased to 13% when the Native Trust and Land Act was passed in 1936). The Act prevented Africans from purchasing or owning land elsewhere except in the Cape Colony and restricted leasing and tenancy. Government attempts (the Native Affairs Act of 1920 and Government Notice 833 of 1921) to regulate land use, register land allotments and tax land users in areas under communal tenure met with resistance in Herschel. People saw the registration certificates as title which would withdraw the land from the control of the people and rest it in the individual, who might then be free to use this land without communal constraints and ultimately even alienate it. Tensions developed between the progressive Christian elite who were in favour of this system and the poorer, "backward" majority who opposed it. This issue was central to protests by the *amafelandawonye*, or "die-hards", which are documented by Beinart (1987).

Efforts to rehabilitate or stabilise agricultural land in the homelands took shape in the 1930s. The 1932 Native Economic Commission drew attention to environmental problems in the homelands which it considered to be a serious obstacle to agricultural development. It was argued that soil erosion, the apparent destruction of grazing areas and the drying up of springs in communal areas were a result of improper land use practices and that the irrational desire of black farmers to keep as many cattle as possible was one of the main causes. The Land Act passed in 1936 vested control over land use and rehabilitation in the Native Trust. Legislation to cull excess livestock was passed in 1939, enabling officials to count and cull cattle when they thought the land was overstocked. The Bantu Authorities Act of 1951 established chiefs as salaried officials of the government, which set in motion the system of homeland government and rule through tribal authorities.

Substantial areas in the homelands were subjected to "betterment" measures in the late 1930s and the 1940s. The betterment strategy combined physical land reclamation measures such as gully rehabilitation with land use planning that reorganised settlements into villages and separated settlement areas, arable lands and grazing areas. The betterment policy was reinforced and restructured after the publication of the findings of the Tomlinson Commission (Union of South Africa 1955). Their report pointed out that the homelands were already severely overcrowded and unable to support their existing populations from agriculture. It identified a major need for agricultural development in the homelands where farming was characterised by improper land use, inefficient methods of cultivation, diminishing soil fertility, low returns from crops and livestock, low agricultural incomes, deficient diet, low health standards and an overall low standard of living.

The Tomlinson report concluded that the future of the reserves depended on the creation of full time farmers farming viable units. After calculating that an area of 52.5 morgen (44.7 ha) was needed to support a household reliant on farming, the commission concluded that the communal areas could carry about 50% of the South African black population recorded in the 1951 census. The rest of the population would have to find a living in activities other than agriculture. The report made it clear that vast amounts of capital were required to implement the necessary economic development of the reserves, which also required that 55% of the total livestock population would have to be culled. In a White Paper in response to the Tomlinson report, the South African government rejected proposals to abolish communal tenure and reduce the reserve population, but decided to adopt the principles of betterment planning and apply them to the existing situation in the reserves. In the Tomlinson report, Herschel was described as one of the most severely degraded districts in the country.

The findings of the commission resulted in the implementation of betterment planning in most of the former Ciskei and Transkei, a policy which was aimed at rehabilitating degraded land and facilitating the provision of services such as veterinary medicine, clinics and schools. The process involved the resettlement of people in planned villages, rezoning and re-allocating arable plots, withdrawing unsuitable lands from cultivation and fencing off grazing camps where rotational grazing and resting were enforced by government officials. The scattered settlements in Herschel were replanned into 21 major Trust villages, and resettlement and fencing of grazing camps and arable areas were implemented between 1961 and 1963. The forced move into villages, the re-allocation of arable land and the fencing off of grazing camps belonging to different wards met with widespread resistance in Herschel, and active refusal to move in a few wards. In Jozanas Hoek, for example, people refused to move to Trust villages and repeatedly cut the fences the government erected. One man was shot during conflict with police, and several people went to prison. People were loath to leave their scattered settlements and rebuild their homes in a densely populated village for a compensation ranging from R 5 for a round, thatched hut and R 12 for a four roomed house with a tin roof. Older people objected to moving because, apart from the great expense and inconvenience involved, they were unwilling to move away from the graves of their ancestors (Desmond 1969, Herschel residents, pers. comm.).

In the process of rezoning and reallocating arable plots, the arable holdings of most households were reduced, while the headmen and councillors reserved the biggest and best plots for themselves (Desmond 1969). Many households, particularly those of poorer people and widows, had no arable land at all. As a result of the rezoning of residential and arable areas, many households found themselves living some way from their arable plot, which in some places turned out to be too far to make cultivation practical. Fencing of the grazing camps took place and rotational grazing was enforced. Livestock culling was proposed but it seems that this was never carried out beyond urging farmers to sell livestock.

During the 1960s and 1970s Herschel saw an influx of people displaced by forced removals which were taking place across South Africa. In 1967, about 150 sheep shearers and their families were forcibly moved from white-owned farms to Orange Fountain, a settlement of tiny tin shacks that are still in place today. Other people arrived after being evicted from farms in the Orange Free State, and some from the Western Cape. At this stage the population of Herschel numbered around 75 000 people (Desmond 1969).

Originally under Ciskei administration, Herschel was ceded to Transkei in 1976. Between 30 000 and 40 000 people left Herschel and moved to other areas in Ciskei (mostly to the notorious Thornhill resettlement areas near Whittlesea) rather than being incorporated into a newly independent Transkei. Herschel was largely ignored by the Transkei administration and seemed to have had minimal government interference or investment. According to people interviewed in Herschel, the fences erected during the betterment era became dilapidated or were actively removed as a form of political protest, and land use has not followed any official system – democratic or imposed – since the late 1970s. Settlement patterns and arable land holdings are still as under betterment, but much of the arable land lies fallow for a number of reasons. Agricultural development initiatives by government and non-government agencies have failed so far to achieve any far-reaching improvements in agricultural productivity, incomes or land management. The constraints on agricultural production and production levels over time will be discussed in Chapters 5 and 6.

2.4 The four study areas

I conducted fieldwork to gather data and information on environmental change, rangeland degradation, livestock production and changes in resource use in four of the 23 administrative areas within the Herschel district, namely Tugela, Bensonvale, Majuba Nek and Upper Telle. The same four areas were used to map changes in soil erosion. The aim was to sample and compare areas with different biophysical conditions and levels of degradation. I chose two areas in the lowlands and two in the highlands, and for each pair, one in relatively good condition and one which appeared to be extensively and severely degraded. Details on population and livestock densities as well as biophysical characteristics are summarised in Chapter 4, where these factors are related to measured levels of soil erosion.

Tugela is a relatively large (6600 ha) area which covers lowlands and mountain slopes. While most of the area is flat and low-lying with large areas of alluvial deposits, it extends to the crest of the Witteberg mountains along the southern boundary of the district. Tugela has high densities of people and livestock and high levels of soil erosion, particularly on abandoned arable lands.

Bensonvale is a small (1400 ha) area in the lowlands with a high proportion of arable land but no access to mountain areas. Much of the geological substrate is dolerite. Although Bensonvale has similar livestock and higher human population densities than Tugela, the area is widely considered to be in good condition in terms of vegetation and soil. Bensonvale and most of Tugela fall into the Moist Cold Highveld Grassland vegetation type.

Majuba Nek is a small (1600 ha) area in the centre of the district. Most of the area is on steep mountain slopes on Elliot mudstones, with some arable land in the centre. Majuba Nek has very high human and livestock densities. Soil erosion, loss of grass cover and encroachment by Karoo shrubs are widespread in this area.

Upper Telle is the largest (14 400 ha) and most remote of the study areas. Upper Telle is very mountainous, with much of its area on Clarens sandstone and basalt. Only one of its three wards was used for the soil erosion analysis, as the remainder is not covered by aerial photographs. Upper Telle has the lowest human and livestock densities of the study areas and appears to be in reasonably good condition overall with isolated patches of soil erosion. Shrub encroachment is fairly dense in places but there appears to be much less loss in grass cover than in Majuba Nek.

3. PRESENT STATE OF VEGETATION AND SOILS IN HERSCHEL: THE INFLUENCE OF LAND TENURE AND ABIOTIC FACTORS

3.1 Introduction

Herschel is rated to be overgrazed and degraded, with widespread soil erosion and encroachment by Karoo shrubs. A nationwide assessment of soil and veld degradation in South Africa, based on extension officers' evaluations (Hoffman et al. 1999), found that Herschel has among the highest soil and vegetation degradation indices in the country, while the neighbouring commercial farming districts were rated to be in very good condition. The survey also found that land tenure is the single most important determinant of land degradation in South Africa. The aim of this chapter is to test this assessment of soils and vegetation in Herschel and neighbouring districts using standard measures of rangeland degradation, i.e. plant composition, basal cover, soil erosion and shrub encroachment. The effects of land tenure relative to those of geology, slope and solar radiation on soil and vegetation characteristics are also assessed.

Although the relevance of overgrazing or degradation assessments based on botanical composition *per se* has been criticised (e.g. Abel 1993, Wilson and MacLeod 1991), grass composition is still considered to be the most important indicator of range condition and has been demonstrated to be correlated with primary productivity, secondary productivity, rain use efficiency and resistance to soil erosion (Danckwerts 1982; Snyman and Opperman 1984, Snyman 1988, Snyman and Fouché 1991, Fynn and O'Connor 2000). Since Herschel is rated to be overgrazed and degraded compared to commercial areas, one would expect to find significant differences in grass composition with a higher proportion of less palatable or less productive pioneer species in the Herschel district. Geology affects soil texture and nutrient status (Bell 1982), while slope and solar radiation affect soil properties and microclimate (Zachar 1982) and these factors are also expected to influence vegetation composition. Soil type also affects the response of grass species to heavy defoliation, and hence compositional changes as a result of grazing (O'Connor 1985)

Herschel sites were also predicted to have lower basal cover, more bare ground and more widespread erosion as a result of continuous intensive grazing. Different geological substrates have different potentials for soil erosion (Weaver 1988b) and may thus also be expected to have different levels of basal cover and soil erosion. Areas on steeper slopes are more vulnerable to soil erosion because of the higher energy gathered by runoff water. The effect of aspect on solar radiation index (i.e. how shady and moist or sunny and dry a site is) is also more pronounced on steeper slopes. The drier, hotter slopes are expected to have less vegetation cover (Zachar 1982) and would hence be more prone to soil loss.

Shrub cover is of interest to land users – and rated as undesirable by commercial and Herschel farmers alike - because the common Karoo shrubs are unpalatable to all livestock with the possible exception of goats. In addition to being unpalatable themselves, Karoo shrubs at high densities can reduce the grazing capacity of an area by reducing the grass cover available to livestock. *Chryosocoma ciliata*, one of the most common shrubs in Herschel, was found to have allelopathic properties (Squires and Trollope 1979), and this can further suppress grass growth and establishment. Karoo shrubs are considered to be indicative of low basal cover and disturbed soil caused by overgrazing (e.g. Schlesinger et al. 1990), and high shrub density is thus expected to be correlated with low basal cover and a high percentage of bare ground. The effect of solar radiation index on shrub cover is also of interest as shrub encroachment is considered to be indicative of a more arid microclimate (Evans et al. 1997).

3.2 Methodology

3.2.1 Sampling methods and data used

Results from a district-level national survey to assess land degradation in South Africa (Hoffman et al. 1999) were used to compare indices of soil, vegetation and combined degradation in Herschel and the three neighbouring commercial farming districts, Lady Grey, Barkly East and Zastron. The latter three districts are entirely under individual tenure, while all of Herschel is under communal tenure. Degradation was rated by extension officers in zonal workshops, where soil and veld degradation were assessed separately and then integrated to give an overall index of degradation. Soil, veld and combined degradation indices were calculated from extension officers' ratings of the degree (light to severe), extent (percentage of the area affected) and rate of spread (slowly or rapidly in- or decreasing) of degradation in different land use types, as well as the percentage each land use type makes up of the total area. The full unpublished data sets were made available by Timm Hoffman (Leslie Hill Institute for Plant Conservation, Cape Town) and the methodology is described in detail in Hoffman et al. (1999).

The vegetation was analysed separately for the two vegetation types found in the study area because of their different geology, climate and plant communities. The two vegetation types are Moist Cold Highveld Grassland (MCHG) and Afro Mountain Grassland (AMG) (Low and Rebelo 1996). Within Herschel, the two vegetation types correspond to Acocks's (1988) veld types Cymbopogon-Themeda Veld and Themeda-Festuca Alpine Veld respectively (see Chapter 2). Nomenclature of grass species follows Gibbs Russell et al. (1990).

Vegetation surveys were conducted by systematically point-sampling 207 sites (125 in the lower lying MCHG, 82 in AMG) in Herschel and the three neighbouring commercial farming districts. Barkly East lies entirely in the AMG type, while Zastron is in MCHG. Both vegetation types are found in Lady Grey and Herschel. The survey data were used to analyze grass composition and relative basal cover, shrub cover, and the extent of bare ground and soil erosion. Mthozami Goqwana (Department of Livestock and Pasture Science, University of Fort Hare) collected most of the data; we conducted a quarter of the surveys together. Each of the vegetation surveys comprised the following components:

1. A 200-point transect, with two rows of 100 points every 2m set parallel 25m apart, where the rooted species nearest the point was identified. Grasses were identified to species level, while sedges, Karoo shrubs and other herbaceous species were grouped as sedges, Karoo shrubs and forbs respectively. Bare ground was recorded where no plant was found within 15 cm of the point. The distance from the point to the nearest tuft was estimated in centimetres. The average point to tuft distance (PTD) is a proxy of basal cover, which gives an indication of the area's resistance to soil erosion. The method used combines the step-point method for assessing herbaceous composition (Foran et al. 1978) with the point-tuft distance measure for assessing relative basal cover (Hardy and Tainton 1993). For details of data collection and analysis see Beckerling et al. (1995).
2. Geology, aspect and slope were recorded at each site. A solar radiation index was calculated from slope and aspect data using the formula by Swift (1976). The solar radiation index gives the amount of solar radiation on a slope of a certain angle and aspect relative to the amount of radiation received by a nearby horizontal surface.
3. The extent of soil erosion at each site was visually assessed and recorded in three classes (1: none evident, 2: isolated and 3: widespread).

The vegetation surveys were collected by Mthozami Goqwana for the purpose of developing a technique for assessing veld condition in communal grazing areas in MCHG and AMG vegetation types. The sample design was thus aimed at covering the greatest possible range of environmental conditions in Herschel and ensuring that comparable sites (in terms of geology, slope and aspect) were selected on the commercial farms. Sampling also aimed at covering the widest range of grazing intensities in both vegetation types in Herschel and commercial farms. Transects were conducted where a homogeneous vegetation unit large enough for the transect was found, and this led to the avoidance of eroded patches. We found that this, and the fact that point-tuft distance was only measured up to 15 cm (above which "bare ground" was recorded), tended to underestimate bare ground and soil erosion in the most severely eroded areas of Herschel.

An effort was also made to avoid areas that had previously been ploughed (so that vegetation change and soil erosion could be attributed to grazing and not previous cultivation), but with the exception of a small area near the town of Herschel, all flat or gently sloping areas we sampled were found to show evidence of having been ploughed at some stage. The fact that all available areas in the district were ploughed was described by Macmillan (1930) who visited the district in 1925. We chose sample sites outside the areas zoned as arable under betterment, i.e. land which had not been cultivated for at least 35 years.

3.2.2 Statistical analysis of vegetation data

All analyses were done separately for the two vegetation types. I performed multivariate analyses of grass composition to assess and interpret the similarity of different sites within a vegetation type. Bray-Curtis similarity indices were calculated between all sites using the percentage of each grass species in the 200-point transect. Grass composition data were square-root transformed to give some extra weight to rare species compared to untransformed data. This still maintains a difference between the contribution of dominant and less common species to similarities between sites, compared to double-root transformed or presence-absence data. The Bray-Curtis similarity matrices were used to produce dendrograms using a hierarchical clustering procedure with group-average linkage, as well as non-metric multi-dimensional scaling (NMDS) ordination plots. I chose NMDS ordinations as they are conceptually simple and make few model assumptions about the form of the data and the interrelationships of the samples (Clarke and Warwick 1994).

I superimposed environmental variables (geology, slope and solar radiation index) and land tenure system (communal or commercial) on the ordination plots to see whether and how these factors contribute to the grouping of sites. Two-way Mantel-type Monte Carlo analyses were used to test for significant differences in grass composition with land tenure and geology. I used similarity percentages (SIMPER) analyses to determine which grass species contribute most to similarities within sites on different geological formations in Herschel and the commercial districts. The multivariate analyses were performed using the PRIMER software package. More detail on the methodology can be found in Clarke and Warwick (1994).

Mann-Whitney U tests were used to assess differences in average PTD, percentage of bare ground, soil erosion score and shrub cover between sites in Herschel and on commercial farms. I used Kruskal-Wallis ANOVAs to test for differences in the same variables on different geology types, and Spearman rank order correlations to examine their relationship with slope and solar radiation index. Additional Spearman rank order correlation analyses were used to test whether increased shrub cover correlates with decreased basal cover (i.e. greater PTD) and a higher soil erosion class. The hypothesis here is that increased shrub cover is a result of overgrazing (which reduces grass cover and increases the risk of soil erosion), and, once established, shrubs further suppress grass growth through allelopathy or competition for water, nutrients and light. Non-parametric statistics were employed because the assumptions of parametric statistics (homogeneity of variance, normal distribution) were not met, and to accommodate the mix of categorical, continuous and percentage data. All analyses were performed on untransformed data.

3.3 Results

3.3.1 Some perspectives from a district-level survey

Data from workshops conducted to assess soil and vegetation degradation in every magisterial district of South Africa (Hoffman et al. 1999) were examined for Herschel and the commercial farming districts of Lady Grey, Barkly East and Zastron to gain a larger scale impression of the impacts of land use system on the condition of natural resources. Unless cited otherwise, all data used in this section are from the degradation workshops. Herschel has one of the highest combined (soil plus vegetation) degradation indices in the country, and the highest in the Eastern Cape (Table 3.2). The combined degradation index for Herschel is nearly ten times greater than that of Zastron and Barkly East, while Lady Grey has a degradation index of zero.

The soil degradation index (SDI) makes up about two thirds of the total degradation index in Herschel. Gully or donga erosion is rated to be the dominant form of soil erosion in all land use types in Herschel (crop areas, grazing land, woodlots and settlement areas), followed by loss of topsoil through sheet erosion. In Barkly East, donga erosion is the more important type of soil erosion, while sheet erosion is the more common form in Lady Grey and Zastron, although all districts experience both types. The degree, extent and rates of spread of soil erosion in all land use types are considerably higher in Herschel than in the commercial districts as shown in Table 3.1. Light or moderate erosion in the commercial districts is largely offset by the fact that erosion rates are judged to be constant or decreasing, which accounts for their low SDI values.

The veld degradation index (VDI) of Herschel is nearly three times as high as that of Barkly East and two thirds higher than that of Zastron, while Lady Grey has a VDI of zero (Table 3.2). The type of vegetation degradation differs between districts. Loss of cover is the most important form of vegetation degradation in Herschel and Barkly East, followed by change in grass composition in Herschel, and bush encroachment and alien plant invasion (by the nuisance grass *Stipa trichotoma*) in Barkly East. Change in grass composition is considered the major form of vegetation degradation in Lady Grey and Zastron, followed by loss of cover and bush encroachment in Lady Grey. Bush encroachment in Lady Grey and Barkly East is by *Leucosidea sericea* (commonly known as "ouhout"), a bush or small tree which is harvested for fuelwood in Herschel and is therefore relatively scarce there. Table 3.2 summarises the degree, extent and rate of veld degradation in the four districts.

3.3.2 Grass composition

A total of 31 grass species, which are listed in Table 3.3, were identified in each vegetation type. Most species occurred in both vegetation types, though in different proportions. *Festuca caprina*, *Eragrostis curvula* and *Pennisetum sphacelatum* were only found in Afro Mountain Grassland (AMG), while *Eragrostis gummiflua*, *E. lehmanniana* and *Trichoneura grandiglumis* were only recorded in Moist Cold Highveld Grassland (MCHG). The same species were present in transects in Herschel and on commercial farms, although again in different proportions. Figure 3.1 shows cumulative contribution to basal cover of the most abundant grass species, Karoo shrubs, forbs and bare ground in

Herschel and commercial sites in the two vegetation types. All the grasses that were identified are perennial species (Gibbs Russell et al. 1990).

Table 3.1 Rating of soil erosion in different land use types in Herschel and three neighbouring commercial farming districts. No woodlots or commercial forests are found in the three commercial districts. SDI: soil degradation index (Source: unpublished workshop data from Timm Hoffman, Institute for Plant Conservation, Cape Town).

Land use	Soil erosion	Herschel	Lady Grey	Barkly East	Zastron
Croplands	**Degree**[3]	Strong	Light	Light	Light
	Extent[4]	Frequent	Infrequent	Common	Common
	Rate	Rapidly increasing	Slowly decreasing	No change in 10 years	Moderately decreasing
Grazing land	**Degree**	Strong	Light	Moderate	Light
	Extent	Dominant	Infrequent	Infrequent	Common
	Rate	Rapidly increasing	Slowly decreasing	Slowly decreasing	Slowly decreasing
Woodlots	**Degree**	Moderate	N/A	N/A	N/A
	Extent	Common	N/A	N/A	N/A
	Rate	Moderately increasing	N/A	N/A	N/A
Settlement	**Degree**	Moderate	Light	None	Light
	Extent	Frequent	Infrequent	None	Infrequent
	Rate	Rapidly increasing	Slowly decreasing	No change in 10 years	Slowly increasing
	SDI	650	0	3	-18

Table 3.2 Rating of veld degradation in Herschel and three neighbouring commercial farming districts. VDI: veld degradation index; SDI: soil degradation index (Source: unpublished workshop data from Timm Hoffman, Institute for Plant Conservation, Cape Town).

Veld degradation	Herschel	Lady Grey	Barkly East	Zastron
Degree[1]	Strong	Light	Light	Light
Extent[2]	Frequent	Infrequent	Frequent	Infrequent
Rate	Moderately increasing	Slowly decreasing	Slowly decreasing	Slowly increasing
VDI	260	0	96	156
SDI + VDI	910	0	99	138

[3] **Light:** Somewhat reduced productivity, restoration possible. Biology intact. **Moderate:** Greatly reduced productivity, major improvements required for restoration. **Strong:** Not reclaimable at farmer level, major engineering works required.

[4] **Infrequent:** 0-5% of area affected. **Common:** 6-10%. **Frequent:** 11-25%. **Very frequent:** 26-50%. **Dominant:** >50%.

Table 3.3. A list of all the grass species identified in the two vegetation types.

Andropogon appendiculatus	*Eragrostis gummiflua*	*Merxmuellera disticha*
Aristida congesta	*Eragrostis lehmanniana*	*Microchloa caffra*
Aristida diffusa	*Eragrostis obtusa*	*Pennisetum sphacelatum*
Brachiaria serrata	*Eragrostis plana*	*Setaria sphacelata*
Cymbopogon plurinodis	*Eragrostis racemosa*	*Sporobolus africanus*
Cynodon dactylon	*Eustachys paspaloides*	*Sporobolus fimbriatus*
Digitaria eriantha	*Festuca caprina*	*Themeda triandra*
Elionurus muticus	*Harpochloa falx*	*Trachypogon spicatus*
Eragrostis capensis	*Heteropogon contortus*	*Tragus berteronianus*
Eragrostis chloromelas	*Hyparrhenia hirta*	*Trichoneura grandiglumis*
Eragrostis curvula	*Melica decumbens*	*Tristachya leucothrix*

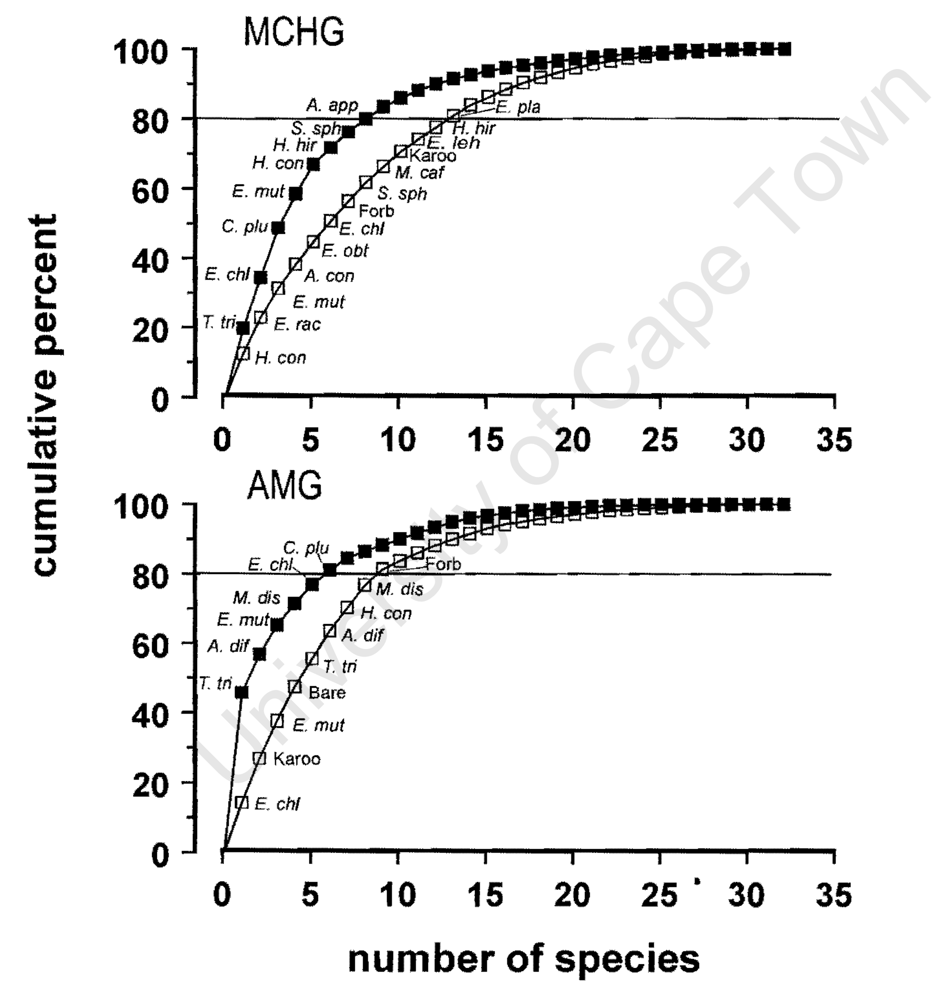

Figure 3.1. The cumulative percentage of basal cover contributed by different grass species, as well as Karoo shrubs, forbs and bare ground in Herschel (open squares) and on commercial farms (solid squares) in the two vegetation types (MCHG: Moist Cold Highveld Grassland; AMG: Afro Mountain Grassland). The full species names are listed in Table 3.3.

In both vegetation types, the most notable difference was a near absence of *Themeda triandra* in Herschel, compared to the commercial sites where this is the most common species. In contrast to *T. triandra*, some species did not show any marked response to differences in grazing regime and appear to be more responsive to environmental factors such as geology, soil type and water availability. These include *Andropogon appendiculatus*, *Heteropogon contortus* and *Elionurus muticus*, which are on average equally abundant in Herschel and commercial areas. Some species such as *Aristida congesta* and *Microchloa caffra* were particularly common on abandoned arable lands, and their higher abundance in Herschel is partly due to the fact that many flat areas in the district have been ploughed and subsequently abandoned.

Moist Cold Highveld Grassland

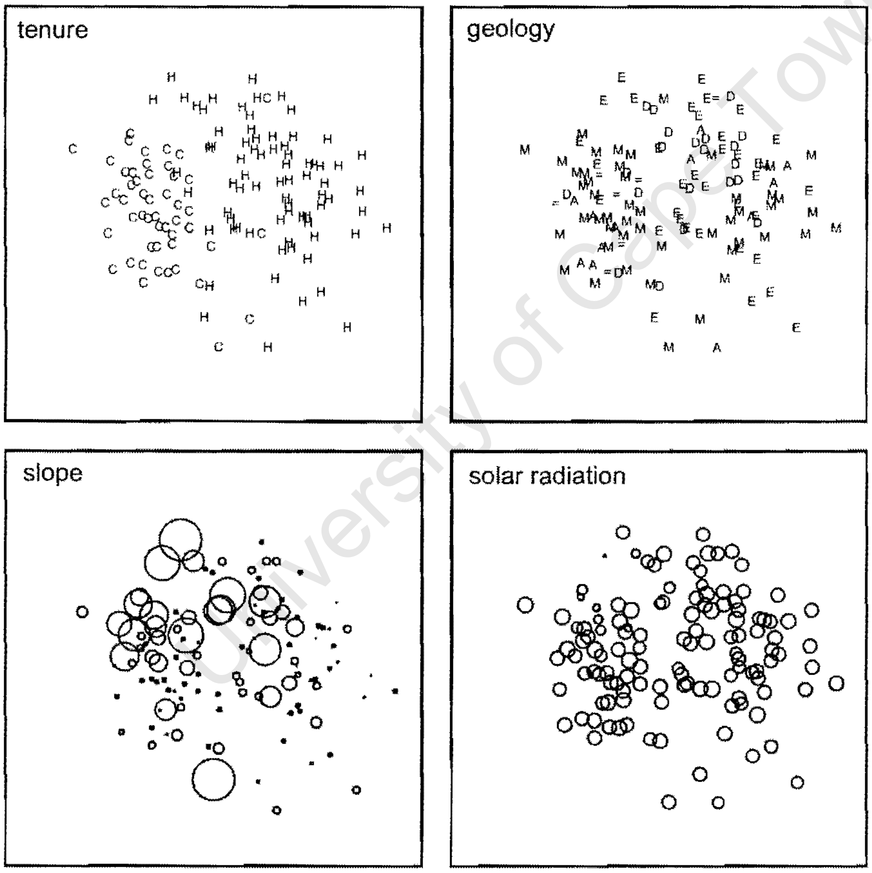

Figure 3.2. NMDS ordination plots for Moist Cold Highveld Grassland based on grass composition (global stress = 0.22). Land tenure (H: Herschel, C: commercial), geology (M: Molteno, E: Elliot, D: dolerite and A: Alluvium; = denotes no data on the site's geology), slope and solar radiation index (radius of circles proportional to value) are superimposed.

The ordination plots in Figure 3.2 show that sites in Herschel and on commercial land are distinct in their grass composition, and the majority of communal sites separate out from the majority of commercial sites at a Bray-Curtis similarity index of less than 35%. The trends for slope are less distinct, although sites on steeper slopes appear to fall largely on one side of the ordination plot. No influence of geology or solar radiation index is apparent from the ordination plots. It is clear from the ordinations that land tenure is the strongest determinant of grass composition in the study area.

A two-way, crosswise Mantel-type Monte Carlo analysis shows that sites under different land tenure (communal or commercial) are highly significantly different in their grass composition ($p<0.0001$), while the effect of geology is not significant overall ($p=0.29$). A pairwise Monte Carlo test, however, shows that sites on dolerite were significantly different from sites on any of the other three geological formations (Table 3.4).

Table 3.4 Pairwise Monte Carlo analysis to test for differences in MCHG sites on different geological formations. Probability values (p) are given, and significant results ($\alpha=0.05$) are highlighted.

	Molteno	Elliot	Dolerite	Alluvium
Molteno (n=49)	xxx			
Elliot (n=35)	0.81	xxx		
Dolerite (n=22)	**0.006**	**0.02**	xxx	
Alluvium (n=12)	0.78	0.86	**0.01**	xxx

SIMPER analyses of groups defined by their geology and land use type show that sampling sites on commercial farms are characterised by different grass species than Herschel sites. Table 3.5 summarises key species characterising sites on different geological formations in Herschel and in the commercial districts. *Themeda triandra*, *Eragrostis chloromelas*, *Cymbopogon plurinodis* and *Heteropogon contortus* characterise the commercial sites, while *Eragrostis obtusa*, *E. racemosa*, *Heteropogon contortus*, *Aristida congesta*, forbs and *Setaria sphacelata* are key species found in different Herschel sites. The SIMPER results show that tenure has a greater effect on vegetation composition than geology.

From Figure 3.1, it can be seen that the grass composition of commercial sites is typical of the vegetation type (Acocks 1988, Low and Rebelo 1996) and comprises a combination of species with high (*T. triandra*, *H. contortus*, *S. sphacelata*), moderate (*E. chloromelas*, *H. hirta*) and low (*C. plurinodis*, *E. muticus*) palatability. In Herschel, a similar combination of species of varying palatability is found, with a greater variety of *Eragrostis* species, very little *Themeda* or *Cymbopogon*, and significant contributions of forbs and Karoo shrubs to total basal cover. The average number of grass species per transect (11) was the same in both land use systems. The most common grass species in the commercial sites was *Themeda triandra*, making up on average 19 % of the grass plants sampled in a transect.

Table 3.5 Summary of key species and average Bray-Curtis similarity among sites categorized by geological formation and area (Herschel vs. commercial farming districts) in Moist Cold Highveld Grassland vegetation. Species listed make the highest contribution (>10%) to within-group similarity but are not necessarily the most abundant species.

Area	**Geology (n)**	**Average similarity**	**Characteristic grass species (average abundance in transects)**
Herschel	Molteno (18)	51.7	*Aristida congesta* (14%) *Eragrostis racemosa* (16%) *Heteropogon contortus* (10%)
Herschel	Elliott (32)	40.7	*Heteropogon contortus* (11%) Forbs (6%) *Eragrostis obtusa* (7%)
Herschel	Dolerite (20)	50.1	*Elionurus muticus* (17%) *Heteropogon contortus* (17%) *Eragrostis obtusa* (7%)
Herschel	Alluvium (6)	54.6	*Eragrostis racemosa* (22%) *Setaria sphacelata* (11%) *Eragrostis obtusa* (7%)
Commercial	Molteno (31)	48.8	*Themeda triandra* (19%) *Eragrostis chloromelas* (16%) *Cymbopogon plurinodis* (12%) *Elionurus muticus* (12%)
Commercial	Elliott (3)	62.2	*Themeda triandra* (36%) *Elionurus muticus* (9%) *Eragrostis chloromelas* (5%)
Commercial	Dolerite (2)	53.0	*Cymbopogon plurinodis* (16%) Bare ground (9.5%) *Themeda triandra* (11%) *Heteropogon contortus* (8%) *Eragrostis chloromelas* (16%)
Commercial	Alluvium (6)	61.6	*Themeda triandra* (25%) *Cymbopogon plurinodis* (17%) *Eragrostis chloromelas* (12%) *Heteropogon contortus* (9.5%)

T. triandra is considered to have the highest forage production potential of all the grass species sampled in this study (Trollope et al. 1990) and is diagnostic of the vegetation type (Acocks 1988, Low and Rebelo 1996). *Themeda* is almost completely absent in Herschel, where no single species was dominant across sites. The most common species in Herschel, when all transects are averaged, was *H. contortus* with an average abundance of 12 %.

Afro Mountain Grassland

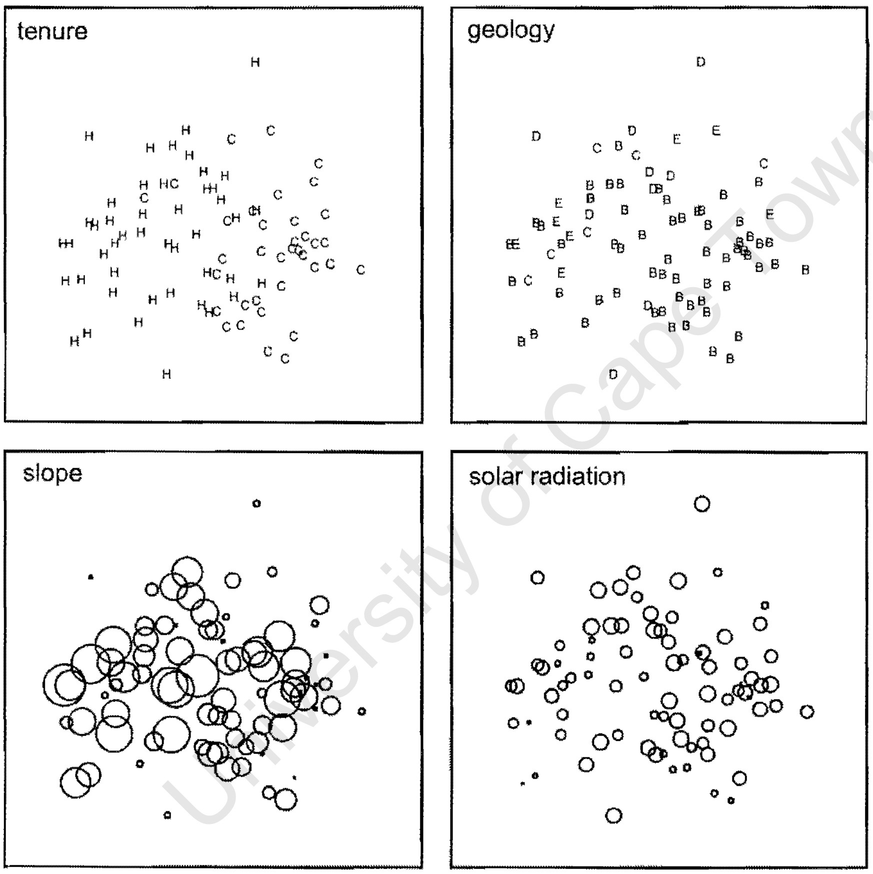

Figure 3.3. NMDS ordination plots for Afro Mountain Grassland based on grass composition (global stress = 0.20). Land tenure (H: Herschel, C: commercial), geology (B: basalt, E: Elliot, D: dolerite and C: Clarens; = denotes no geology data for the site), slope and solar radiation index (radius of circles proportional to value at the same scale as Figure 3.2) are superimposed.

The ordination plots in Figure 3.3 show that, as in MCHG, grass composition in AMG is different at sites in Herschel to those in the commercial districts. Basalt is the most common geological formation in AMG, especially in the commercial farms surveyed which lie largely on a high basalt plateau. Only five commercial sites lie on geology other than basalt, four on Elliot red mudstone and one on Clarens sandstone. Patterns in the geology are not distinct, although sites on sedimentary rock (Elliot red mudstone and Clarens sandstone) tend to fall along the edges of the ordination plot. The influence of slope and solar radiation on grass composition is not clear from the ordination plots. Slopes overall are steeper in this vegetation type than in MCHG.

A two-way crosswise Monte Carlo analysis showed that sites under different land use were highly significantly different ($p<0.0001$), and that geology also underlies significant differences between groups of sites ($p=0.004$). A pairwise Monte Carlo analysis (see Table 3.6) shows that sites on basalt were significantly different from sites on Elliot red mudstone and almost significantly different from sites on Clarens sandstone at the 5% level. Dolerite was omitted from the analysis because no commercial sites were situated on dolerite.

Table 3.6 Pairwise Monte Carlo analysis to test for differences in sites in AMG on different geological formations. Probability values (p) are given, and significant results ($\alpha=0.05$) are highlighted.

	Basalt	**Elliot**	**Clarens**
Basalt (n=58)	**xxx**		
Elliot (n=9)	**0.012**	**xxx**	
Clarens (n=6)	0.054	0.083	**xxx**

Table 3.7 summarises the species contributing to similarity within groups of sites in different land tenure systems and on different geological formations. Again, the biggest difference was between Herschel and commercial sites. *Eragrostis chloromelas*, Karoo shrubs and bare ground are found to characterise all three geological formations in Herschel, with forbs contributing to within-group similarity of sites on Elliott mudstone in Herschel. *Themeda triandra* is the dominant species in the commercial areas on all geological formations with an average abundance of 46 %, and *Harpochloa falx*, *Elionurus muticus*, *Tristachya leucothrix* and *Aristida diffusa* were additional key species.

Figure 3.1 illustrates the dominance of *T. triandra* on the commercial farms. The most abundant co-occurring species were *A. diffusa*, *E. muticus*, *Merxmuellera disticha*, *E. chloromelas* and *Cymbopogon plurinodis*, all unpalatable except *E. chloromelas*. Herschel had no clearly dominant species, and the important contribution of *E. chloromelas*, Karoo shrubs, *E. muticus* and bare ground are clear from Figure 3.1. *Themeda* contributed 8% to average total cover of Herschel sites, but this was unevenly distributed. *Themeda* abundance was low in Herschel except at sites in Jozana's Nek and Jozana's Hoek, which are less heavily grazed because of their distance from villages and rather inaccessible location above the Jozana Dam. The grass composition of these sites was similar to commercial sites with an intermediate *Themeda* cover. The mean number of species per transect was higher in Herschel (9.2) than on commercial farms (7.4).

Table 3.7 Summary of key grass species (as well as Karoo shrubs, forbs and bare ground which were recorded as species in the transects) in Herschel and commercial farming sites on different geological formations in Afro Mountain Grassland vegetation. Species listed make the highest contribution (>10%) to within-group similarity, but are not necessarily the most abundant species at these sites.

Area	Geology (n)	Characteristic grass species (average abundance in transects)
Herschel	Elliott (5)	Karoo (21%) *Eragrostis chloromelas* (23%) Forb (10%) Bare ground (12%)
	Clarens (5)	*Eragrostis chloromelas* (20%) Karoo (20%) Bare ground (6%)
	Basalt (27)	Karoo (13%) *Eragrostis chloromelas* (11%) Bare ground (13%)
Commercial	Elliott (4)	*Elionurus muticus* (27%) *Themeda triandra* (27%) *Harpochloa falx* (8%) *Tristachya leucothrix* (8%) *Aristida diffusa* (11%)
	Clarens (1)	N/A
	Basalt (31)	*Themeda triandra* (49%) *Eragrostis chloromelas* (5%)

3.3.3 Basal cover and soil erosion

The average point-tuft distance (PTD), percentage of bare ground and erosion score of a transect all indicate actual erosion or erosion risk and are thus of great interest when considering sustainability and degradation in different areas. The three variables were found to be closely correlated with each other in both vegetation types (Table 3.8).

Table 3.8. Spearman rank order correlations between point-tuft distance (PTD), soil erosion score and % bare ground in the two vegetation types.

	MCHG			AMG		
	R	**N**	**p**	**R**	**N**	**p**
PTD vs. erosion	0.42	119	<0.00001	0.73	81	<0.000001
PTD vs. % bare	0.36	125	<0.0001	0.76	82	<0.000001
% bare vs. erosion	0.24	119	<0.01	0.59	81	<0.000001

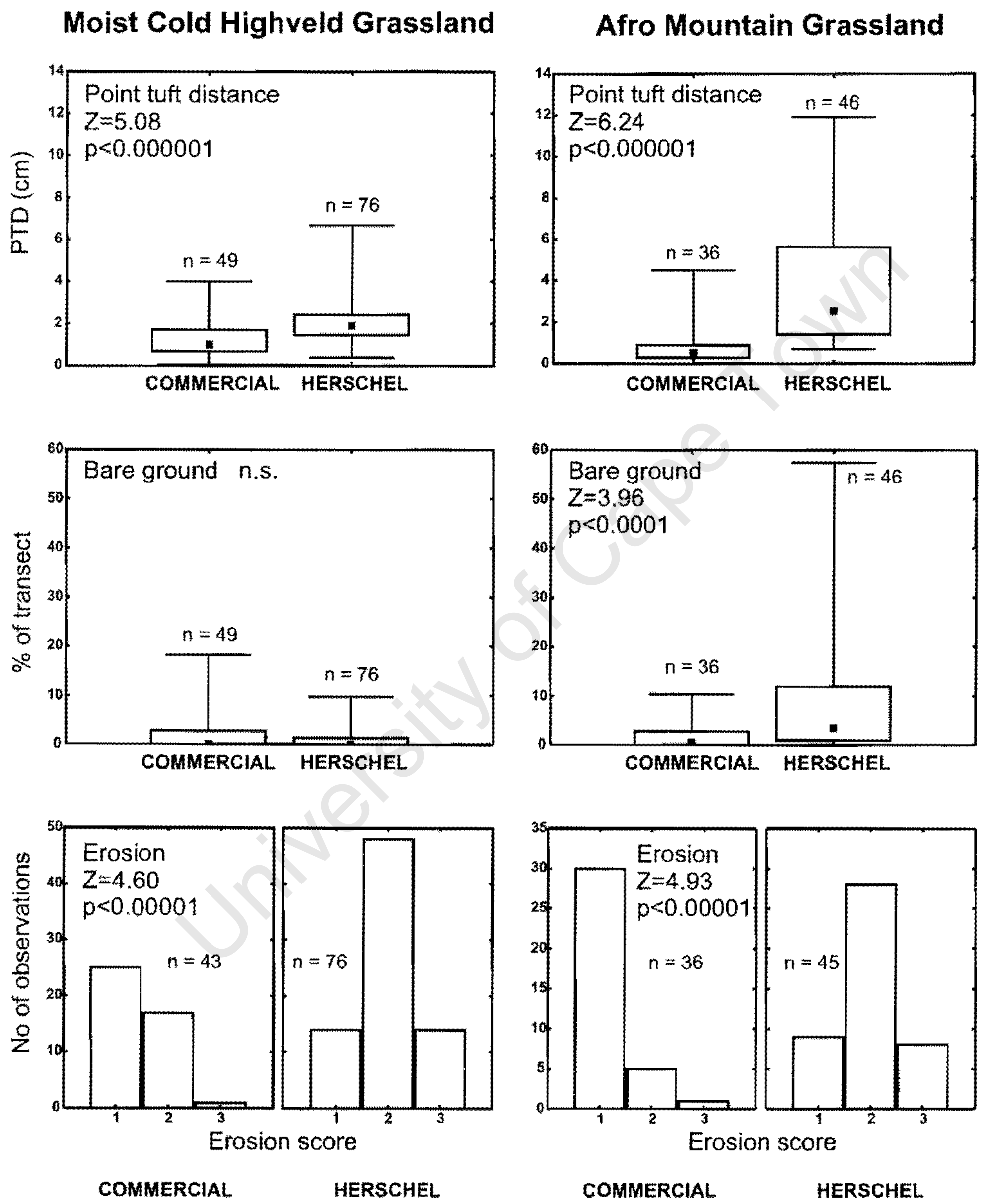

Figure 3.4. Average point-tuft distance (PTD), % bare ground and soil erosion scores on transects in Herschel and on commercial farms. PTD and bare ground graphs give median value, quartiles and range, and all graphs give significance values from Mann-Whitney U tests.

Figure 3.4 shows comparisons of PTD, % bare ground and the soil erosion score between Herschel and commercial farming sites. In both vegetation types, average PTD was higher in Herschel than in the commercial areas. Beckerling et al. (1995) suggest that a PTD less than 3 cm indicates high basal cover, PTD between 3 and 6 cm indicates moderate to low basal cover with probable need for concern, and PTD greater than 6 cm indicates low or very low basal cover and a threat of invasion by pioneer grass species and soil erosion. Although PTD was greater in Herschel than on commercial farms, median PTD values in Herschel fell below 3 cm in both vegetation types. In slope (Spearman R=0.34, N=125, $p < 0.001$). No relationships with solar radiation index were found, which may be attributable to the gentler slopes and thus less pronounced effect of aspect in this vegetation type when compared to AMG.

In AMG, geology had no significant influence on PTD and erosion score, but % bare ground was highest on Clarens sandstone (Kruskal-Wallis ANOVA, H(3, N=82)=9.53, $p<0.05$). In many cases, this was bare rock rather than exposed soil and thus did not necessarily pose a risk of accelerated soil erosion. All three measures were highest on steep slopes, suggesting that steeper slopes were more eroded and more vulnerable to soil erosion (Spearman rank order correlation, PTD: R=0.40, N=82, $p<0.001$; erosion: R=0.37, N=81, $p<0.001$; % bare: R=0.44, N=82, $p<0.0001$). A negative relationship between % bare ground and solar radiation index (R=-0.27, N=82, $p<0.05$) was found in this vegetation type, suggesting that shadier sites have less bare ground. However, there were no significant relationships of PTD and soil erosion with the solar radiation index.

3.3.4 Shrub composition and cover

The shrub species most commonly encountered in MCHG were *Chrysocoma ciliata*, *Felicia muricata*, *Stoebe vulgaris* and *Pentzia globosa*. *Rhus erosa* was common on slopes on Elliot mudstone. In AMG, the most common shrub was *Chrysocoma ciliata*, followed by *Felicia filifolia*, *Passerina montana* and *Relhania pungens*. *Senecio asperulus* and *Helichrysum odoratissimum* were two large forb species commonly found in Herschel in this vegetation type. *Leucosidea sericea* was considered to be a problem on some commercial farms, although none of the transects in this study showed very high densities. Karoo shrubs were found to be rare on the commercial farms; where they are found, the species composition was similar to that in Herschel. Line intercept transects were done in a subset of the transects in AMG vegetation, and shrub densities of up to 15% aerial cover (% of line intercepted by shrubs at 30 cm height above ground level) were encountered.

The relationships of Karoo shrub density with land tenure, geology, slope, solar radiation index, PTD and % bare ground are presented in Figure 3.5 with their significance levels. Transects in Herschel had significantly higher densities of Karoo shrubs than transects on commercial farms, and this contrast was clearly visible in the field along fences separating Herschel from commercial farms. This difference is more pronounced in AMG where shrub densities were higher overall.

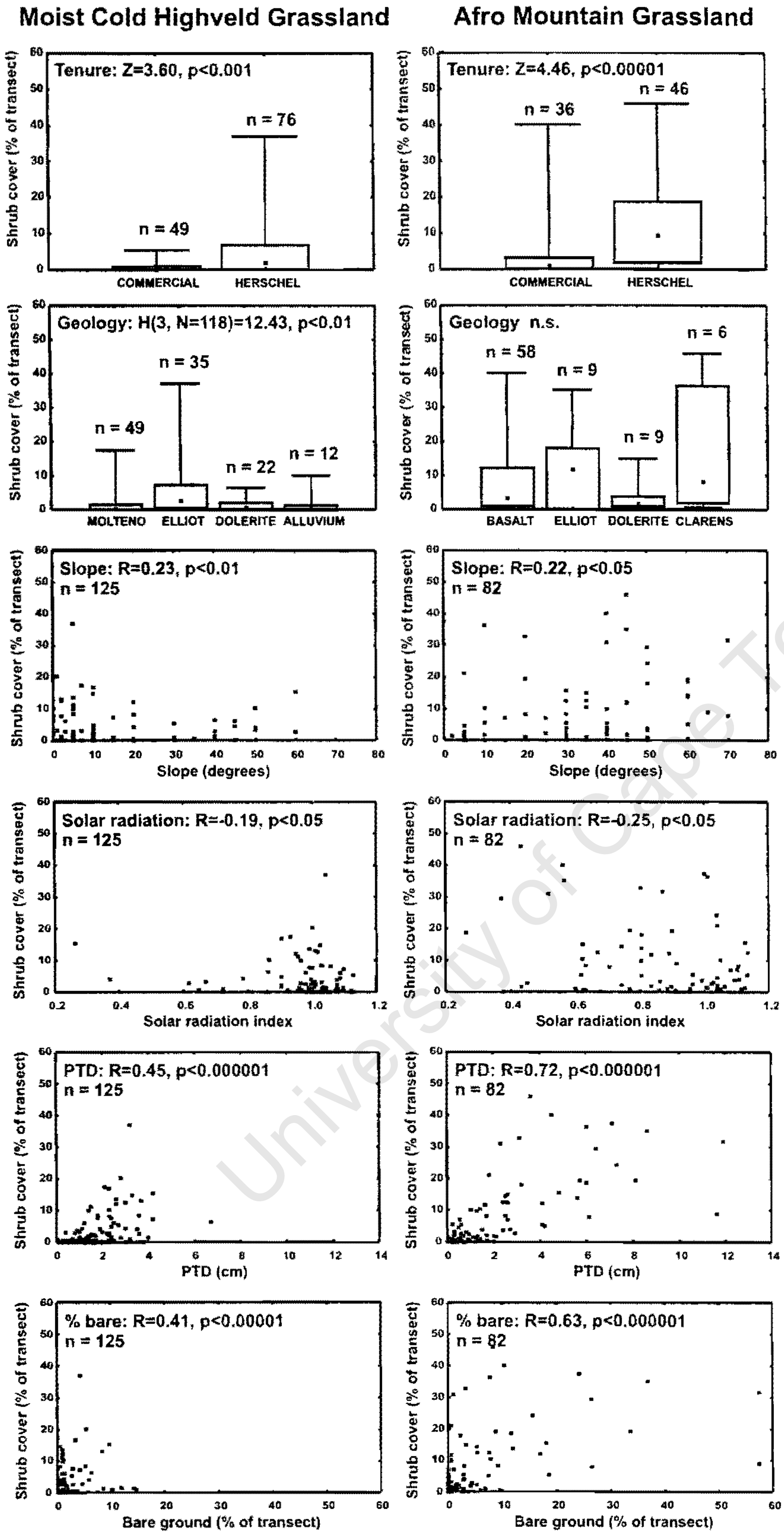

Figure 3.5. Shrub cover as a function of land tenure, geology, slope, solar radiation index, PTD and % bare ground on the transect. Statistical tests were Mann-Whitney U Test for tenure, Kruskal-Wallis ANOVA for geology and Spearman rank order correlation for the remaining relationships.

In MCHG, the highest Karoo shrub densities were found on Elliot mudstone, which was also the geology type worst affected by soil erosion and low basal cover. No significant relationship between shrub cover and geology was found in AMG, although the unbalanced design (with the great majority of sites on basalt) may have contributed to this result. Shrub cover increased with slope angle and decreased with solar radiation index, and was also positively correlated with PTD and % bare ground in both vegetation types.

3.4 Discussion

This chapter set out to examine the assessment of soil and vegetation degradation in Herschel and neighbouring commercial farming areas made by extension officers (Hoffman et al. 1999) using standard measures of rangeland degradation. The key findings of the district level survey were that land tenure has the overwhelming influence on vegetation and soil degradation, that soil degradation in Herschel is more severe than vegetation degradation, and that loss of cover is the most significant form of vegetation change in Herschel. These findings are supported by the data from the vegetation transects, which show that Herschel has different grass composition, lower basal cover, more bare ground and erosion, and higher shrub density than the commercial farms. Encroachment by Karoo shrubs was, however, not mentioned in the extension officers' rating of vegetation degradation in Herschel.

A further aim of this chapter was to assess the relative importance of land tenure and physical factors (geology, slope and solar radiation) in determining the state of the vegetation and soils. The transect data showed that land tenure had the greatest influence on botanical composition, basal cover, bare ground, erosion and shrub density in both vegetation types, but that geology, slope and solar radiation also have an effect on vegetation and soil characteristics. This highlights the need to control for environmental characteristics when comparing sites under communal and commercial tenure.

The observed state of the vegetation in Herschel was consistent with predictions of the rangeland succession model (Tainton 1981, Tainton and Hardy 1999, van Oudtshoorn 1999). This does not prove that succession (*sensu* Clements 1936) is the underlying mechanism for the observed changes, but it shows that in the long term, grazing impact is a stronger determinant of vegetation composition and structure than abiotic factors. The severe encroachment of Karoo shrubs is not easily reversible, and a state-and-transition model may be more useful to describe vegetation change in Herschel (Westoby et al. 1989, Friedel 1991).

3.4.1 Grass composition

Although the same grass species were represented in both land use systems, continuous intensive grazing in Herschel has clearly resulted in a different plant community than that found in neighbouring commercial farming areas. In Herschel, there has been an increase in the proportion of less palatable or less productive species and a loss of *T. triandra*, the species which is considered to be the best single indicator of veld that is highly productive and resistant to soil erosion (Foran et al. 1978, Willis and Trollope 1987). The effects of geology, slope and solar radiation were secondary to those of grazing in affecting grass composition and cover.

The same was found to be true in some other comparisons of communal rangelands with commercial cattle farms and/or game reserves (e.g. Kelly and Walker 1976, Evans et al. 1997, Parsons et al. 1997). Other studies, however, found slope position to have a greater influence on soil erosion, herbage production and grass species richness and diversity than grazing intensity (e.g. Venter, Liggitt et al. 1989), and studies in arid Namibia (Ward et al. 1998, Ward and Ngairorue 1999) found no differences in the vegetation and soil characteristics between lightly and heavily grazed areas. In a synthesis of grazing studies around the world, Milchunas and Lauenroth (1993) found slope position to be a better predictor of vegetation structure and composition than grazing effects. The relative importance of "bottom-up" factors such as rainfall, soil type, slope position and geology, and "top down" controls such as grazing and fire, in determining vegetation structure and composition is often debated (e.g. Higgins et al. 2000) and will not be discussed here. It appears to differ between environments and with the nature, frequency and intensity of grazing and fire. In environments where rainfall and soil characteristics allow sufficient biomass production to support grazers and/or fires, the effects of the latter have the potential to be substantial. Conversely, rainfall may be the overriding driver of plant productivity, composition and structure in environments with very low and unpredictable rainfall, with grazing having a negligible long-term effect on vegetation characteristics (Ellis and Swift 1988, Ward et al. 1998, Ward and Ngairorue 1999).

Grass composition has been shown to affect primary production and susceptibility to soil erosion *via* processes influencing available soil moisture and the water use efficiency of the species present (Snyman 1989, O'Connor and Bredenkamp 1997 and references therein). Grass composition is also correlated with basal cover, with pioneer communities characterised by low basal cover and climax communities characterised by high basal cover and often high standing biomass (e.g. Tainton and Hardy 1999). The latter were found to have up to three times the mean phytomass production and water use efficiency (WUE) of pioneer swards (Snyman and Opperman 1984, Snyman 1988, Snyman and Fouché 1991), with subclimax swards having intermediate production and WUE. In the studies cited above, pioneer, subclimax and climax communities are synonymous with low, intermediate and good veld condition, based on botanical composition and basal cover. The composition of the climax community in these studies, dominated by *T. triandra*, is similar to that found on many of the commercial farms sampled in this study, while most Herschel sites are similar to the subclimax community (dominated by *E. lehmanniana* and *E. chloromelas*). The Herschel sites in poorest condition – mainly abandoned arable lands – resemble the pioneer community (dominated by *A. congesta* and *Tragus koelerioides*). Interestingly, *E. chloromelas* was found to have the highest WUE under conditions of moisture stress (Snyman 1989), and this may explain its success in overgrazed areas where increased run-off and evaporation reduce moisture availability.

The relationship between grass composition and secondary production is more contested, and complicated by the fact that biomass production and the nutritional value of grasses and other herbaceous plants are not necessarily correlated (Danckwerts 1989, Turner and Tainton 1989, O'Reagain and Mentis 1990, Ash et al. 1996). In Australia, Ash et al. (1996), compared weight gain by cattle grazing vegetation in two states, the first dominated by palatable tussock perennial grasses, the second dominated by less palatable perennial grasses, annual grasses and forbs. At low stocking rates, weight gain was higher in cattle grazing vegetation in the second state, but weight gain decreased more rapidly with increasing stocking rate, and the total number of cattle which could be supported was lower than on vegetation dominated by palatable perennial grasses. This could be explained by the greater nutritional value, but substantially lower biomass production, of the vegetation with a high proportion of annual grasses and forbs. The effect of vegetation change is thus dependent on the ratio of animal demand to forage available (Owen-Smith 1991, Ash et al. 1996). Spatial heterogeneity in resource production and quality further complicates prediction of secondary production at larger scales from grass composition data (Fynn and O'Connor 2000, Owen-Smith 2002).

In terms of recovery, grass composition is probably less worrying than soil erosion and the encroachment Karoo shrubs, both of which are effectively irreversible without active interventions. The grass sward, while not considered desirable for animal production because of its suboptimal palatability and biomass production, is nevertheless composed of perennial species. This is unlike situations found in warmer, drier areas such as southern Zimbabwe (Kelly and Walker 1976) and the South African Lowveld (Parsons et al. 1997) where a shift to annual grasses was observed under heavy grazing. Herschel has the same grass species as the commercial areas, although the relative abundance of species is very different and *Themeda* appears to have become locally extinct in Herschel (O'Connor 1991). If grazing pressure were reduced or better managed in Herschel, some species like *Themeda* will be extremely slow to recolonise areas from which they have become absent (O'Connor and Pickett 1992), while some unpalatable species like *Elionurus muticus* are likely to persist. Recovery of abandoned arable lands is also often slow due to altered soil characteristics or the loss of mycorrhizal symbionts (Allsopp 1999). This is illustrated in Herschel by the large areas of land ploughed more than 30 years ago, many of which are still dominated by *Aristida congesta* and *Microchloa caffra*, both weak perennials with very low biomass production.

3.4.2 Basal cover, bare ground and soil erosion

In Herschel, soil erosion is rated to be the most widespread and severe form of degradation (Hoffman et al. 1999). Vegetation and soil are intimately related to one another within the ecosystem, and vegetation cover is a key variable in controlling soil erosion. Plant cover protects the soil from raindrop impact, increases water infiltration and increases resistance of the soil surface to erosion (Rowntree 1988, Venter, Smithen et al. 1989). Infiltration capacity is linearly related to the basal cover of perennial grasses (van den Berg et al. 1976, cited in O'Connor and Bredenkamp 1997). The strong correlations between PTD, percentage of bare ground and soil erosion scores in Herschel illustrate the relationship between basal cover and soil loss. Standing grass biomass also affects resistance to erosion as it intercepts rainfall (Venter, Smithen et al. 1989), and reduced litter leads to a drier soil microclimate (Kelly and Walker 1976). The susceptibility of soils to erosion varies with the type of vegetation, with grass offering more protection than an equivalent cover of karooid shrubs (Selby and Hosking 1973, Roux 1981; both cited in Rowntree 1988). The low grass biomass and shrub encroachment in Herschel thus further increase the risk of accelerated soil erosion.

It is clear from the data that Herschel is more eroded and more susceptible to further soil erosion than neighbouring commercial farming areas. There is more erosion and bare ground in Herschel than on commercial farms. Average basal cover is lower in Herschel, with high levels of variability. Although many of the transects had a relatively low average point-tuft distance (indicating high basal cover), it must be borne in mind that extremely eroded areas were avoided during sampling and more bare ground is exposed than the

PTD data suggest. Geology and slope had some influence on basal cover and soil erosion. Most noticeable is the fact that slopes on Elliot mudstone were most severely affected by loss of grass cover, soil erosion and encroachment by Karoo shrubs. Clearly, comparisons between tenure systems need to take geology and the susceptibility of soils to erosion into account.

Land tenure was found to be the strongest predictor of soil erosion scores in South Africa (Hoffman et al. 1999). In a study of the soil erosion history of the Peddie District in the Eastern Cape of South Africa, Kakembo (1997) similarly found that the greatest difference in soil erosion levels was between communal and commercial grazing areas, the latter showing no sign of erosion over the entire study period (1938 to 1988). In the Mfolozi catchment of KwaZulu-Natal, Venter, Liggitt et al. (1989) found that rates of soil loss in communal areas were consistently, though not significantly, higher than in the adjacent Umfolozi Game Reserve. However, not all comparisons of soil erosion between communal and commercial farming areas show communal areas to be more eroded. Garland and Broderick (1992), for example, found no significant difference in soil erosion between the commercial and communal districts in the Tugela Basin of KwaZulu-Natal. These differences may be attributed to differences in the temporal and spatial scales considered, environmental characteristics such as soil type and rainfall, as well as the degree of contrast in land use practices, e.g. the difference in stocking rates between the systems compared. Herschel has very erodible soils and one of the highest soil erosion scores in the country, and thus represents an extreme example.

3.4.3 Encroachment by Karoo shrubs

Shrub composition was the same in Herschel and on commercial farms, but shrub cover was significantly higher in Herschel. Encroachment of grassland by shrubs is also documented in other parts of South Africa and in the semi-arid south-western USA and is associated with desertification, denudation and loss of productivity (Schlesinger et al. 1990, van Auken 2000, Berlow et al. 2002, Huenneke et al. 2002). In both continents, the main cause of shrub encroachment is understood to be intensive, continuous grazing by livestock (Acocks 1964, Evans et al. 1997, Schlesinger et al. 1990) and its effect of suppressing fires by reducing fuel loads (van Auken 2000).

Karoo shrubs are considered to be characteristic of a drier climate, and shrub encroachment is often seen as an indicator of a drier microclimate caused by vegetation and soil changes as a result of grazing (Acocks 1964, Hoffman and Cowling 1989, Evans et al. 1997). However, shrub cover in Herschel and neighbouring commercial farms increased with slope angle and decreased with solar radiation index, i.e. sunnier, drier sites had lower shrub cover than wetter, shaded sites. This agrees with findings by Berlow et al. (2002) in the Sierra Nevada, USA, where shrub establishment was favoured by mesic conditions in conjunction with soil disturbance and proximity to parent plants.

The positive correlations between PTD, % bare ground and shrub density in both vegetation types in Herschel are consistent with the hypothesis that Karoo shrubs invade and increase the size of bare, disturbed areas. Schlesinger et al. (1990) propose that shrubs take advantage of locally increased water and/or nutrient availability caused by grazing, and once established, cause further localisation of water and nutrients under their canopies (Allsopp 1999). This in turn results in depleted resources between shrubs which, together with a loss of grass cover caused by grazing, facilitates and perpetuates soil loss and bare patches. Many slopes in Herschel, particularly on Elliott mudstone, are characterised by Karoo shrubs on almost bare ground. Loss of topsoil, crusting of the soil surface, localised depletion of nutrients and the allelopathic effects of some shrub species (Squires and Trollope 1979) make recovery of such areas slow and difficult. In the south-western USA, for example, Valone et al. (2002) found that it took more than 20 years for grass cover to increase in areas which had been encroached by shrubs.

Laboratory experiments (Squires and Trollope 1979) demonstrated that *Chrysocoma ciliata* (formerly *C. tenuifolia*) has a strong allelopathic effect on other plant species and suppresses grass germination and growth. Thus once established, *C. ciliata* leads to a further loss of grass cover. The fact that *C. ciliata* is killed by fire and the allelopathic effect stops after fire indicates that fire can be used to eradicate this shrub and promote the regrowth of grasses. It is possible that other Karoo shrub species are also allelopathic. In another communal area in the Eastern Cape, *Euryops floribundus* was reported by farmers to suppress grass growth with its resinous leaf litter (Vetter and Goqwana 2000). Considering the concern about the spread of the Karoo into grasslands and savannas (reviewed in Hoffman et al. 1999), there is, however, a surprising lack of empirical data on allelopathy in Karoo shrubs.

Vegetation dominated by Karoo shrubs is relatively resilient to intensive continuous grazing, and primary productivity of shrub dominated plant communities was found to be less variable interannually than that of grasslands in the Chihuahuan desert, New Mexico (Huenneke et al. 2002). However, grasslands had higher overall productivity and less spatial variation in productivity. In Herschel, most of the shrubs are unpalatable, and thus the benefits of any additional primary productivity of the shrub component are negligible. The positive correlations between shrub cover and percentage bare ground and PTD strongly suggest that forage production is in fact reduced in areas with high shrub densities.

3.4.4 Conclusions

The data presented in this chapter have given a once-off picture of grass composition, basal cover, bare ground, erosion and shrub cover in the communal area of Herschel and in neighbouring commercial farming districts. Vegetation dynamics over time, particularly in response to rainfall variations, droughts, or variations in stocking rates, were not considered in this investigation, nor were plant growth rates, biomass production or forage quality assessed. All of these are known to vary with annual rainfall (e.g. Snyman and Fouché 1991, O'Connor 1994, O'Connor and Roux 1995, Fynn and O'Connor 2000). More research in this regard would be desirable, but a long-term study of this nature fell outside the scope of this research.

For the purpose of this study, i.e. assessing the costs of degradation to livestock farmers in Herschel, it has been established that Herschel has a different grass composition with a higher proportion of unpalatable or less productive species, lower basal cover, more bare ground and soil erosion, and a higher cover of unpalatable shrubs than neighbouring commercial farms. All of these are understood to lower the productive potential of the land, by increasing run-off and reducing water-use efficiency and primary production (Snyman and Opperman 1984, Snyman 1988 and 1989, Venter, Smithen et al. 1989, Snyman and Fouché 1991, Fynn and O'Connor 2000), and also through irreversible soil loss. The question that remains is how this affects livestock production, and how livestock numbers in Herschel have been maintained. This will be addressed in later chapters.

4. SOIL EROSION IN THE HERSCHEL DISTRICT – PRESENT STATUS, HISTORY, CORRELATES AND PERCEPTIONS

4.1 Introduction

Chapter 3 showed that soil erosion is more widespread in Herschel than in neighbouring commercial farming areas. This chapter explores where, why and when soil erosion has spread and intensified in Herschel. Its three main aims are to establish (1) how far back degradation dates and how soil erosion rates have changed over time, (2) how it varies within Herschel and what variables correlate with high levels of soil erosion, and (3) how the perceptions of the local people reflect the realities of degradation.

Livestock records show that stock numbers fluctuated over the last 100 years, but there has been no net decline in total livestock units over this time (see Chapter 1). Current levels of land degradation are judged to be severe at present, but in order to determine the effect of degradation on livestock numbers and production, we need to establish how far back the degradation goes, and when it reached its present levels. The first aim of this chapter is to investigate the history of land degradation, especially soil erosion, so that any information on livestock numbers and productive output can be seen against the levels of degradation at the time. The results of several studies (Marker 1988, Watson 1990 and 1996, Garland and Broderick 1992, Kakembo 1997 among others) suggest that rates of soil erosion increase dramatically following initial settlement and other land use changes, but slow down or even stabilise or reverse a few decades after the change has taken place. Often, the rates vary with rainfall after the initial increase has stabilised. This chapter examines whether rates of soil erosion changed over time, and whether there are any specific events that have led to sudden changes in the extent and severity of soil erosion in the Herschel district.

The second aim of this chapter is to explore which variables are responsible for differences in levels of soil erosion between different areas in the Herschel district. In Chapter 3 it was established that the land tenure system (commercial or communal) is the overriding factor leading to changes in vegetation and the condition of the soils, and this finding is reported in a number of other studies (e.g. Weaver 1988a, Kakembo 1997, Hoffman et al. 1999). Here I will investigate factors that are responsible for differences within Herschel, in order to determine what factors to take into account when planning sustainable resource management within a communal tenure system. Several studies have documented the importance of physical, land use and socio-economic factors in shaping soil erosion within areas under the same land tenure. Authors have variously identified geology, soil type and sediment properties (Weaver 1988b and 1991, Watson 1990, van Oudtshoorn 1988), average slope steepness (Hoffman et al. 1999), mean annual rainfall (Weaver 1988b, Hoffman et al. 1999), rainfall variation and individual rainfall events (Watson 1990, Garland and Broderick 1992, Kakembo 1997), livestock and population pressure (Fox and Rowntree 2001), and land use changes including villagisation and abandoning cultivated lands (Watson 1990 and 1996, Kakembo 1997, Kikula 1997) as variables leading to differences in levels of soil erosion.

People's perceptions and how these relate to the actual extent, severity and spread of soil erosion are of interest as these are thought to reflect the kind of relationship people have with their natural resources, especially their level of dependence on them (Brinkcate and Hanvey 1996, Kikula 1997, Leduka 1998). Also, when trying to develop some form of natural resource management in a community, understanding community members' perceptions of soil erosion – especially whether it is perceived as a problem or not - is crucial (Brinkcate and Hanvey 1996, Pile 1996a and 1996b, Ward et al 1999).

I used a combination of data sources in an attempt to assess the present status of soil erosion, to broadly reconstruct the spread and intensification of degradation over the hundred years covered by livestock data, to investigate factors contributing to the degradation process and to explore people's perceptions of the situation. Throughout this chapter, the term "erosion" refers to soil erosion.

4.2 Methodology

4.2.1 Literature

A summary of historical literature and other publications was the first step in trying to reconstruct environmental and socio-economic changes in Herschel over as long a time period as possible, especially for the period predating aerial photographs and the memories of people alive today. This information also provided background information against which I planned and conducted the field research and mapping.

4.2.2 Interview data

I conducted semi-structured interviews with residents of the four study areas (Tugela, Majuba Nek, Bensonvale and Upper Telle; see Chapter 2) to gain an overview of people's perceptions of the current state, changes in and causes of degradation. The main aim of the interviews was to provide some hypotheses that could be investigated when mapping soil erosion from aerial photographs, and information helpful in interpreting the mapped data and making recommendations for future land use. The questions about environmental conditions and change formed part of more extensive interviews covering the current state and changes in the environment, livestock production, inputs, outputs and management. The livestock data are presented in Chapter 5.

I discussed environmental and degradation issues with 36 individuals and seven groups of between 10 and 15 people. In my selection of people to interview, I tried to represent a range of people, including owners and herders of small and large livestock herds, men and women and people of different ages. For accounts of environmental change, I sought out old people who had grown up in Herschel. An additional interview took place with a group of people from Magadla, an administrative area neighbouring Bensonvale, at the request of farmers' representatives who had heard that I was doing research in the area.

I asked livestock owners to describe the current state of the land, and how this related to the productivity of their livestock. Old people were asked to describe the state of the vegetation and soils when they were younger and compare it to the present state. Usually, farmers would remember what conditions were like when they herded their fathers' flocks or first started keeping their own livestock. People were also asked to discuss their perceptions and observations of when and why degradation became more severe, and whether there were any events that had any particular positive or negative impacts on the state of soils and vegetation. In the interviews, I would generally begin by asking very broad questions to explore which aspects of the degradation issue people brought up without being prompted, and how they explained their perceptions. This was then followed by more detailed questions to explore their responses more fully and to obtain answers to other, more specific questions I had.

I conducted the interviews with the help of a different translator in each study area, in each case a local resident with an adequate command of English. To minimise confusion over culturally specific or difficult to translate concepts (including terms like "degradation" and "erosion"), I kept the questions open-ended and simple, and recorded answers verbatim as they were translated. Answers that were ambiguous, contained unfamiliar expressions or where there was doubt over the accuracy of the translation were cross-checked by asking the same question in a different way or repeating the answer using different expressions and asking if this was a correct interpretation.

4.2.3 Mapping soil erosion from aerial photographs

Sequential black and white aerial photographs were analysed to gain an objective and relatively precise assessment of the extent, severity and distribution of soil erosion at different dates. The dates of the aerial photographs used in this study were 1950, 1969 and 1995, which included the earliest and most recent sets of aerial photographs covering the Herschel District, and one of three available sets (1965, 1969 and 1974) in-between. I only investigated three sets due to constraints of time and cost - a detailed reconstruction of the soil erosion history was beyond the scope of this study, and the present analysis was considered adequate for the aims of this study. I chose the 1969 photographs as their quality and resolution were better than those of the 1965 and 1974 sets.

The areas mapped were the four study areas where field work was conducted. In the case of Upper Telle, I mapped only Makumsha, the westernmost of the large administrative area's three wards, as the other two wards were not covered in the 1969 set of photographs. Photographs taken in 1950 do not cover Upper Telle at all. The dates and scales of the aerial photographs used are given in Table 4.1 below.

Table 4.1. Dates and scales of aerial photographs used in the mapping of soil erosion in the Herschel district. Rainfall in the 24 months prior to photography (including the month the photograph was taken) is included. Mean annual rainfall in Sterkspruit is 640 mm. For Upper Telle, rainfall data from a neighbouring farm (Funnystone) were used, where mean annual rainfall is 818 mm.

Year	Month	Scale	Rainfall (Sterkspruit)	Rainfall (Upper Telle)
1950	August	1 : 30 000	768 mm, following a dry year (423 mm).	No photograph available.
1969	July	1 : 20 000	563 mm, following a very dry year (379 mm).	786 mm, following a very dry year (437 mm).
1995	June	1 : 50 0000	343 mm, the last of four consecutive dry years (445, 385 and 542 mm in 1992, 93 and 94).	604 mm, a dry year following three more or less average seasons.

A mirror stereoscope with x3 magnification lenses was used to map the extent and distribution of areas of different types and intensities of soil erosion. This technique has been used successfully and reliably in a number of studies (Marker 1988, Weaver 1988a, Watson 1990 and 1996, Kakembo 1997 and numerous studies cited therein). For the soil erosion maps, I used the classification system used by Kakembo (1997; see Table 4.2), which is adapted from the Southern African Regional Commission for the Conservation and Utilisation of Soil erosion classification system (SARCCUS 1981). This system was designed specifically for mapping soil erosion in southern Africa to allow for comparisons between studies, and the appearance of different erosion classes on aerial photographs and in the landscape is illustrated in detail in this publication. The original scheme was simplified to include fewer categories and modified to exclude wind erosion and mass movement types such as landslides, terracettes and creep which were not investigated by Kakembo (1997) or in the present study.

Table 4.2. Classes used in mapping soil erosion in the Herschel district (after Kakembo 1997; modified from SARRCUS 1981).

Erosion class	Description	SARCCUS (1981) class
1	No apparent erosion	S1
2	Slight sheet erosion without rilling	S2
3	Severe sheet erosion with incipient rilling	S3R2
4	Severe rill and gully erosion	R3G2, S3R4G2
5	Intricate gully patterns and degraded gully remnants	G3, G4, G5, GR

During the time spent collecting field data in the four study areas, I checked the distribution and appearance of different erosion classes on the aerial photographs against their appearance and distribution on the ground. By the time I performed the mapping, I was familiar with the study areas and in addition to notes and photographs taken in the field, could easily picture many of the features found on the aerial photographs.

The information extracted from the aerial photographs at each date was transposed onto transparent overlays on 1:50 000 topocadastral maps. I chose the topocadastral maps to overcome distortion, allowing the overlays to be superimposed to analyse changes over the time period between each set of photographs. Orthophoto maps, which would have allowed superior precision when transposing the data, are unavailable for the Herschel District.

I digitised the erosion maps into GIS format using ArcInfo software. In ArcView, the coverages were converted to Transverse Mercator Projection to match that of the digitised 1:50 000 topocadastral maps. The overlays were converted to grids with a cell size of 50x50 m, a scale coarse enough that mapping and digitising errors would not distort the mapped results, but fine enough to observe changes from year to year in relatively small areas.

I used the digitised topocadastral map data (obtained from the Mapping and Surveys section of the Department of Land Affairs) to derive Triangulated Irregular Networks (TINs) from the vertex points of the contour lines (interval 20 metres). The TINs were used to create a surface model for each study area. The erosion maps as well as rivers from the digitised topocadastral map sheets were superimposed onto these three-dimensional surface models to show on what parts of the topography erosion of different classes occurred and intensified.

4.2.4 Spatial data analysis

All spatial analysis was done using ArcView software. From the erosion map grids, I calculated the percentage of each study area at the three different dates affected by erosion classes 1-5. From these figures, overall changes in soil erosion could be observed.

To look at the spread and intensification of erosion in more detail, I used the ArcView Image Analyst's "Thematic Change" function to create maps showing the exact change each grid cell underwent between different years, giving the erosion class at the beginning and the end of the time period. Some cells near the edge of an erosion area showed apparent changes that were caused by lines of two overlays not overlapping perfectly, which, for example, resulted in some cells changing from severe gullies to light sheet erosion. Most of these artifacts were eliminated by smoothing the maps, a process which changes the class of a single different grid cell to the value of the neighbouring grid cells. The percentages of each area undergoing the different changes were then summarised in a table to see which changes were most common in the time periods 1950-1969 and 1969-1995.

To investigate the influence of slope angle and geological formation on the incidence of different erosion classes, I created grid overlays with cell size 50x50 m (to match that of the erosion overlays) of slope class and geology that could be superimposed on the erosion grids. The mean slope angle of each grid cell was derived from the TIN surface models, and five classes were used: 0-10°, 10-20°, 20-30°, 30-40° and >40°. To obtain geological data, I digitised the Herschel area off the Geological Survey's 1:250 000 geology map (sheet 3026 Aliwal North). Soil erosion classes in 1995 were cross-tabulated separately against slope class and geology from the superimposed grids, and the data were used to show differences in the occurrence of erosion on different geological substrates and on different slopes.

4.3 Results

4.3.1 History of degradation from the literature

The historical literature yields some information about changing social, economic and environmental conditions in Herschel. The general impression gained is that a notable decline took place from the late 1800s. More general historical information can be found in Chapter 2, while a detailed analysis of changes in production in Herschel over time is presented in Chapter 6.

In 1862, Herschel was described as "a beautiful settlement of well-watered fertile hill and dale" in the Blue Book for the Cape Colony (Bundy 1979). Visitors to the district commented on the high levels of agricultural productivity and the prosperity of the population. These favourable conditions remained evident throughout the early 1870s (Bundy 1979), with high levels of production and export of grain and wool being reported.

Already in the 1870s, there was evidence of population pressure, social stratification and migrant labour in response to economic pressure (Bundy 1979). In 1875, 2500 people (about 10 % of the population) left the district in search for work. From the 1870s, there was also increasing conflict over land use, especially the expansion of arable areas, between people who were primarily cultivators and people who mainly reared livestock. A number of large stock owners left Herschel permanently to look for more land in areas such as East Griqualand.

The severe drought of the late 1870s and early 1880s heightened the difficulties of farmers, particularly the poorer people. A single report by the magistrate in 1880 mentioned land disputes, overstocking, overgrazing and the creation of dongas (Bundy 1979). Many people experienced a shortage of land and either tried moving to other districts or became migrant labourers. Social stratification was becoming strongly evident in Herschel, with employer-employee relations emerging between the wealthy and educated (through the missions) classes and the poorer, more "backward" people. Droughts, locusts and rinderpest between 1895 and 1899 further devastated agricultural production. The wealthier farmers managed to recover much more easily than the poorer farmers, many of whom were left destitute and became reliant on migrant labour in the long term. Drought in 1903 forced more people to sell or barter their livestock and to seek employment. Reports from the following years show increasing reliance on migrant labour and food sources from outside the district.

By the end of the century, contemporary accounts indicate that all potentially arable land was ploughed, and that the shortage of arable land was exacerbated by unfair and nepotistic allocation by the headmen.

Macmillan (1930), who visited Herschel in 1925, reported the district to be eroded, overpopulated, overgrazed, poor in production and very low in consumption, with most of the population dependent on outside sources of income and food. The human population in 1925 was estimated at 40 000, about twice that of 1870. No data on access to arable land were available at the time because Herschel residents resisted land registration (Macmillan 1930, Beinart 1987), but Macmillan observed that all available land (with the exception of the Herschel commonage) was already ploughed, that access to land was highly skewed, and he estimated that around 10 % of households had no access to arable land at all. From the numbers of passes issued, tax data and remittance figures from the Post Office, Macmillan concludes that in the 1920s, about 75 % of Herschel men left the district for at least six months of every year.

The report of the Tomlinson Commission, whose brief was to investigate the options for rehabilitation of the Native areas, described Herschel as one of the most badly eroded parts of the country (Union of South Africa 1955). The findings of the commission led to the implementation of betterment planning in most of the former Ciskei and Transkei, a policy which was aimed at rehabilitating degraded land and facilitating the provision of services such as veterinary medicine, clinics and schools. The process involved the resettlement of people in planned villages, rezoning and re-allocating arable plots, withdrawing unsuitable lands from cultivation and fencing off grazing camps where rotational grazing and resting was enforced by government officials.

The implementation of betterment planning in the early 1960s was followed by the influx of people displaced by forced removals later in the 1960s and '70s. Cosmas Desmond, a Franciscan priest who travelled the country in 1969 to investigate forced removals, reported the Herschel population to number 75 000 people, and described the district as follows:

> "A lot of the area is mountainous and the rest is badly eroded, so there is not much left for cultivation and what is left is not very fertile since the whole area is very dry. According to the Tomlinson Report, the Herschel area is one of the most badly eroded in the whole country, yet at the time of its study had a population density as high as 100 per square mile." (Desmond 1969, pp. 196-197).

Hoffman *et al.* (1999) conducted a nationwide degradation audit in the late 1990s, in which the authors concluded that Herschel was one of the most degraded districts in South Africa. Soil erosion in particular was judged to be severe, widespread and increasing in extent and severity. The 1991 census set the population of Herschel at 131 000 people.

4.3.2 Interview information

Perceptions of degradation types

In all areas visited, the majority of people felt that the land was generally in a poorer condition than in the past, though the details of these perceptions varied somewhat. Some farmers stated that the condition of grazing land was satisfactory, but that dongas were a problem – in other words, gully erosion was seen as a different process and problem to sheet erosion and vegetation change.

Dongas were perceived to be a result of neglect, when people do not take action to stop the beginnings of gully erosion as soon as they are noticed. Few people perceived a direct link between grazing pressure and donga formation. People felt that once dongas are left to expand, they soon extend and deepen to a point where individuals and even communities feel unable to halt their progress without technical assistance from the state.

While nobody who was asked about dongas denied their existence, and people usually stated that dongas had increased in length and depth over the years, the impacts of dongas were seen differently by different people. Depending on where the dongas were found, their impact was variously described as making grazing areas and croplands inaccessible, presenting a hazard to children and grazing animals (particularly sheep) which fall into the dongas and injure themselves when trying to cross, being a hazard in residential areas, sheltering stock thieves as well as reducing the size of the grazing lands.

Some of the erosion gullies I observed in Herschel are very deep with steep, unstable sides, and expand partly through the creation of tunnels and pipes under ground. It is easy to see the danger they present to people and animals, particularly during and after heavy rains. A Tugela resident, Mr. Mpambo, showed me around a particularly extensive and deep gully system near the village of Entsimekweni in 1998, which exceeded depths of 10 metres in places. He told me that his father, who was born in 1920, used to play in the area as a child in the 1930s, when there was no major gully. In the 1950s, a wagon could still cross the donga. I observed a fence erected during betterment planning in the early 1960s dangling above a five metre-deep gully, and according to Mr. Mpambo, the expansion of the gully system can be observed from year to year. When we walked around the gully, many large columns of subsoil could be observed separating from the surrounding areas, and large blocks of soil with rooted plants flowering on the top surface were visible inside the gully. Badlands with erosion pipes and large areas of sheet erosion, where all topsoil had been lost and the soil surface is eroding from cracks and rills, surround the entire donga system.

Sheet erosion was often not perceived as a form of soil erosion, but more frequently described in terms of a lack of grass cover. One farmer described the previously "clothed" mountainsides as being "naked" now. Another man said that, while there used to be tall grass on the mountains of Tugela, one could now "see a snake moving from a long way away". This denudation of the vegetation was generally perceived to be a direct result of overcrowding of people and livestock and the resultant overgrazing which leaves the veld bare with not enough food to support livestock through winter. Drought in recent years was also cited as a reason for poor veld condition. In most cases, farmers felt that this was reversible given a few years of good rainfall and a reduction in grazing pressure.

Some farmers described a change in grass species composition and loss of desirable grasses, though they were not sure whether a reduction in grazing pressure would allow these species to re-establish. In Upper Telle, people also described a loss of woodlands and a decline in thatching grass as a result of overharvesting, frequent fires and heavy grazing in the case of thatching grass.

Not many farmers commented on the proliferation of Karoo shrubs, and opinions of those farmers who talked about them differed. Some farmers felt that, being evergreen, they provided at least some winter forage, for goats in particular. While some argued that the shrubs helped to control erosion because of their long roots, others found that they suppressed grass growth and were therefore undesirable. It was also recognised that Karoo shrubs are able to grow on eroded areas where grasses are unable to establish, and some people felt that this was better than nothing.

Perceptions of factors contributing to degradation

The most commonly cited reason for the poor condition of the land in Herschel was a lack of management, co-operation between land users and effective leadership – at the moment, anybody uses the land as they see fit. No official grazing rules exist since betterment was abandoned in the 1970s. In Tugela and Bensonvale, village committees attempt to regulate grazing and maintain some form of rotational resting, mainly to ensure forage reserves for the dry winters. However, the dilapidated state of the fences and a lack of community co-operation prevent this from being successful. Bensonvale appears to have the most success in managing grazing, and residents described the lack of fences as a major problem in their veld management as this allows residents of neighbouring communities to graze their livestock in Bensonvale. A similar situation is found in Tugela, where one village has been fairly successful in instituting a rotational resting programme, but villagers find it hard to keep their neighbours, whose grazing lands are in poorer condition, from sneaking their livestock in without permission.

In all areas visited, farmers described the veld management that was practised before betterment planning. Using stone beacons, the chief and village elders would set aside areas where grazing was prohibited until the area was officially opened. The aim of this was to provide grass reserves for winter (especially in drought years), and to allow grasses to flower and set seed. Also, areas with thatching grass (*Hyparrhenia* spp.) and grazing areas near arable lands were not grazed in the growing season, and livestock spent the summer months on the higher slopes. In areas such as Upper Telle and Tugela, which have large and fairly remote mountainous areas, farmers would often have stock posts away from their homes where livestock would be herded in summer. After the harvest and through winter, animals would graze in the lower areas, taking advantage of crop residues and the rested grazing areas.

A number of farmers are of the opinion that the widespread, frequent and uncontrolled setting of fires, for example to stimulate green growth in winter, is a major factor leading to reduced grass cover and degradation. According to these informants, burning used to be regulated and could not be undertaken without the consent of the chief. If a fire was discovered to be out of control, people would work together to put it out. Nowadays, people do not adhere to any regulations and feel no responsibility for controlling fires set by others. This has also led to tense relationships with some of the neighbouring commercial farmers in Lady Grey and Barkly East, whose grazing camps are often burned when fires in Herschel get out of control.

Betterment planning is an event commonly perceived to have caused increased degradation, though opinions on this vary. People described a number of reasons why betterment had resulted in environmental decline instead of the intended improvement. Many people saw the concentration of the population in villages as the main problem, which became worse as the population grew and more people moved into the district. Before betterment planning, people lived in scattered homesteads, and pressure on grazing and other natural resources was more evenly distributed. Now, badly eroded paths can be seen where livestock and people leave and return to the village every day. A farmer described how erosion around the gates of grazing camps took hold, as people continued to kraal their animals at home. Now that rotational grazing is no longer enforced, many people graze their livestock close to the village all year, often due to a shortage of herding labour. Harvesting of other natural products and other impacts such as litter are also concentrated around villages.

Although grazing land was managed communally before betterment, individuals felt responsible for maintaining its good condition by respecting the grazing rules and halting soil erosion near their homes and in their arable lands which were near their homesteads. When betterment was instituted, people were forced to move into planned villages, with their new homes often far from their allocated arable plots which had been rezoned as well. Homesteads and arable lands which were abandoned and fell into grazing camps soon eroded because they were susceptible to erosion and no longer looked after. From the aerial photos, it is evident that people attempted to control erosion in 1950 with rows of sisal plants, although with little success. After betterment, these efforts appear to have been abandoned entirely, and this is confirmed by interview information.

Under betterment, all land officially came under custody of the Native Trust, and government officials planned land use, grazing strategy, stock sales and veterinary services (which also served to census the stock population). For some years, the government also enforced rotational grazing and stock reduction, the latter with seemingly little success. This met with resistance in many parts of Herschel, and one of the results of this enforced change in home area, land use and land allocation was that people felt their land had been confiscated and that it was no longer theirs to manage. Even today, there is a prevalent attitude that land management, provision and maintenance of infrastructure and other initiatives to improve agricultural production are the responsibility of the government.

Not all people interviewed agreed on the negative effects of betterment planning. In the Makumsha ward of Upper Telle, several of the people interviewed said that livestock production and grass condition were better while betterment planning was still actively enforced – from 1963 until about 1968 – than before or after this period. My translator explained that the zoning and fencing of grazing areas favoured this ward at the expense of the neighbouring Mabele ward, whereby people fom Mabele were kept out of their traditional grazing areas, making additional grazing land available to Makumsha residents.

The destruction of the fences, particularly after the district's incorporation into Transkei in 1976, a lack of an effective and respected leadership and the resultant "free for all" approach to grazing are seen to have led to a further deterioration of the land. People say they feel unable to exercise any control over the management or improvement of the land.

4.3.3 Analysis of erosion from aerial photographs

Present erosion levels in the four study areas

All four of the areas investigated had high levels of soil erosion in 1995, but there were considerable differences between areas (see Figure 4.1). Majuba Nek had the highest erosion levels, with 56 % of its surface affected by erosion, and 53 % of its total area affected by erosion classes 3 and higher, i.e. severe sheet erosion and worse. Tugela is nearly as badly eroded, with 52 % of its area affected, and 44 % falling into erosion class 3 or higher. Tugela has by far the highest percentage of its area affected by erosion class 5 (intricate gully patterns and gully remnants), and Majuba Nek and Tugela have the highest levels (14 %) of erosion class 4 (severe gully and rill erosion). Bensonvale is in better condition with 38 % of its total surface eroded, and 31 % of the total area affected by erosion classes 3 to 5. Present-day erosion levels are lowest in Upper Telle with 30 % eroded, and 23 % affected by erosion classes 3 and higher.

Erosion levels over time

Figure 4.1 summarises the percentages of each study area affected by different erosion classes in 1950, 1969 and 1995. Maps showing the distribution of different erosion classes in the four areas at the three dates are presented in Figures 4.2 to 4.5. It is evident from these maps and graphs that considerable levels of erosion already existed in

1950. Most of the major gully systems along drainage lines on deep alluvial soils had already formed, and headward erosion of the steeper upper reaches of stream systems had taken place by that time. This is particularly noticeable in Tugela (Figure 4.2), where deep incisions along streams on alluvial soils in valleys can be observed, fanning out into sheet, rill and gully erosion along the foothills of the steeper mountains. In Tugela and Majuba Nek, 29 and 30 % respectively of the land surface was already eroded in 1950, with a greater proportion in the more severe classes in Tugela. Erosion levels were much lower in Bensonvale, with 15 % of the surface eroded, most of this in the form of slight sheet erosion without rilling (class 2). No aerial photographs covering Upper Telle in 1950 were available.

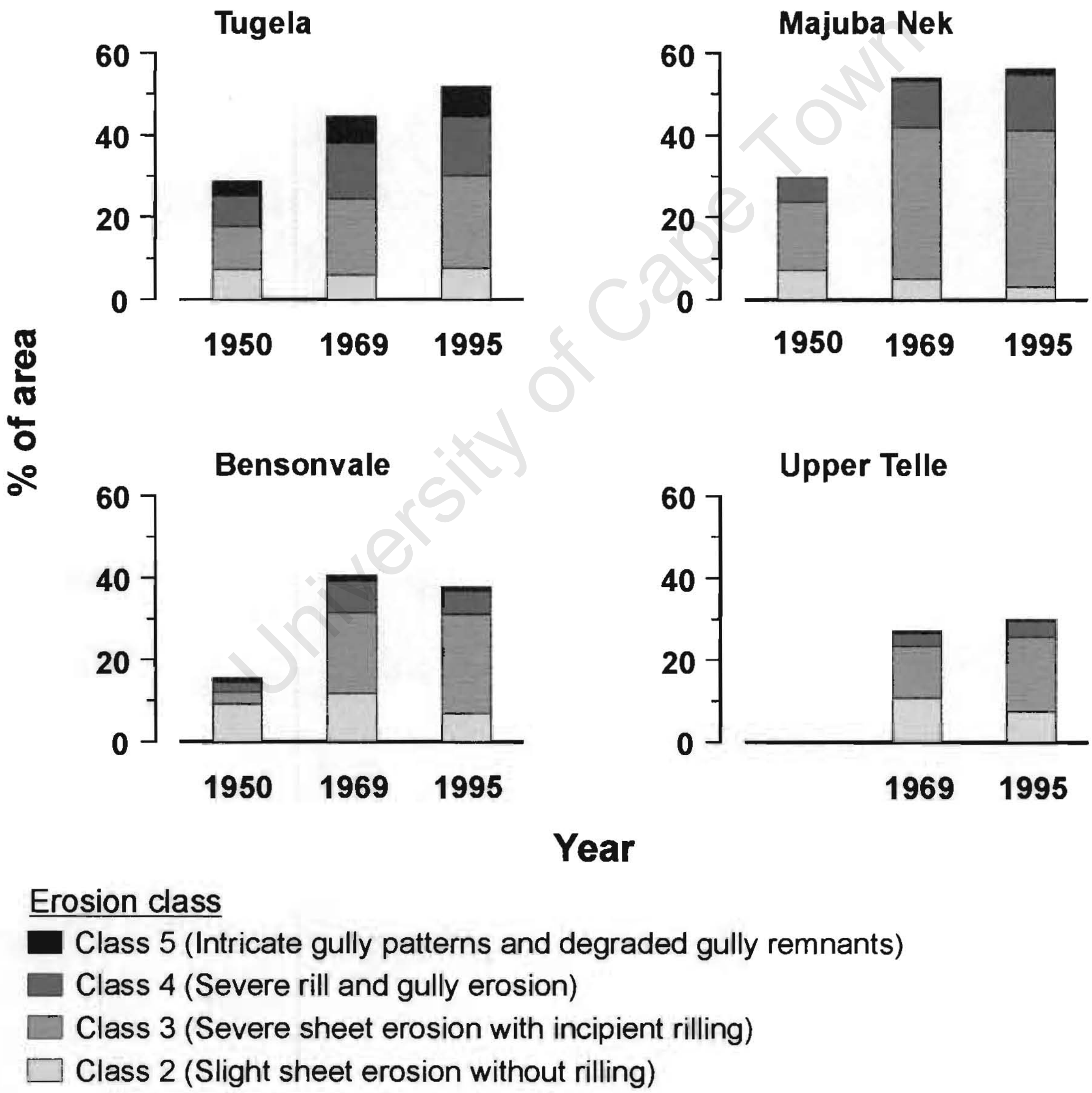

Figure 4.1. The percentage of each of the four study areas affected by different erosion classes in 1950, 1969 and 1995, derived from aerial photographs.

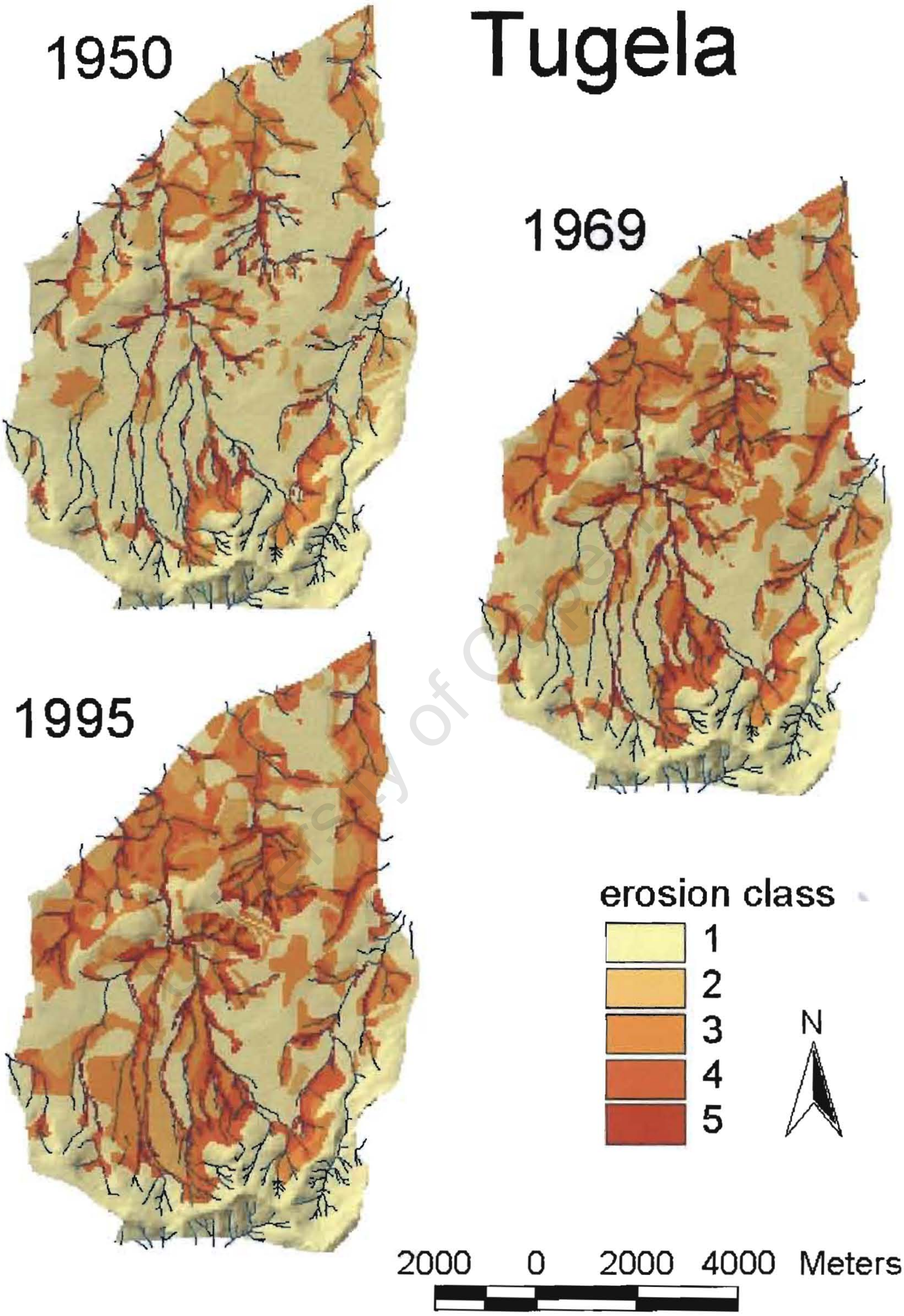

Figure 4.2. Maps of the Tugela study area showing the extent and severity of soil erosion during the period 1950 to 1995.

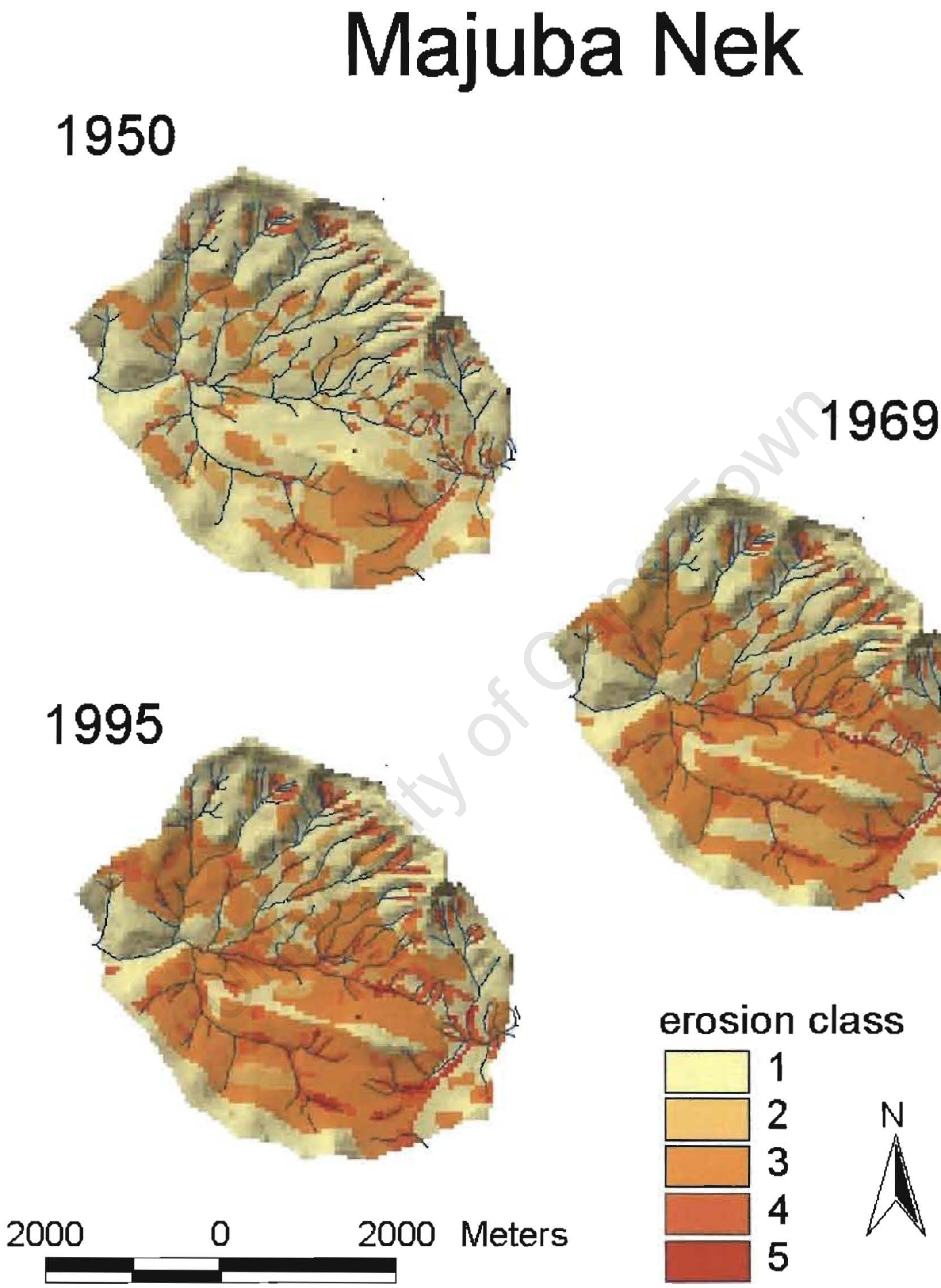

Figure 4.3. Maps of the Majuba Nek study area showing the extent and severity of soil erosion during the period 1950 to 1995.

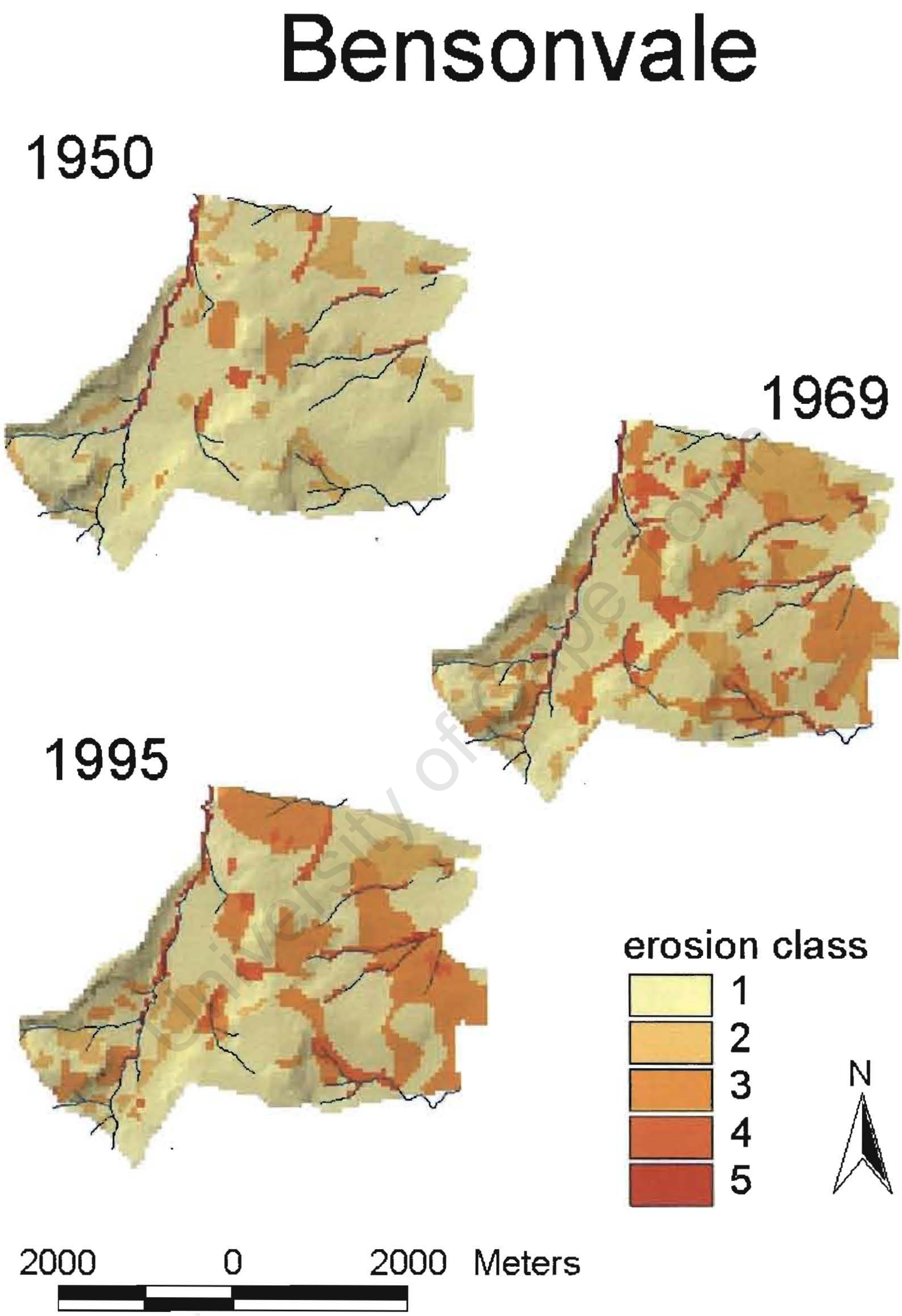

Figure 4.4. Maps of the Bensonvale study area showing the extent and severity of soil erosion during the period 1950 to 1995.

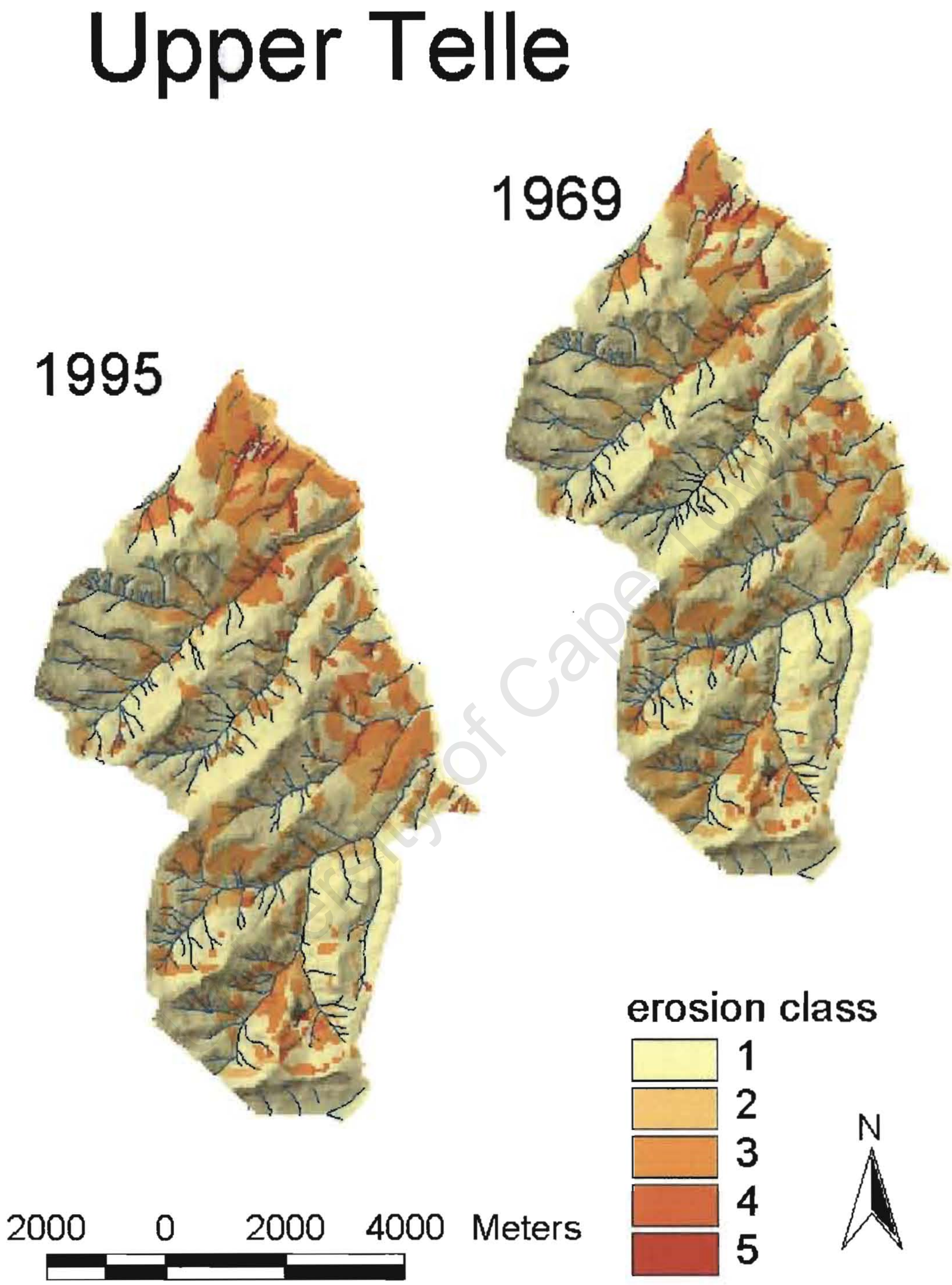

Figure 4.5. Maps of the Upper Telle study area showing the extent and severity of soil erosion during the period 1950 to 1995.

A large increase in sheet erosion, as well as intensification of existing eroded areas, took place between 1950 and 1969. Most noticeable from the maps in Figures 4.2 to 4.5 is the increase in the areas of relatively flat or gently sloping land affected by sheet erosion. Table 4.3 shows clearly that the most common change in erosion between 1950 and 1969 was that from no erosion (class 1) to sheet erosion with incipient rilling (class 3). Some existing eroded areas degraded further so that previously lightly affected areas were in many cases quite severely eroded by 1969. Gully systems on steeper slopes did not change in many places, while in others they deepened and the length of the stream affected increased. Recovery and revegetation of areas affected by sheet erosion appears to have taken place in a few areas, and some stabilisation of gullies occurred in Bensonvale.

Table 4.3. Detailed changes in soil erosion over the periods 1950-69 and 1969-95 in the four study areas. Values are the percentage of the study area undergoing a change from one erosion class (1-5) to another.

Change	**Tugela**		**Majuba Nek**		**Bensonvale**		**U.Telle**	**Average**	
from→to	**50-69**	**69-95**	**50-69**	**69-95**	**50-69**	**69-95**	**69-95**	**50-69**	**69-95**
1→1	55	48	44	44	61	51	71	54	53
1→2	4	4	2	3	9	4	2	5	3
1→3	10	4	22	0	13	8	2	15	3
1→4	3	0	2	0	3	0	0	3	0
1→5	1	0	0	0	0	0	0	0	0
2→1	1	0	2	0	2	6	2	2	2
2→2	1	3	3	1	2	3	5	2	3
2→3	4	2	5	3	3	3	4	4	3
2→4	1	0	1	0	1	0	0	1	0
2→5	0	0	0	0	0	0	0	0	0
3→1	1	0	2	0	0	6	0	1	2
3→2	0	1	1	1	0	1	0	0	1
3→3	5	17	12	36	2	11	12	6	19
3→4	3	1	3	1	1	1	0	2	1
3→5	0	0	0	0	0	0	0	0	0
4→1	0	0	0	0	0	2	0	0	0
4→2	0	0	0	0	0	0	0	0	0
4→3	0	1	0	0	0	2	0	0	1
4→4	5	12	1	9	1	2	2	3	6
4→5	1	0	0	0	0	0	0	1	0
5→1	0	0	0	0	0	0	0	0	0
5→2	0	0	0	0	0	0	0	0	0
5→3	0	0	0	0	0	0	0	0	0
5→4	0	1	0	0	0	0	0	0	0
5→5	3	5	0	1	0	0	0	1	2

The changes in erosion between 1969 and 1995 were considerably smaller. The greatest change in total eroded area took place in Tugela, with an increase of 7 %. Total eroded area increased by only 2 and 3 % in Majuba Nek and Upper Telle respectively, and in Bensonvale, recovery of some areas resulted in an overall 3 % decrease in the eroded area. Comparing the 1995 levels of soil erosion to those of 1950, the maps and graphs show that the total area eroded has nearly doubled in Majuba Nek and Tugela, while in Bensonvale the present erosion levels are more than twice as high as those in 1950.

Changes in erosion and rainfall patterns

Droughts and extreme rainfall events can both influence erosion rates, especially when heavy rainfalls follow a period of low rainfall where grass cover has been reduced. In Herschel, rainfall occurs mostly in relatively short, but heavy, storms which have a high erosive potential. From the rainfall chronology in Chapter 2 (Figure 2.4), one can see that rainfall in Herschel is very variable, with periods of drought alternating with wet periods. The 1950 aerial photographs were taken during a year of good rainfall, which followed two drought years. Droughts also occurred in 1932-33 and 1944-45, and old Herschel residents remember these two droughts as severe and devastating. Rainfall in the late 1950s and early 1960s was mostly above average, and betterment planning took place during three years of high rainfall. This was followed by a series of dry years, during which the 1969 photographs were taken. High rainfall followed in 1975 and 1976. The droughts of the early 1980s were followed by higher rainfall until the droughts of the early 1990s. Rainfall has been below average in most years since then.

The rainfall chronology does not give any indication why the erosion increase should have been so much greater in the 1950-69 period than between 1969 and 1995. Rainfall fluctuations and extremes were greater in the latter period, which included two droughts that devastated the entire country. The fact that betterment was followed by several dry years may have exacerbated the effects of land use change. For example, less cultivation takes place in dry years, and the re-allocation of arable lands further discouraged cultivation as fields were now further away from people's homesteads. If much of the land was left fallow, the soil would have been more exposed to trampling by livestock and the erosive effects of rainfall.

Daily and monthly rainfall records provide more information about very erosive rainfall events than annual or seasonal totals do. In much of the Eastern Cape, a few heavy rainfalls often account for most of the year's total, and such extreme rainfall events are therefore expected to cause much of the erosion. In the period 1944 to 1998, the highest monthly totals occurred during the months of January to March, as part of above average wet seasons. No extremely high rainfall episodes were found during the winter months, and no particularly high rainfall events occurred between the introduction of betterment planning and 1969. Two of the highest rainfall months occurred in the summers during the implementation of betterment planning, and where land use changes were already underway, they may have led to the initiation of new erosion. The wettest month by far was February 1988, in an extremely wet year between two major droughts.

Table 4.4. Details of the wettest months on record between 1944 and 1998. All months with total rainfall exceeding 200 mm are listed, including the total rainfall during that season (July of previous year until June of the current year), the number of days it rained during that month, the highest total in one day, and the total rainfall of the preceding 12 months.

Year	Month	Month total (mm)	Season total (mm)	Month Raindays	Highest day total (mm)	Previous 12 months (mm)
1954	March	230	646	16	63	506
1955	January	201	672	13	42	526
1961	March	207	885	11	92	718
1962	February	244	713	16	33	749
1976	March	211	952	9	64	796
1986	February	207	817	3	94	773
1988	February	350	1040	10	193	681
1991	January	247	727	9	74	533

Distribution of erosion as a function of topography and geology

Field observations and the erosion maps indicate that large, intricate gully networks (classes 4 and 5) and large areas of severe sheet erosion (class 3) were primarily found on flat or gently sloping areas on deep soils. On steeper rocky slopes with thinner soil cover, gullies occurred along streams, and while they were often deep and visible from a distance (e.g. on the steep slopes in the northern part of Majuba Nek), their areal extent was relatively small. They also seemed not to change very much once erosion had exposed the bedrock in the streambed and the gully no longer deepened. During field work, few of the mountain slopes were found to be entirely free of sheet and light rill erosion, but this seldom resulted in the kind of large, bare areas that could be identified on the aerial photographs.

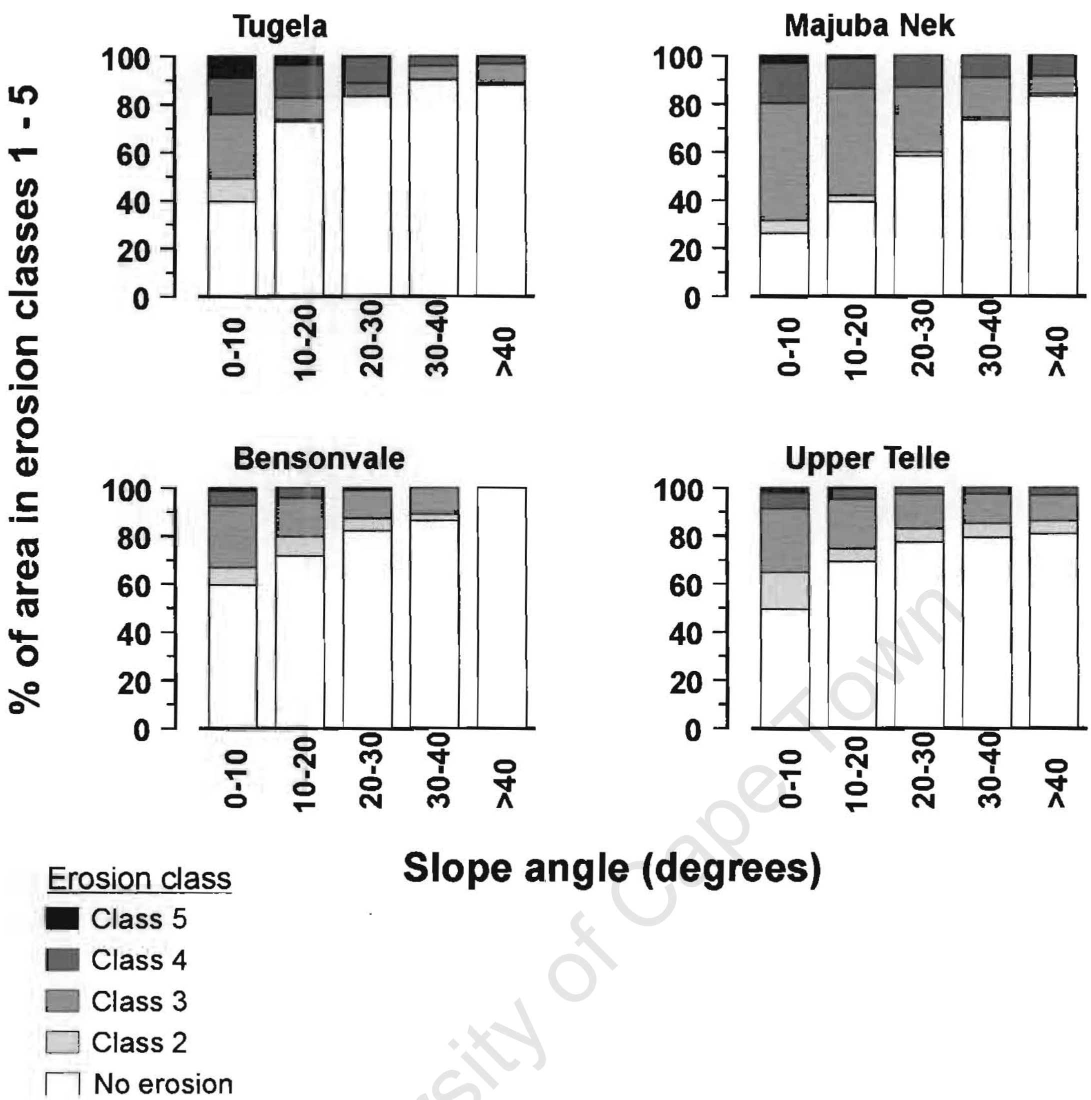

Figure 4.6. Extent to which areas of different slope classes in the four study areas are affected by different erosion classes.

Figure 4.6 shows how areas of different slope are affected by erosion. From the graphs, it is evident that the flatter areas experience more erosion, and higher percentages of the more severe erosion classes. Flat or gently sloping areas with a slope angle of up to 10° are the most severely affected. Only small areas of steeper slopes were eroded, and severe gully erosion (class 5) was largely absent from slopes with an angle greater than 20°. However, it was also noticeable that within each slope class, there are differences between the study areas, with Majuba Nek being the most severely eroded, followed by Tugela, Upper Telle and Bensonvale. The percentages of each of the study areas falling into the five slope angle classes are shown in Figure 4.7.

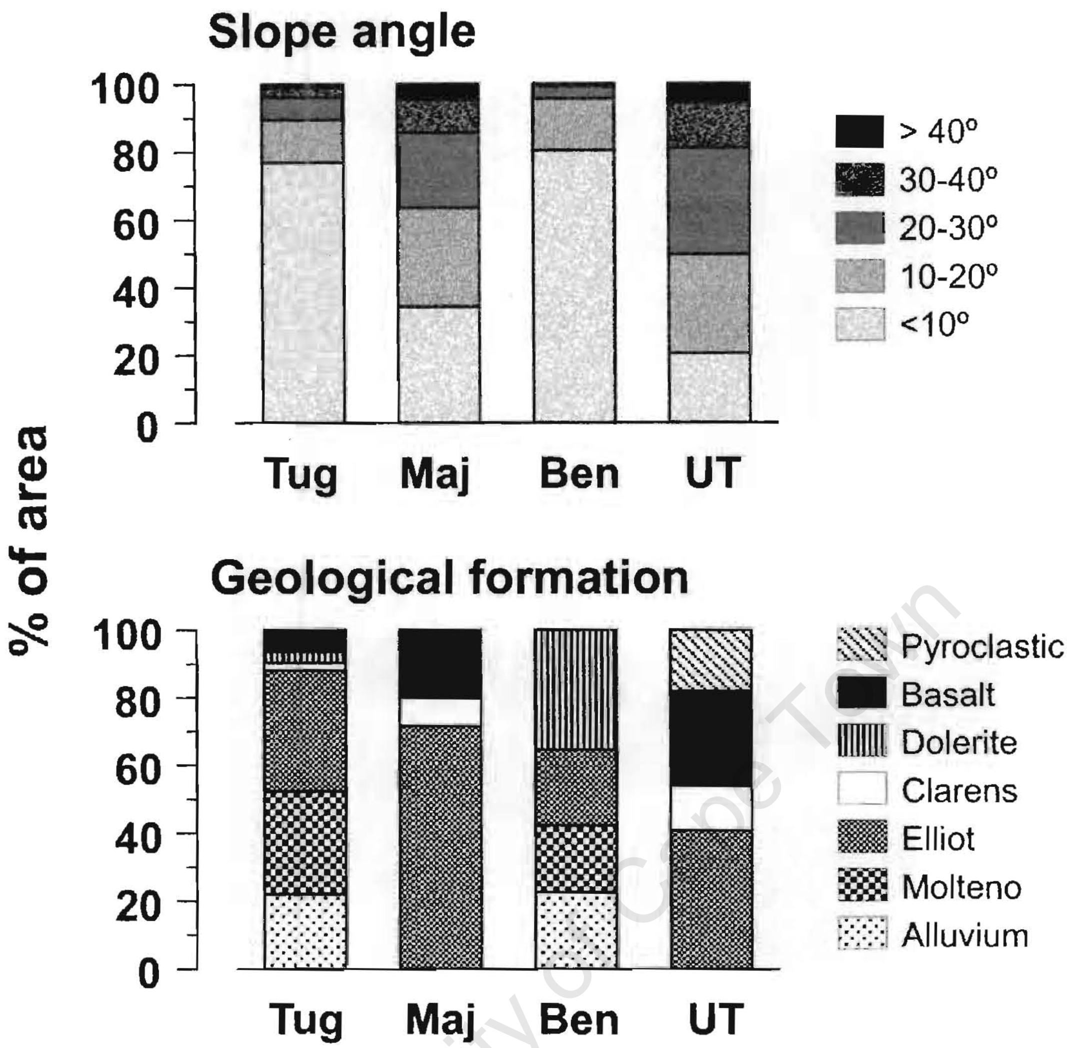

Figure 4.7. The percentages of each study area on different slope classes and geological formations.

During fieldwork, I observed that erosion appeared to be more common and severe on sedimentary rocks of the Karoo series (Molteno and Elliot) and alluvium, while areas on dolerite and basalt appeared more resistant to erosion and maintained better grass cover. Figure 4.8 shows that there are indeed differences in the extent and severity of erosion in areas on different geological formations although as with slope, each geological formation experiences different erosion levels in the four study areas. Overall, Molteno sediments are the most severely eroded, followed by Alluvium and Elliot sediments. Clarens sandstone, though also of sedimentary origin, and the igneous rock formations (dolerite, basalt and pyroclastic material) have far lower erosion levels. The percentages of each study area falling into the different geological formations are shown in Figure 4.7. Majuba Nek has only a very small area of dolerite (1% of the total area), compared to 3 % in Tugela and 30 % in Bensonvale.

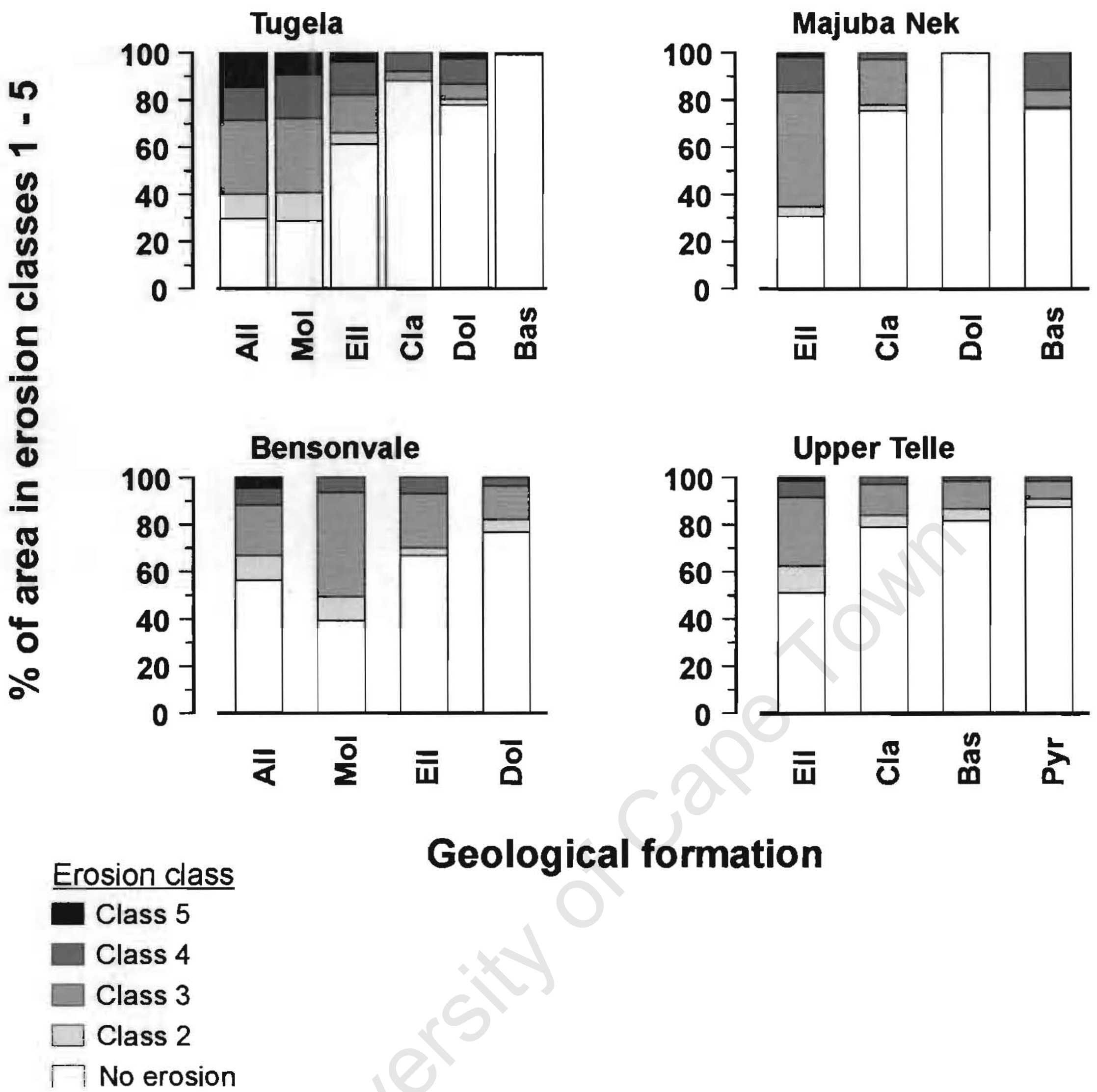

Figure 4.8. Occurrence of erosion classes 1 to 5 on different geological formations in the four study areas (All: Alluvium, Mol: Molteno, Ell: Elliot, Cla: Clarens, Dol: Dolerite, Bas: Basalt, Pyr: Pyroclastic material).

Figure 4.9 shows the relationship between geology and slope in the whole of the Herschel district. These relationships reflect the positions of the geology layers, with alluvium and Molteno sediments forming the valley bottoms while the higher layers (Elliot, Clarens, Pyroclastic material and basalt) largely make up the steeper mountain slopes formed through erosion of the layered rocks. The geological formations with the highest incidence of erosion (Alluvium and Molteno sediments) occur predominantly on flat or gently sloping areas. Dolerite occurs in localised sills with relatively gently sloping sides, while the distribution of Tarkastad sediments of the Karoo group is limited to small areas in the northwest of the district where the Orange River has cut below the Molteno sediments. This geological formation is not represented in the four study areas.

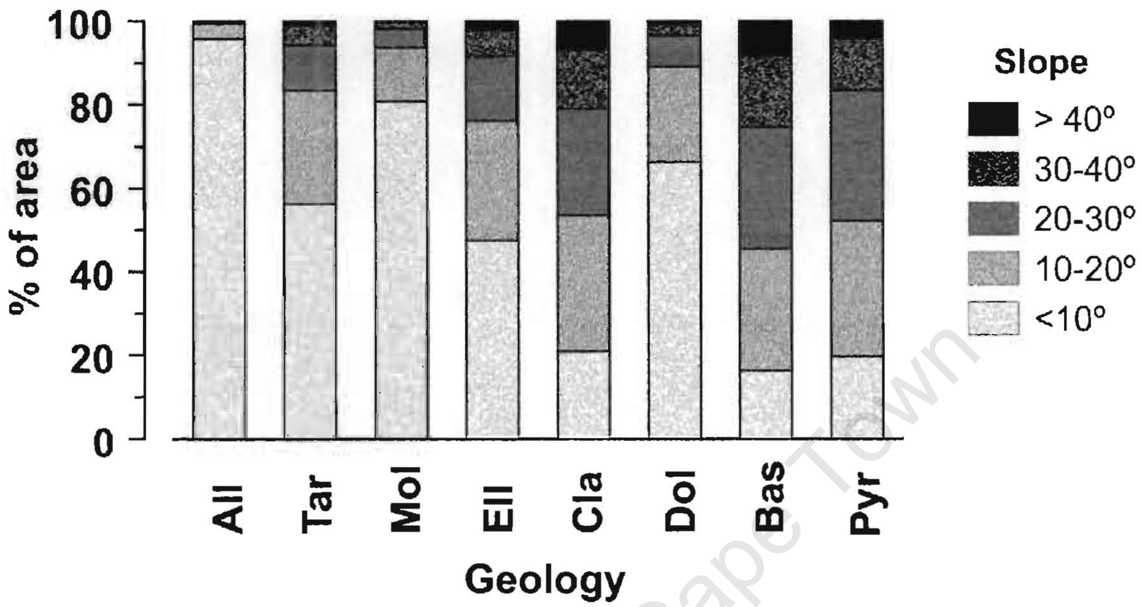

Figure 4.9. Relationship between geological formations and slope classes in the Herschel district.

Degradation and possible correlates in the four study areas

The four study areas were affected to different degrees by soil erosion. The aim of this section is to explore possible correlates of erosion levels which could be used as district-wide predictors of where erosion is most likely to occur. The preceding section showed that the extent and severity of erosion varies with slope and geology, but that within each geology and slope class, there are still differences between the four study areas. Interview informants cited high stocking rates, high human population densities, and land use changes (in particular abandoning cultivated areas) as factors that have led to increased degradation. Table 4.5 summarises some of the characteristics of the four study areas that are thought to influence soil erosion levels. With only four sample areas, this remains exploratory and will need more data to statistically test the relationships between the different factors.

Table 4.5. Summary of some factors that are thought to influence the degree of soil erosion in the four study areas: human population (1991 census), livestock densities in different years, and the percentage of the area on erodible sediments (Alluvium, Molteno, Elliot), on slopes of less than 10 degrees and on slopes <10° not zoned as arable.

	Eroded % ('95)	People/ km^2	AU/km^2 1974	AU/km^2 1980s	AU/km^2 1997	Recom AU/km^2	% All, Mol, Ell	% slope <10°	% flat - arable
Majuba Nek	56	138	34	52	67	31	72	35	23
Tugela	52	99	31	38	47	23	88	78	57
Bensonvale	38	131	43	37	34	44	65	81	27
Upper Telle	30	48	21	22	28	38	19	21	18

There appears to be no clear relationship between erosion levels in 1995 and human population density in 1991. No 1996 census data were available for Tugela and Majuba Nek. While Upper Telle, the least eroded of the four study areas, has the lowest population density, human densities in Bensonvale, the area with the second lowest levels of erosion and some degree of observed recovery, are more than twice as high. Bensonvale has the same population density as Majuba Nek, which is the most eroded of the four study areas.

Livestock densities in 1974 show a similar lack of correlation with erosion level with Bensonvale having the highest stock densities of all the areas studied. However, in the 1980s and 1997, the most eroded areas had the highest livestock densities. Tugela and Majuba Nek in fact show a substantial increase in livestock numbers between 1974 and 1997, and these areas became increasingly overstocked relative to the recommended stocking rates. The latter were generally higher in the less degraded areas, and reflect the judgement of extension officers of the carrying capacity of an area which is a function of its grass composition and cover (see Chapter 7). While Tugela and Majuba Nek had been overstocked since 1974, Bensonvale and Upper Telle had been stocked at lower than recommended densities. Also, in Bensonvale, stocking rates decreased between 1974 and 1997, while those in Upper Telle increased at lower rates than in Tugela and Upper Telle.

During field work and erosion mapping from the aerial photographs, I observed that virtually all flat or gently sloping areas except those on hilltops showed evidence of having been ploughed in the past, although the aerial photographs and 1:50 000 topocadastral maps proved insufficient to delineate the extent of arable land abandoned during and after betterment with any precision. Macmillan (1930) observed that "The evidence alike of ears and of eyes is that the arable soil of the district is fully taken up..." (p. 148) and that "In this crowded district [...] the only obvious unused but potentially arable land was the large commonage of the European village of Herschel..." (p.149). The arable areas currently used are more or less those zoned under betterment, though not all land presently zoned as arable is currently ploughed. If one assumes that all land of slope less than 10° was ploughed at some stage, and only the land zoned as arable at present is still cultivated, the difference of the two areas gives a rough indication of the percentage of each study area that is abandoned arable land. No relationship emerged between apparently abandoned arable land and soil erosion, however. Neither the total percentage of the area on slopes less than 10°, nor the percentage of flat (<10°) land not under cultivation, was higher in areas with high with soil erosion levels.

The relationship between soil erosion and the percentage of the area on sediments other than Clarens sandstone is not conclusive from the four data points, although Tugela and Majuba Nek have higher percentages of their areas on these sediments than Bensonvale and Upper Telle.

4.4 Discussion

4.4.1 Rates of soil erosion over time

The first aim of this chapter was to determine how soil erosion progressed over the last century, to see whether the fact that the number of livestock units in Herschel has not declined could be explained by the fact that degradation goes back as far as the early livestock records. From oral accounts, historical literature and aerial photos it is clear that there has been an increase in soil erosion over the last 100 years which has not been paralleled by a decline in livestock numbers.

From the historical data available, it appears that the first substantial increase in soil erosion in Herschel took place in the late 1800s, when the human population had increased to a level where resource shortage was beginning to be felt, much marginal land had been put under cultivation, and conflicts between cultivators and livestock farmers were emerging. Degradation in the form of overgrazing and dongas was already mentioned in reports from the late 1870s, and reports from the 1920s onwards describe the erosion problem in Herschel as being severe. It is thus apparent that some visible level of degradation goes back as far as the livestock records, but it is difficult to determine from the different reports whether it worsened from decade to decade, and at what rate. Unfortunately, no aerial photographs exist prior to 1950, and the erosion levels and rates over the first half of the century cannot be determined with any certainty. Aerial photographs from 1950, around the time the Tomlinson Commission pronounced Herschel to be one of the most severely degraded districts in the country, already indicate advanced levels of degradation with soil erosion affecting between 15 and 30 % of the areas studied here. The total extent of erosion in these areas roughly doubled between 1950 and 1995, and most of this increase took place before 1969. The fact that the increase between 1950 and 1969 was much greater that between 1969 and 1995 shows that degradation rates have not been constant, so it is impossible to extrapolate back in time to get any idea how degraded the district was in the 1920s, the turn of the century and before. Nor is it possible, from the limited data available here, to predict future erosion rates with any confidence.

Other studies of soil erosion changes in an area (e.g. Marker 1988, Watson 1990, Kakembo 1997) also found erosion rates to vary over time. Most studies suggest that in the long term, erosion rates are accelerated by land use change and eventually level out or even reverse, especially in years of good rainfall (Marker 1988, Watson 1990 and 1996, Garland and Broderick 1992). Kakembo (1997) found that in the betterment villages of the Peddie District in the Ciskei, severe erosion on abandoned arable lands developed within three years following the implementation of betterment. Also in the Eastern Cape, Marker (1988) similarly found a sudden increase in soil erosion following betterment, particularly on abandoned arable land. In both studies, however, erosion rates stabilised after a while. Total eroded area had decreased to levels similar to those in traditional villages in Peddie by 1988 (Kakembo 1997), and recovery of erosion features was found near Alice in 1975 after aerial photographs taken in 1972 had shown great increases in soil erosion since 1963 (Marker 1988). Based on the findings of a study of soil erosion before, during and after settlement of a previously unoccupied area by communal farmers in the Mfolozi catchment in KwaZulu Natal, Watson (1996) concludes that soil erosion processes are far more receptive to land use change than intensification, and that after an initial period of high erosional activity, the system stabilises in the absence of further land use change despite the continued increase in human and livestock numbers.

The data presented here are consistent with this interpretation. Soil erosion in Herschel appears to have increased substantially in the period following betterment planning in the 1960s. The increase in severe sheet and gully erosion on flat to gently sloping areas appears to be mostly related to abandoned cultivation. Although some of these fields may have been eroded before betterment and abandoned for this reason, converting them to grazing areas and thus exposing them to grazing and trampling by livestock year-round is likely to have increased erosion. Given the fact that many of the areas cultivated were on marginal land unsuitable for cultivation, it is likely that in time they would have been abandoned and used as grazing eventually, though perhaps not all areas within the same two years as happened as a result of betterment. Since 1969, erosional activity in Herschel seems to have slowed considerably. This may represent a stabilisation following the initial increase in erosion following betterment, and it is possible that erosion rates may remain stable until some other form of land use change takes place.

Single extreme rainfall events are often held to have particularly devastating effects on soil erosion, particularly if they occur after a dry period where vegetation cover has been reduced. Kakembo (1997) found that a single four-day rainstorm producing a total of 254 mm in the Peddie District of the Ciskei accounted for much of the observed increase in soil erosion. In Herschel, no such extreme rainfall events during a dry period occurred. Two very wet summer months during the implementation of betterment may have led to increased soil erosion on some abandoned fields or homesteads. However, two severe droughts followed by some high rainfall events during the 1969-95 period did not result in the widespread increase in soil erosion observed between 1950 and 1969, so the effects of rainfall appear to be secondary to those of land use change. Another, so far unexplored, possibility is that erosion rates are slowing down because the more erodible soils are already lost. A better understanding of the events causing erosion rates to increase is necessary before predicting future erosion rates with any confidence.

4.4.2 Factors influencing the distribution and severity of soil erosion

In Chapter 3, and in the nationwide audit of soil and veld degradation (Hoffman et al. 1999), land tenure system was established as the overriding determinant of degradation at the level of whole districts. While slope and geology seem to be the factors most strongly correlated with soil erosion within Herschel, the erosion levels within each slope angle and geology class differ between the four study areas. In each case, they are highest in Majuba Nek. This indicates that physical factors alone do not wholly account for the different levels of degradation in the four study areas. With only four areas studied, it is difficult to determine conclusively which factors correlate with high degradation levels, especially since these factors (e.g. slope and geology, slope and land use) interact in different ways. Other factors which may lead to different soil erosion levels in the four areas, such as different attitudes and management, are difficult to quantify.

Geology and slope

The effects of different geological formations, soil types and sediment properties on the severity and distribution of soil erosion are well documented. It is clear from the data presented here that in Herschel, areas on alluvium and Karoo sediments are more susceptible to erosion than Clarens sandstone, dolerite, basalt and pyroclastic material. Chapter 3 also showed that areas on Elliot mudstones had more bare ground and erosion. Weaver (1991) and Marker (1988) similarly found that areas on dolerite were significantly less eroded than those on Karoo sediments in parts of the Ciskei. The reason for these differences is largely due to the influence of parent material on soil structure. In a study conducted on a farm 15 km south of Herschel, van Oudtshoorn (1988) compared the sediment properties of two basins of colluvium, one derived from Elliot mudstone and Clarens sandstone, the other from Elliot, Clarens and Drakensberg basalt parent material. The first basin was found to be more eroded with branching gullies while the other had fewer, linear gullies. The Elliot/Clarens sediments had a higher fraction of fine particles and higher levels of Na^+ ions than the Elliot/Clarens/basalt sediments. The fine particle size reduces infiltration and hence leads to increased run-off, and the higher cation levels found in the Elliot/Clarens sediments make the clays more dispersive, increasing the risk of crusting and increased run-off.

While the patterns of erosion on different geological formations were as expected, the positive correlation between flat or gentle slopes and high erosion levels is somewhat surprising. Looking only at districts predominantly (>80 %) under communal tenure, Hoffman et al. (1999) found steep slopes and high altitudes to be the only two physical variables that correlate with high erosion levels. General predictions are that steep slopes are more erodible because of the greater energy of run-off on long, steep slopes. Compared to other districts, Herschel is very mountainous with high altitudes and steep slopes, but it is interesting to note that within the district, there appears to be no such correlation. The highest and steepest of the study areas is Upper Telle, where the lowest erosion levels were recorded. The maps in Figures 4.2 to 4.5 show that erosion is often associated with streams or drainage lines, and it may be that the interaction between flat areas with deep soils and the surrounding very steep, long slopes results in particularly high erosion levels where run-off gains momentum flowing down the slopes before incising the vulnerable sediments below.

While this offers a satisfactory explanation for some of the gully networks that have developed in Tugela and Majuba Nek, much of the erosion in these areas is in the form of sheetwash which is not likely to be influenced by run-off from surrounding slopes. The consistent relationship between flat or gently sloping areas and increased erosion is most likely due to interactions between slope and geology, and the fact that many flat areas are abandoned arable land. The flat and gently sloping areas are more frequently found on alluvium and Karoo sediments than on the less erosion-prone geological formations (Figure 4.9). Also, the flat and gently sloping areas generally have deeper, more erodible soils, where extensive rilling and gullying can develop. The highly erodible duplex soils found in Herschel (Valsrivier, Sterkspruit) are found on relatively flat areas with deep deposits. In KwaZulu-Natal, Watson (1990) also found that levels of severe erosion were highest in bottomlands with duplex soils where ploughing was responsible for much of the observed erosion.

Human and livestock densities

People interviewed in Herschel blamed much of the degradation on excessive numbers of people and livestock. The high human and livestock densities relative to available production found in communal areas are often implicated in causing degradation (Fox and Rowntree 2001), and high human and livestock densities were found to be correlated with degradation levels in the analysis of all South African districts (Hoffman et al. 1999). However, the latter analysis found no correlation between livestock and human densities with degradation within communal districts. In the rural areas of KwaZulu, Garland and Broderick (1992) also found that erosion extent was unrelated to rural population density. In Kenya, Tiffen et al. (1994) found that degradation in the Machakos district increased with overpopulation and overexploitation up to a point, after which higher human population densities resulted in more intensive resource use accompanied by recovery of the natural resource base. From the data available for Herschel, no clear relationships were found to exist between population density, stocking rates and erosion levels.

From historical accounts, it appears that the onset of visible degradation in Herschel coincides with population densities reaching a point where a shortage of resources was commonly perceived (Bundy 1979), about 15 people per square kilometre in the late 1800s. However, erosion did not increase dramatically between 1969 and 1995 although the human population of the Herschel district almost doubled between 1970 and 1991. It is quite likely that once population pressure is very high, as it is in Herschel with an average of about 80 people per square kilometre, the differences in population density between different parts of the district are less important than biophysical factors and land use practices.

The relationship between stocking densities and rates of erosion over time is unclear from the data presented in this chapter. While human densities and erosion levels have increased, livestock density, and hence grazing pressure, has remained more or less the same over the last 100 years. The data suggest that the areas with higher levels of overstocking are more degraded, but cause and effect are difficult to determine, especially since the recommended stocking rate is a reflection of existing degradation levels and would thus be lower on more degraded areas. The greatest increase in erosion during the period studied took place between 1950 and 1969, while stock numbers in Tugela and Majuba Nek increased in the 1990s. The data thus suggest that the increase in stock numbers took place despite high erosion levels, rather than directly causing them. There may be some threshold density of people and livestock, above which degradation is highly probable and increases at rates not directly related to population density.

4.4.3 People's perceptions of rangeland degradation and its causes

In Herschel, people's perceptions of erosion and its causes varied, and there were some people who demonstrated a very good grasp of the nature and causes of soil erosion processes. While most people I spoke to found the condition of the land unsatisfactory, their explanations of the causes and possible remedies differed. A common thread running through most of the interview information was the perception of dongas and sheet erosion as two different and largely unrelated phenomena with different causes. People in Herschel blamed donga formation on neglect when dongas start in arable or residential plots, where they are quite obvious and have the greatest impact. Sheet erosion was viewed not so much as a form of erosion but evidence of overgrazing ("bare veld"), which has the potential to recover given better rainfall and/or lower livestock densities. This is interesting, as there is an association of severe forms of sheet, rill and gully erosion largely with cropping and abandoned cultivation, and sheet erosion with grazing areas (Watson 1990, Kakembo 1997).

People's perceptions of the causes of degradation and what can be done about it are of interest from the point of view of future land management. People recognized high human and livestock densities as leading to overgrazing, but stock reduction was not considered to be an acceptable solution. People argued that they had too little land, and pointed to the size of commercial farms belonging to a single family in support of their argument. Beside the shortage of land, a lack of grazing management resulting in uncontrolled grazing and burning was frequently blamed for the poor condition of grazing areas. Many livestock owners interviewed saw improved grazing management, particularly resting of some areas to provide a dry season forage reserve, as an essential step to improve the condition of the vegetation and livestock. Many saw the re-establishment of fences, to control access by outsiders as much as to manage grazing, as a prerequisite to successful management.

People frequently attributed increased soil erosion to the changes that occurred as a result of betterment. The physical land use changes – abandoning or re-allocating arable lands, enforcing the use of grazing camps, concentrating resource demand around villages – were seen to have initiated more erosion. People also described how their attitudes to land management changed as a result of the dispossession inherent in the villagisation and land-reallocation process, whereby all land came under control of the Native Trust and was no longer theirs to manage. Aerial photos illustrate that erosion control structures, such as rows of sisal plants, were employed before betterment, but how widespread or effective these were is uncertain. It is clear, however, that they were abandoned after betterment was implemented.

Apart from feeling a lack of ownership that might inspire better land care, people also feel quite helpless given the enormous task of rehabilitating eroded areas in Herschel. The poverty and lack of resources make investment in erosion control not only a low priority, but something many households cannot afford – especially since the perceived benefits to individuals are small compared to the individual's work inputs. There are some examples of successful reclamation done by community members, for example a donga which was blocked and revegetated with kikuyu grass (*Pennisetum clandestinum*) in Sunduza village south of Bensonvale. As a general rule, however, it appears that agriculture makes such a small contribution to most households that investment in resource management which would boost agricultural production is not considered to be worthwhile by most individuals. In fact, given the fact that livestock numbers would probably have to be reduced if vegetation cover is to improve, many people would suffer a loss rather than a gain from rehabilitation if the human population stays the same.

4.4.4 Implications for management and planning

From the above discussion, some noteworthy implications for land use planning and management emerge. While not all communal areas experience the same levels of degradation, most evidence indicates that in South Africa, communal areas are more vulnerable to erosion than commercial farming areas (Hoffman et al. 1999). For policy making in the existing communal areas, and land reform in rural areas, where some form of communal tenure will most likely be the norm (Cousins 1996, Ainslie 2002), it is important to identify ways of making land use under communal tenure more sustainable.

The data for Herschel demonstrate the important influence of the physical environment on degradation potential. For example, this study as well as others (e.g. van Oudtshoorn 1988, Watson 1990, Weaver 1991) has shown that areas with deep duplex soils derived from Karoo sediments are highly vulnerable to disturbance, especially ploughing. It is clear that great care must be taken to plan land use and appropriate soil conservation measures on such areas from the outset. On the other hand, areas on dolerite appear to be relatively robust to cultivation and high livestock densities under the same slope and rainfall conditions.

Most importantly for land reform, the objectives of the future land users must be established. Whether an area is intended to mainly provide space for housing, or whether people are supposed to be able to subsist on agriculture will determine how many people an area can support. In an area such as Herschel, which has highly erodible soils, steep slopes and variable rainfall patterns, overcrowding an area intended to be farmed has resulted in overutilisation of the resource, which caused increased erosion. Now, much of the arable land is left fallow, and the area is in effect "underfarmed" (*sensu* Hoffman *et al.* 1999). With the small amount of resources available per family, investment in resource management is unlikely to be economically attractive to farmers.

5. THE LIVESTOCK PRODUCTION SYSTEM IN THE HERSCHEL DISTRICT

5.1 Introduction

The data so far presented have shown that livestock numbers in Herschel have not declined while degradation, particularly soil erosion, has increased over the same time period. In order to determine whether this ongoing degradation carries a cost to livestock farmers in Herschel, their objectives for keeping livestock need to established. In particular, the assumption that livestock numbers *per se* are a meaningful measure of farming success and sustainability needs to be tested. This chapter explores the livestock production system in Herschel, including ownership patterns, production objectives, inputs, production and herd dynamics for cattle, sheep and goats.

Patterns of livestock ownership – who owns livestock, what kind, and how many – are of interest in interpreting farmers' objectives and management strategies. Owners of small herds are more limited in their production options. If herd size is too small to fulfil subsistence needs, farmers will often be reluctant to sell livestock (Bembridge 1984, Tapson 1990, Ainslie 2002). Also of interest, particularly for policy and development interventions, is the distribution of livestock among owners – what proportion of the population owns livestock (and thus how representative livestock owners are of an area's total population), how livestock ownership by men and women differs and how skewed livestock ownership is.

The objectives of livestock owners determine whether livestock number, sales, or a mixture of products is the most appropriate measure of farming success. A commonly perceived problem in South African communal areas is that the grazing land is grossly overstocked, that offtake from the herd is unreasonably low, and that an increase in offtake would lead to increased personal and national income as well as relieving pressure on the natural resources (Tapson and Rose 1984). As a result, development of South African communal rangelands has focused very strongly on increasing the production and sale of meat, milk and other livestock products, and it has been stressed that livestock production in the former homelands needs to become more market-oriented (e.g. Bembridge 1979; Steyn 1982; Bembridge 1984). An alternative, and increasingly common, view is that livestock numbers are a better reflection of farming success than sales and other offtake in a system where livestock farmers derive a number of different benefits from a multi-species and "multipurpose" herd. Most of these benefits are derived from live animals and maximised at higher stocking rates than beef production (Sandford 1983, Tapson 1990, Behnke and Abel 1996), and it is thus the number of livestock, rather than offtake, that best reflects farming success.

Current views on the objectives of communal farmers tend to focus on the benefits derived from cattle, and farmers' objectives of maximising cattle numbers as a form of "working capital" (e.g. Bembridge 1979; Tapson and Rose 1984; Tapson 1990). In Herschel, sheep and goats make up about 40% of the total livestock units (at a cattle : sheep : goats ratio of 6 : 1.5 : 2.5 LSU)[5], and in terms of numbers, they far exceed cattle. It is therefore important to examine the different roles, dynamics and requirements of cattle, sheep and goats in Herschel.

Material or cash inputs into livestock farming are generally thought to be low since it is perceived that communal farming is not aimed at generating much output or profit (e.g. Behnke and Scoones 1993, Tapson 1993, Behnke and Abel 1996). This contrasts with commercial farming systems where production costs are high and optimum stocking rates and production levels are determined by optimising the difference between profits and production costs. If communal farmers have negligible production costs, it is thought to be economically viable to maintain high stocking rates since no loss is incurred as productive output (i.e. sales of animals and animal products) is sacrificed. Inputs by Herschel livestock owners, such as feed and veterinary medicines and purchases of livestock, are examined here to test whether the above assumptions hold in the Herschel context. The inputs farmers make can also influence the ecological dynamics of the system, particularly changes in stock numbers during and after droughts.

Production efficiency and herd dynamics are examined for cattle, sheep and goats in the four study areas of Tugela, Bensonvale, Majuba Nek and Upper Telle, and related to the stated objectives of the farmers interviewed. The aim of this is to determine how successfully farmers are achieving their objectives, what constraints prevent them from achieving production objectives, and whether the different degradation levels in the four study areas correlate with production efficiency. Relationships between herd and flock size with offtake are also examined to test the idea that small herd size limits offtake which people would be inclined to make if they had more animals.

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[5] Large stock units (LSU) were calculated by multiplying the number of cattle by 0.8 and the number of sheep and goats by 0.17.

5.2 Methodology

Production data, ownership patterns and information on production objectives were obtained by conducting semi-structured interviews with 79 individual farmers and eight groups in Tugela, Upper Telle, Bensonvale and Majuba Nek, and an additional group of farmers in Magadla, an administrative area neighbouring Bensonvale. All interviews were performed between March 1998 and May 1999. An exhaustive livestock production survey was beyond the scope of this study, and hence sample sizes for certain types of information are small. Semi-structured interviews were done in preference to a questionnaire-based survey for a number of reasons. In the early phases of the study, this approach allowed issues important to the farmers to be identified and explored. Also, the breadth of the topics covered (production objectives and constraints, production data and livestock dynamics; and changes in resource use and perceptions of degradation which are covered in other chapters) would have resulted in exceedingly long interviews. Lastly, different farmers were knowledgeable, interested or comfortable discussing different aspects of the issues investigated, and each interview therefore covered a different subset of the topics in different degrees of detail.

Sampling of herds was subjective rather than random and aimed at interviewing owners of as great a range of herd size and composition as possible. Between 16 and 24 herd owners were interviewed in each area. How great a fraction of livestock owners in each area this represents is not clear, as the number of livestock owners is not known and cannot be deduced from the population census data. The percentages of cattle, sheep and goats sampled differed between areas, as similar numbers of livestock were covered but total numbers of livestock differed between areas.

Table 5.1. Numbers of cattle, sheep and goats in Tugela, Majuba Nek, Bensonvale, Upper Telle and the whole Herschel district, and the percentage of animals sampled during interviews with livestock owners in the four study areas. Stock numbers are from the 1997 livestock census, while interview data are from 1998 and 1999.

Area	Cattle total	% sampled	Sheep total	% sampled	Goats total	% sampled
Tugela	1993	8	4165	35	2611	31
Majuba Nek	670	18	667	45	1693	22
Bensonvale	329	40	841	72	33	76
Upper Telle	2454	6	3468	43	6478	7.5
Herschel	48 783	1	55 008	7.5	84 832	2

Data were obtained only from stock owners, and the fact that many people do not own any livestock is thus not reflected by the data. The few farmers who own large herds are somewhat over-represented in the sample compared to the many owners of small herds, as I tried to interview one or two owners of large herds in each area. The choice of interview subjects was also somewhat biased by the fact that people resident in Herschel more or less full time were more likely to be interviewed than people who spend long periods away on migrant labour, and the fact that the locally hired translators sometimes chose people they knew owned livestock and were keen to be interviewed or were particularly knowledgeable. As a result, active and knowledgeable farmers may be over-represented in the final analysis. Overall, an effort was made to choose a sample as representative of different livestock owners as possible with the help of the translator and interview subjects. The use of ordinal statistics (such as medians) in the presentation and analysis of data reduces the influence of a few very large herds on the results, and helped to make the results more representative of the average herd owner.

Cattle were classified into mature animals (cows, oxen and bulls) three years or older, juveniles of both sexes younger than three years and calves of a year or less. In the absence of written records, it was difficult to obtain a reliable detailed age breakdown, and three years was assumed to be the boundary of maturity. Although crude, this division provides an indication of animals of breeding, working and selling age (Tapson 1990).

Cattle population dynamics were investigated using the progeny history method (ILCA 1990), often referred to as "cow interviews". This involves recording the breeding history of each breeding female in the herd by "interviewing" the cow through its herder or owner. For each cow, the following are recorded: its age, how it was acquired (bought, born in the herd, etc.), how many calves it had, and at what age it gave birth to its first calf. For each calf, its age or birth year, sex and subsequent fate were determined: whether it was still in the herd, sold, slaughtered or died from other causes; and whether, in the case of females, it had calved and at what age. From this data, reproductive indices (age at first calving, number of calves per lifetime and calving intervals/rates) were calculated. To determine the number of calves born per cow life time, only data from cows older than eight years were used, where owners considered the cow to be at the end of its reproductive life. Data where farmers were unsure about details or vague were excluded from the analysis.

Information about all the gains and losses to an owner's cattle herd in one year (initial herd size and number of cows, births, purchases, lobola transactions, deaths, sales, slaughter, theft and other losses) were used to calculate annual rates of gains and losses (these data are hereafter referred to as "herd transaction data"). Unless otherwise specified, rates are calculated as a percentage of the total number of cattle present at the beginning of the year, as follows:

- Herd crude reproductive rate (HCRR): the number of calves born as a percentage of the total herd;
- Annual reproductive rate (ARR): the number of calves born as a percentage of mature cows at the beginning of the year; this is checked against the calving rate calculated from progeny history data, as well as the cows:calves ratios calculated from stock census data and composition of all respondents' herds.
- Buying: the number of cattle purchased or obtained by trading against other livestock;
- Mortality: the total number of cattle (including calves) that died;
- Slaughter: the number slaughtered by the owner;
- Sales: The number of cattle sold or traded, within or outside the district.

Information on all cattle lost or removed from the herd over the sample period was compiled from progeny history and herd transaction data sets. The relative frequencies of death, slaughter, sale and other types of losses were then cross-checked against mortality and offtake rates calculated from herd transaction data. An idea of the relative frequency of births and purchases was similarly obtained by adding up all the cattle whose origin (born, bought or received as lobola) was known.

The number of animals annually brought into Herschel from other districts was obtained from stock permit data which were available for a period of nine years (1984 to 1992). Until 1994, any livestock crossing district borders into or out of the Transkei had to be accompanied by 'Permits to Remove Animals' issued by the Veterinary Services and kept by the Department of Agriculture office in Sterkspruit. After the incorporation of Transkei into the Eastern Cape Province in 1994, the permit system was abolished. The stock permits state the number and type of stock brought in, where they come from, and for what purpose they were brought into Herschel. The reliability of the stock permit data is assumed to be at least consistent from year to year. Purchases and sales of livestock within Herschel are also recorded, but they are likely to be incomplete (especially when sales are taking place within one village) and were left out of the analysis.

Herders or owners of small stock were asked to recall the number of goats and sheep as well as the age and sex composition of the flock. The latter was sometimes difficult to determine accurately, especially for large flocks where farmers often did not know the details. Where possible, the number of ewes of breeding age at the beginning of the year was recorded in addition to the total flock size. All transactions (buying, selling, slaughtering, other), births, juvenile and adult mortality were recorded and rates calculated for each flock. The rates were calculated as for cattle, with the exception that mortality was sub-divided as follows:

- Lamb/kid mortality: the number of unweaned lambs/kids that died as a percentage of lambs/kids born that year
- Adult mortality: the number of mature sheep/goats that died as a percentage of the total number present at the beginning of the year
- Total mortality: the number of adults plus lambs/kids that died as a percentage of the number of adults present at the beginning plus lambs/kids born that year.

Wool production data for the years 1994, 1995, 1996 and 1998 were obtained from the Environment and Development Agency (EDA) and Cape Mohair and Wool, who buy wool from Herschel farmers.

When summarising data on herd size and production coefficients, I found that the data tended to be skewed by a few extremely high values. I therefore used medians and quartiles which I found to be a better representation of central tendency than mean values, which were invariably higher than the median value.

To examine the influence of herd size on production coefficients, particularly offtake in the form of sales and slaughter, I performed Spearman Rank Correlations. Kruskal-Wallis ANOVAs were used to determine differences in production coefficients between the four study areas and for three classes of feed input into cattle production (grazing only, grazing plus stover, grazing plus purchased and/or cultivated feed with or without stover). Mann-Whitney U tests were used to determine differences in production and offtake between owners who provided/never provided their sheep and goats with purchased and/or cultivated feed. The same test was done to test for differences in production and offtake from herds where owners provided or never provided veterinary medicines. In the latter case, the use of traditional remedies (usually salt) was included in the "no veterinary medicines" category. I used non-parametric statistics because none of the variables had normal distributions.

5.3 Results

5.3.1 Livestock ownership

Ownership patterns by livestock species

Among the 79 livestock owners interviewed in the four study areas, most (82%) had cattle, while only 51% owned sheep and 62% owned goats. Average livestock holdings were small, as expected given the large human population. Loxton, Venn and Associates (1990) found that in Herschel, "only a small percentage of households do not own any cattle and a higher percentage of households do not own sheep or boer goats". Other studies in the Eastern Cape (Steyn 1982, Bembridge 1984, Ainslie 2002, Ntshona and Turner 2002) also found that small stock, especially sheep, were owned by a smaller proportion of farmers than cattle.

Cattle were generally considered to be the most important species of livestock, and an integral part of rural livelihoods. However, average herd size in Herschel was small, with a median of 7 (quartiles 5-15). Most (72%) of the 50 cattle owners interviewed had fewer than ten cattle, the number considered by Bembridge (1979) to be the minimum number necessary to cover subsistence and socio-cultural needs before any secondary income can be generated. Surveys in Bophutatswana (Seobi 1979, cited in Steyn 1982), Ciskei (Steyn 1982), Transkei (Bembridge 1984) and KwaZulu (Tapson and Rose 1984) showed that in all these areas, similarly high percentages of cattle owners had fewer than ten head of cattle. Only 18% of the cattle owners interviewed in Herschel had more than 18 cattle, the number estimated by Tapson and Rose (1984) to be the minimum required in a mixed farming system in KwaZulu to fulfil primary needs of two cows in milk and four draught oxen.

Only about half of the stock owners interviewed owned sheep, as sheep were considered to be the least hardy and thus most difficult of the livestock species to keep. However, there was a relatively high proportion of sheep owners in Herschel who kept very large flocks, and some sheep owners were successful wool producers. Eight of the 32 sheep owners interviewed had more than 100 sheep. Average sheep flocks recorded in Cikskei by Steyn (1982) and in Transkei by Bembridge (1984) consisted of 18 and 21 sheep respectively, compared to a mean flock size of 129 $\pm$ 40 in Herschel. The skewed distribution of sheep ownership becomes apparent when comparing this mean to the median of 36 (quartiles 17-113).

Many people kept goats and liked them because they are hardy and reproduce well. Others found goats too troublesome as they are notorious for invading croplands and gardens and thus require more herding labour than other livestock species. In Bensonvale, where the majority of people are Basotho, only two farmers in the whole area kept goats. This was explained to be due to Basotho culture, where sheep are the animal preferred for ritual slaughter, and some people even refuse to eat goat meat. Most goat owners had relatively small flocks, although median goat flocks in Herschel (22; quartiles 9-32) were much larger, and the largest flocks far bigger, than those reported from other parts of the Eastern Cape (Steyn 1982, Bembridge 1984), where average flocks consisted of 10 and 8 goats respectively. Eleven per cent of goat owners interviewed in Herschel had flocks exceeding 100 goats.

Skewed distribution of herd size

Interviews showed that livestock holdings among stock owners were highly skewed in Herschel. Some households had no livestock at all, and while a few people owned large numbers of cattle, sheep and goats, most livestock owners had small herds and flocks, which were in most cases insufficient for subsistence production. Since only people who owned livestock were interviewed, the proportion of people in Herschel who did not own any stock is not reflected in the data presented here. From livestock data gathered at dip tanks, EDA calculated that 20% of the livestock owners in Herschel owned 80% of the total livestock in the district (Dick Isted, pers. comm.). This finding is supported by the data presented in Figure 5.1, which shows herd size as cumulative percentages of the total number of livestock owned by the people interviewed.

The graphs reflect the differences in ownership patterns of different livestock species described above. Sheep showed particularly skewed ownership, with just over 20% of owners owning 80% of sheep. The goat ownership curve is steep initially (10% of farmers own 60% of goats), but levels out from there. Cattle were more evenly distributed among owners as shown by the most gentle of the slopes. The LSU curve rises steeply at first, with 25% of people owning 80% of total LSU, and falls off above that. Among the biggest livestock owners were local shopkeepers and other businessmen who would often make a substantial income from livestock and livestock products, but this was usually secondary to the income they derived from other business ventures. There were, however, some men in Herschel who were primarily livestock farmers, and who derived a significant income from livestock. These farmers made considerable investments of time, labour and money into livestock production, and they formed the backbone of Herschel's very active

Farmers Union. In KwaZulu, Tapson (1990) found that resident owners had bigger herds of cattle than migrant workers, and the same was observed, though not quantified, in Herschel.

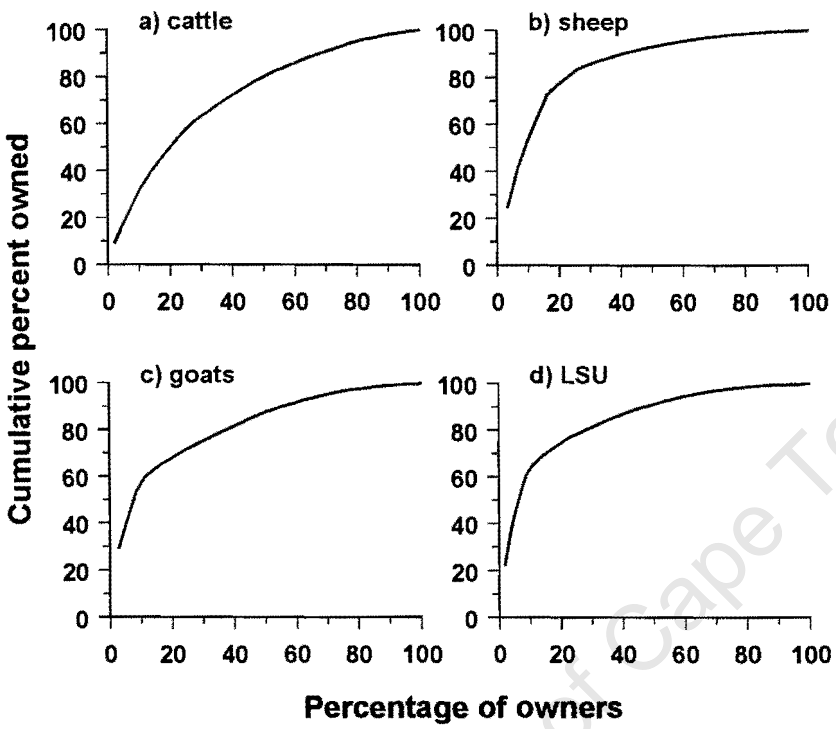

Figure 5.1. Cumulative percentages of cattle, sheep, goats and large stock units (LSU) in a sample herd when plotted against the percentage of owners in the sample. The graphs illustrate the skewed livestock ownership among livestock owners in the Herschel district. Data were combined for the four study areas.

The data presented here are somewhat biased towards large herd owners because in an attempt to cover different types of livestock owners in around twenty interviews per area, the big livestock owners (who make up only a small percentage of livestock owners in Herschel) and their large herds contributed disproportionately to the data set. However, even when the big livestock owners interviewed are seen in context of livestock census data (which gives the total number of livestock in each study area), it is obvious that most of the livestock were owned by a minority of people. For example, one man interviewed in Tugela owned 52 cattle, nearly 1000 sheep and 500 goats, which made up 19% of the total LSU recorded in Tugela (livestock census data from 1997). Three farmers, who each had over 100 sheep, owned 37% of the total sheep population in Tugela. In Upper Telle, four owners of 100 or more sheep owned 39% of the total sheep population, and one man with a flock of 470 sheep owned 56% of all the sheep in Bensonvale. The figures for goats showed less of a concentration of goats in the hands of a few farmers (two men with over 100 goats each in Tugela and Upper Telle owned 27% and 5% of goats in these areas respectively), and cattle were even more evenly distributed.

Herschel is unusual in having such large flocks of small stock when compared to studies in other communal areas in the Eastern Cape (Steyn 1982, Bembridge 1984). However, in semi-arid areas of the Western Cape such as Namaqualand and the Richtersveld, where small stock farming is based at stock posts, many farmers keep several hundred sheep and goats (Todd and Hoffman 2001, Howard Hendricks, unpublished data). It appears that the existence of large, remote and inaccessible areas in some parts of Herschel, where a few farmers who can afford to pay herders are able to expand their flocks by keeping them at stock posts, may partly explain the big flocks found in Herschel. Differences in areas within Herschel support this: there was a virtual absence of large flocks of small stock in Majuba Nek and Bensonvale. There were no stock posts in Majuba Nek and Bensonvale because these areas have no remote mountainous areas and are more densely settled. In Tugela and Upper Telle, on the other hand, some people had hundreds of sheep and goats, which were kept at stock posts in the mountains far from the village, where the grazing was better and where goats in particular could be kept away from crops and gardens.

Ownership patterns by gender

Livestock ownership by men and women differed, with a smaller proportion of female stock owners, and women having smaller herds (Table 5.2). The same was found to be the case in other parts of the Eastern Cape and KwaZulu (Steyn 1982, Tapson 1990, Ainslie 2002, Kepe 2002, Ntsebeza 2002). Livestock farming, particularly with cattle, was generally considered to be a man's occupation, and the women interviewed who owned their own livestock were single heads of households and mostly of middle age and older. Women and men interviewed would ascribe ownership of livestock to the male head of a household where there was one, even if the man spent most of the year working and living outside Herschel. In these cases, the man was still the major decision maker in livestock matters. While many female livestock owners were widows who had inherited their livestock from their husbands, some had built up their own herds or flocks in the absence of a husband or partner. Women's livestock were usually herded by some family member (usually a boy) or herded with those of other family members, though Steyn (1982) found that three women in his survey owned, herded and milked cattle. With one exception, (the owner of the Majuba Nek trading store who has 15 cattle, mainly to sell milk), the women interviewed kept livestock mainly for traditional or subsistence purposes such as security, milk and ceremonial slaughter.

Table 5.2. Mean and range of number of LSU, cattle, sheep and goats owned by men and women in the Herschel district.

	Male livestock owners (N=53)			Female livestock owners (N=12)		
	Median	**Min.**	**Max.**	**Median**	**Min.**	**Max.**
LSU	10.7	0.9	297	5.7	0.5	12.6
Cattle	9	1	52	5.5	2	15
Sheep	45	6	1000	9	5	12
Goats	27	3	500	8	3	29

5.3.2 Livestock production objectives

Cattle

According to farmers, cattle serve as a form of savings and security (people often refer to cattle as their "bank") and are also kept for ploughing, milk, as a source of cash income, for traditional slaughter and (rarely) slaughter for meat. The use of kraal manure for fertilizer or fuel was not mentioned by any of the cattle owners interviewed. All cattle kraals that were observed, however, had pats of manure stacked around them, which were used as fuel. Table 5.3 summarises the most important functions of cattle according to farmers in the four study areas.

Table 5.3. Responses of 43 cattle owners in the Herschel district who were asked what they considered to be the most important functions of their cattle. If farmers rated two functions as equally important, both were included in the table. "Traditional" includes ceremonial slaughter and lobola.

Production objective	Most important	Secondary importance	Not mentioned
Savings / security	15	5	23
Ploughing	10	7	26
Milking	8	12	23
Sale	6	11	26
Traditional	6	8	29
Slaughter for meat	0	3	40
Use of manure	0	0	43

Cattle were seen by many farmers primarily as a form of savings and security, and were usually sold to meet *ad hoc* cash needs such as school fees, home building and maintenance, furniture, settling of debts and family emergencies. Similarly Colvin (1984, cited in Tapson and Rose 1984) found that at stockyards in KwaZulu, most cattle were sold to cover school fees, food and health requirements arising at the time of sale. The same was true for 90% of cattle sales in the South Gwanda district in Zimbabwe. Food needs accounted for most of the sales in South Gwanda where farmers are heavily dependent on cattle sales for cash income. While no correlation existed between rates of sales and herd size, there was a strong positive relationship between the number of cattle sold and family size, suggesting that sales are mainly need-driven (ARDA 1982, cited in Tapson 1990).

Farmers in Herschel usually sold cows and oxen when they were old and no longer useful. When money was not immediately needed, an old or male animal would frequently be traded against one or two heifers, or heifers would be bought with the money earned from selling cattle. When cattle died from disease or during a drought, farmers often bought replacements. Most farmers interviewed said that they would like to be able to derive a regular income from the sale of cattle but found that their herds were too small, and reproduction too slow, to permit this. Farmers in Herschel were thus trying to increase the number of their cattle, although there were a few exceptions who have reduced their cattle numbers so they could afford to feed them through winter when necessary. Similarly, Tapson (1990) found that farmers in KwaZulu, especially owners of very small herds, made considerable efforts to increase the size of their herds by restricting offtake and purchasing cattle.

Oxen provided traction power, although the importance of this varied among farmers and between areas, depending on the availability of arable land. According to unpublished data on degradation and land use trends (Timm Hoffman, Leslie Hill Institute for Plant Conservation; Hoffman et al. 1999) the area of Herschel under cultivation is rapidly declining. This, with the (limited) availability of tractors in the more central areas, has resulted in a diminished demand for oxen as draught animals. The shortage of oxen in most households may also influence how important ploughing is considered to be as a cattle production objective. In Herschel, most farmers did not have enough mature oxen to make up a ploughing team and had to either borrow oxen or use immature oxen or cows from their own herd.

Traditionally, milk production was an important function of cattle, and milk a major food source. It is therefore interesting to note that more than half of the people interviewed in this survey did not accord milk production any importance. Several of the people who did cite milk as a production objective did not actually milk their cows at the time, and some had not milked for some time previous to the interview. Tapson and Rose (1984) also found that, while milk production was considered to be by far the most important function of cattle, the amount of milk actually available was small and most respondents bought several litres per week. In this study, Bensonvale was the only area where milk emerged as the most commonly cited objective of keeping cattle, and where a substantial proportion of farmers (eight of the ten people who were asked) were actually milking their cows.

Cattle are required for traditional purposes such as paying lobola and ceremonial slaughter on occasions such as funerals, weddings and initiation ceremonies where the meat is also used to provide a feast for the guests. Practically everyone living in rural society has to provide for such occasions at some time or another, and if the person does not own cattle, he or she must purchase the necessary number at considerable expense. Very few people in Herschel slaughtered cattle for their meat outside the context of traditional ceremonies. This is not surprising, given the high value and great size of cattle. Of the three respondents (all from Majuba Nek) who mentioned slaughter for meat, one was the headman, another a wealthy farmer, and the third was the woman who owns the trading store in Majuba Nek. It is likely that, except in wealthy households, cattle are slaughtered for meat only when they are old, starved or injured and are likely to die.

Sheep

Sheep are kept for wool production, sale and slaughter, and benefits to the farmer are thus derived primarily from the sale or consumption of animals and animal products. Table 5.4 summarises farmers' responses about their main reasons for keeping sheep. Wool emerged overwhelmingly as the most important production objective, followed by sale and slaughter for meat. Some farmers used sheep for ceremonial slaughter, mainly Basotho who prefer sheep to goats traditionally according to informants in Bensonvale. Unlike cattle, sheep were not kept as a form of security or savings.

Table 5.4. Responses of 30 sheep owners who were asked what they considered to be the most important functions of their sheep. If farmers rated two functions as equally important, both were included in the table.

Production objective	Most important	Secondary importance	Not mentioned
Wool	27	2	1
Sale	6	9	15
Slaughter for meat	3	15	12
Ceremonial slaughter	2	5	23
Savings / security	0	0	30

According to EDA (1997, unpublished report), Herschel receives most of its income in agriculture from the production of wool, and farmers unanimously reported sheep to be the animals that generate most income. Before the Transkei government forced the (white) owners of trading stores to leave Herschel after independence in 1976, farmers would sell their wool at trading stores, which were the main pathway of wool sales in Ciskei (Steyn 1982). While part of an independent Transkei (until 1994), wool produced in Herschel had to be sold as "Transkei wool", unsorted and for much lower prices than via the commercial system. During the 1988/89 season, BKB Butterworth (the wool broker dealing in Transkei wool) quoted 76 c/kg for unsorted wool and some traders who bought wool in Herschel paid 80 c/kg, while wool brokers buying sorted wool from commercial farmers paid between R 3.00 and R 3.50 per kilogram (Graham Frost, EDA, pers. comm.). A marketing system for wool through the commercial sector (and hence at worthwhile prices) has been developed since the late 1980s with the help of EDA.

Under this system, wool is shorn and marketed from all areas of the district under co-ordination of the Herschel Farmers Union. Shearing takes place in the second half of the year, usually in spring, although the process of shearing and marketing from all the sheds can take several months and is usually only completed early the following year. With the exception of a few big farmers who market their wool under their own name, farmers using any of the 40 shearing sheds in Herschel sort, bale and sell their wool collectively under the name of the shed. Each farmer's contribution is weighed, and farmers are paid individually by cheque from the wool company which buys the Herschel clip. The wool from all sheds is usually transported and sold together. This system has encouraged even farmers with few sheep to market their wool; as one farmer put it, "I discovered you can eat sheep while they are alive". Among the sheep owners interviewed, only one old woman did not sell wool.

Farmers sold sheep fairly regularly, mostly within the district when interested buyers approached them. One farmer who was interviewed also sold sheep to butcheries outside Herschel. Because of the great value of wool, farmers tried to maintain large sheep flocks and sold mostly old animals, and several of the bigger sheep farmers in Herschel regularly bought surplus stock from neighbouring commercial farmers (Llewellyn Gush, pers. comm.). Some farmers on the other hand preferred to maintain their flock at a size that they could afford to provide with feed and medicines.

None of the farmers interviewed mentioned selling sheep skins, and Loxton Venn and Associates (1990) found the number of hides sold in Herschel, given the number of livestock in the area, to be "low". Prices obtained were below R20 per skin. According to a former trading store owner and local businessman (Charlie Mather, pers. comm.), Herschel farmers used to sell hides to local traders, but most farmers no longer sold animal skins because of a lack of marketing opportunities.

Goats

Goats were used primarily for slaughter and sale, ceremonial slaughter being the most important motivation for keeping goats (Table 5.5). Goats could also form part of lobola payments. Farmers agreed that goats did not generate as much income as sheep because sheep produced wool in addition to meat. However, goats were indispensable for traditional ceremonies and there appeared to be a substantial local market for goats.

Only two of the farmers interviewed produced mohair, and mohair production was not important on any significant scale in the district. Angora goats are vulnerable to feed shortages and cold, while indigenous breeds and boer goats reproduce better and have much lower mortality rates. Given this and the poor marketing situation until recently, it is not surprising that few farmers invested in mohair production.

People in Herschel generally did not milk goats. Loxton Venn and Associates (1990) found that "only a small percentage" of livestock owners in Herschel milked goats. The reasons for this appeared to be negative attitudes to drinking goat milk rather than a lack of sufficient production.

Table 5.5. Responses of 32 goat owners in the Herschel district who were asked what they considered the most important functions of their goats to be. If farmers rated two functions as equally important, both were included in the table.

Production objective	Most important	Also important	Not mentioned
Ceremonial slaughter	14	9	9
Sale	10	9	13
Savings / security	6	0	26
Slaughter for meat	1	15	16
Milk	1	1	30
Mohair	1	1	30

Farmers were generally interested in production and turnover rather than a large standing stock of goats, especially since goats were hardy and reproduced fast, and there was thus little need for many extra animals in case of a drought. As with sheep, a lack of marketing opportunities and infrastructure prevented most farmers from selling goats outside Herschel, and goats were thus usually sold one by one within the village. The number of sales thus depended on the local buyers' demands. When asked why he had such a large flock of goats, one farmer replied, "I have goats to be able to sell them. I don't want a huge flock of goats, but I cannot throw them away".

5.3.3 Production inputs

Farmers made different types and amounts of inputs into cattle, sheep and goat production. The inputs farmers made also depended on their time, labour and financial resources. The main inputs Herschel farmers made in livestock production were labour, feed and veterinary medicines, as well as capital for the purchase of livestock.

Herding

All livestock species were kraaled at night and herded during the day, although goats were said to require more herding effort than other species as they covered long distances while browsing and were most likely to stray into fields and gardens. The increasing stock theft problem also made close supervision of livestock, particularly small stock, necessary, especially in the more remote, mountainous areas near the border with Lesotho. Another reason livestock owners in Herschel herded their livestock was the poor condition of the land which necessitated herding to ensure adequate nutrition (Mthozami Goqwana, unpublished data). Traditionally, boys of the family would herd livestock but since most children now go to school, herding labour is becoming increasingly scarce.

Farmers who were unable to herd their own livestock often hired boys from Lesotho for this job, especially if their livestock grazed far from the village. An alternative for people who could not afford to hire herders was to leave livestock unattended during school hours and sending their boys out after school.

Feed inputs

Most farmers felt that a shortage of grazing was a limitation to livestock production, and many farmers thus provided different types of feed in addition to natural grazing. Among the stock owners asked to rank livestock species according to how much extra feed they required, there was strong agreement that sheep needed the most feed and goats the least. Table 5.6 summarises responses of livestock owners on the nature and frequency of the feed inputs they made into cattle, sheep and goat production.

The use of additional feed inputs seemed to be fairly common in Herschel, particularly in drought years. In a single operation organised by EDA and the Farmers Union during the 1994 drought, 1380 bales of lucerne hay were bought by Herschel farmers at a cost price of R11 each (EDA 1994), and this figure excludes any feed that was bought directly from other sources. Prices for lucerne at the time of this study ranged from R18 to R25 per bale, with prices rising in drought years. Some farmers bought feed regularly, in some cases to improve production, in others simply to keep their animals alive. For example, one full-time livestock farmer in Upper Telle (who owns 30 cattle, 660 sheep and 200 goats) spent R 1600 on feed for all his animals (about R10 per LSU) in 1998. Even owners of small herds would sometimes make considerable investments in feed. For example, two women in Majuba Nek who each owned two cows said they each bought six bales of lucerne at a total cost of R150 per year, two per month between June and August (about R90 per LSU).

Cattle were considered to be valuable assets, and only one in three cattle owners interviewed relied on grazing alone. The most common form of supplementary feed was crop residues, which were usually grazed in the fields after the harvest. Although different versions of the accepted rules were reported by different people, there seemed to be no effective restrictions on whose cattle could graze in the croplands, which are allocated to individuals for cultivation. In Majuba Nek, some farmers said they harvested and stored crop residues for use in winter, and I observed several covered piles of stover in fields after harvest. This is an unusual practice, and suggests that people did have free access to stover at least after a certain date (and the owners of the crop tried to prevent others from using their stover), and that stover was in great demand in Majuba Nek due to a lack of grazing. Majuba Nek was the one area where everybody made some feed inputs into cattle production, even owners of very small herds.

Table 5.6. Feed inputs farmers made towards cattle, sheep and goat production in the four study areas. If a farmer made more than one type of feed input, both were included in the table.

	Cattle (N=36)		Sheep (N=31)		Goats (N=28)	
	N	%	N	%	N	%
Graze only	12	33	13	42	19	68
Crop residues	19	53	2	6	0	0
Buy when necessary	11	31	5	16	4	14
Buy every year	5	14	5	16	5	18
Plant feed crops	2	6	12	39	4	14

Nearly half the cattle owners interviewed bought feed such as dairy meal and lucerne hay at least some of the time, particularly in dry years when the availability of both grazing and crops (and hence stover) was reduced. Such feed was bought from the co-operative in Zastron, Barkly East or Lady Grey, or sometimes via the Farmers' Union. A few farmers planted fodder crops such as wheat or oats for their cattle, which could be grazed in winter. More farmers in Majuba Nek and Tugela, the two most densely stocked and eroded areas, bought or cultivated feed for their cattle than in Upper Telle and Bensonvale. Some farmers from Tugela paid to graze their cattle on neighbouring farms because of the better grazing conditions there, especially if they were planning to sell them and wanted them to fetch good prices. Grazing cattle on Fairview farm, which belongs to the Herschel Development Trust, cost R15 per head per month, though it was not ascertained whether these fees were actually paid.

Most farmers agreed that sheep needed additional feed inputs to be productive. Most ewes lambed in winter, and without feed, lamb mortality was high due to the lack of adequate grazing. Stover (mainly maize or sorghum stalks) was considered to be unsuitable for sheep, so additional feed had to be bought or cultivated. The most common forms of feed were bales of lucerne hay bought from co-operatives or neighbouring farms, and wheat, oats or lucerne cultivated by Herschel farmers on their own arable plots. Not having arable land (or having an arable plot too far from the homestead where sheep were kraaled) was viewed as a constraint to sheep production. Whether farmers provided their sheep with additional feed appeared to be a function of commercial aspirations rather than land degradation. While all sheep owners interviewed in Tugela provided feed, most sheep owners in Majuba Nek let their sheep rely on grazing alone.

The majority of goat owners did not provide their goats with any additional feed. The reason for this, according to farmers, was that, unlike cattle and sheep, goats survived and reproduced well even if they relied on grazing and browsing alone. Goats were considered to have an advantage over cattle and sheep as they are able to utilise shrubs as well as grass, although many of the Karoo shrubs found in Herschel, such as *Chrysocoma ciliata, Felicia* species and many of the *Helichrysum* species, are not browsed at all. This was the general situation with respect to boer goats and indigenous goat breeds, which were by far the most common. Few farmers had Angora goats, which are much less hardy but provide additional income from mohair. Angora goats were usually kept in conjunction with sheep flocks by wool-producing farmers, and they usually received feed as sheep did.

Veterinary Medicines

As with feed, inputs of medicines varied between farmers and between livestock species. Sheep, according to farmers interviewed, required the most medicines and goats the least. People generally said they used more medicines now than they used to, or than their fathers did. Some felt that diseases were more prevalent today, but that the better availability of medicines from the commercial farmers' co-operatives as well as the breakdown of government veterinary services (dipping, dosing and inoculations) also contributed to the increasing purchase of medicines by farmers. This was illustrated by the fact that only one respondent said that he made use of government veterinary services. Some of the bigger farmers spent large sums of money on medicines. For example, the man in Upper Telle who spent R 1600 on feed also spent R 3000 on medicines for all his livestock in 1998 (R20 per LSU). Most farmers' efforts to provide their livestock with veterinary medicines were limited by a lack of money. A lack of extension advice and information on the correct usage of veterinary medicines may also have resulted in ineffective treatment, such as underdosing, in many cases.

The majority of people interviewed bought some kinds of medicines for their cattle, at least some of the time (Table 5.7). These included dips against ectoparasites such as ticks, which were bought more frequently since the government dipping services had started breaking down. Some farmers regularly dosed their cattle against internal parasites, and bought other medicines as needed. Four people interviewed (three women and one man, all from Majuba Nek) said they used traditional medicines such as herbs, tar and salt.

Almost all sheep owners provided their sheep with medicines, and nearly half the farmers interviewed bought medicines every year. Dosing against internal parasites and treatment for sheep scab were most commonly used on a regular basis. A variety of other treatments were obtained when sheep were sick, e.g. with gall sickness or blue tongue. On the whole, farmers felt that goats needed hardly any medicines at all. Still, half the goat owners bought medicines at least some of the time. Dosing against internal parasites and occasional treatments for infectious diseases were the most common veterinary inputs.

Table 5.7. The responses of cattle, sheep and goat owners in the Herschel district when asked whether they give their livestock medicines (including preventative treatments such as dipping against ectoparasites), and how frequently.

	Cattle n = 22		Sheep n = 23		Goats n = 19	
	n	%	n	%	n	%
None	5	23	3	13	9	47
Government provided	0	0	1	4	0	0
Traditional remedies	4	18	0	0	1	5
Buy when necessary	6	27	8	35	5	26
Buy every year	7	32	11	48	4	21

Buying livestock from outside the district

The numbers of cattle, goats and sheep brought into Herschel in the years 1984-92 were added up from stock permits. These "imports" included lobola received (and hence not all records refer to purchases), as well as livestock bought by people other than livestock farmers, such as butcheries and people who did not own livestock and required animals for slaughter. Commercial farms in the neighbouring districts of Lady Grey, Barkly East and Zastron were the source of most of the livestock brought into Herschel. Some livestock however came from as far as Johannesburg, Cape Town and Kimberley, where they would have been bought by migrant workers.

Figure 5.2 shows how many cattle, goats and sheep were brought into Herschel for different purposes and rainfall fluctuations over the same period. The data series was preceded by a severe drought in 1981/82, for which stock permit data were unavailable. The highest numbers of livestock were imported in the years following the drought, and Figure 5.2 d) shows that the rate of importing livestock (imports as a percentage of livestock present in the district at the beginning of the year) was highest in those two years. Absolute numbers, as well as rates of imports, declined as rainfall increased in the 1987/88 season. Imports increased again following a dip in rainfall in 1989/90 (actually a year of average rainfall) and then declined during the low rainfall years that followed. Unfortunately no stock permit data were available after the dry years of the early 1990s. During progeny history interviews, more farmers reported having bought cows or heifers in the early 1990s than later in the decade.

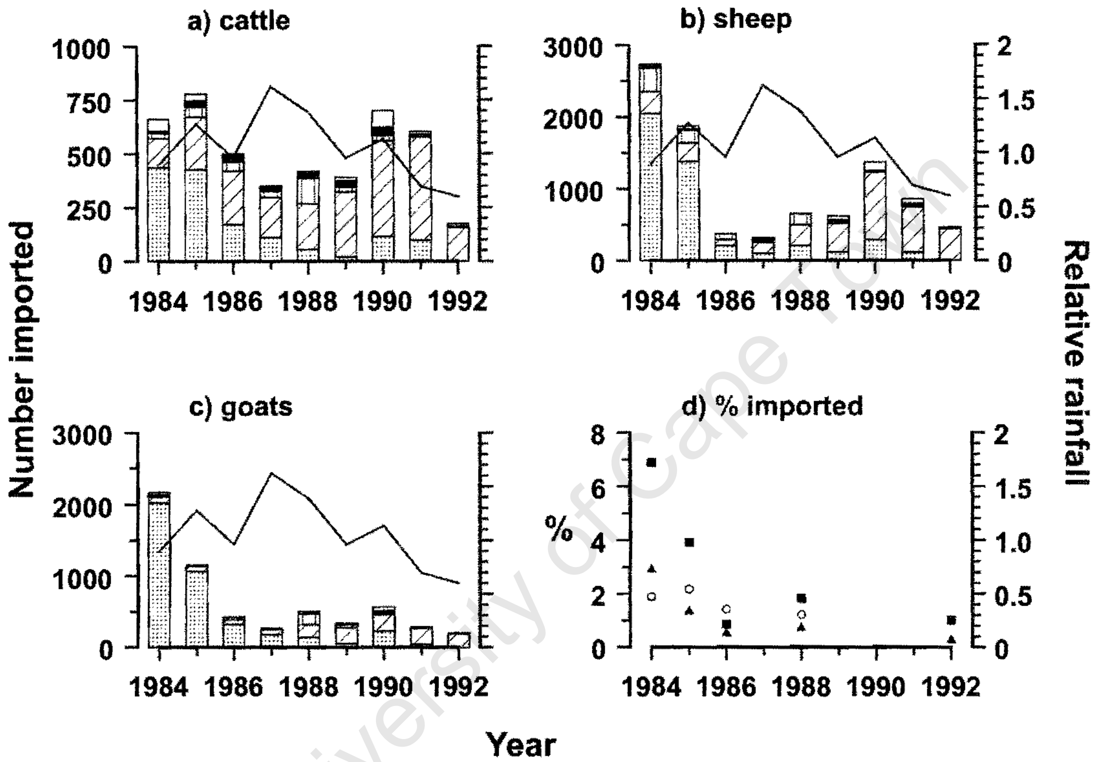

Figure 5.2. The total numbers of a) cattle, b) sheep and c) goats brought into Herschel from other districts by speculators (dotted bars) and by individual farmers for breeding (diagonally hatched bars), slaughter (vertically hatched bars), as part of lobola (solid bars) and unspecified purposes (open bars). Relative rainfall is current year's rainfall divided by mean annual rainfall. Figure 5.2 d) shows imports of cattle (open circles), sheep (solid squares) and goats (solid triangles) as a percentage of the total number of each species present at the beginning of the year. Sources: Stock permit data and stock census data, Department of Agriculture office, Sterkspruit.

Also noteworthy is the high percentage of livestock that were brought into Herschel by speculators in 1984 and 1985, where up to 50 cattle, 100 sheep and/or 100 goats were brought into Herschel in a single transaction. Some of these speculators are commercial livestock farmers. Large numbers of sheep were also bought by butcheries from outside the district during the same period with rates of sheep imports approaching 7% in 1984, more than twice the import rate of cattle or goats. From 1986 onwards, most animals were brought in a few at a time by farmers who wanted them for breeding, while the numbers brought in for home slaughter and lobola remained fairly similar over the years. The large number of livestock imported by speculators and butcheries after the drought indicates that there is a market for livestock in Herschel, particularly for slaughter. Speculators may have been selling livestock to farmers who wanted to rebuild their herds or flocks after the drought, and people who normally buy animals for slaughter from livestock owners in Herschel probably bought them from speculators while farmers were reluctant to sell livestock while their herds recovered. The fact that the proportion of livestock brought in by speculators decreased substantially as rainfall improved (and herds presumably were recovering) suggest that the demand for livestock in Herschel is normally supplied by livestock farmers within Herschel.

5.3.4 Cattle production

Productive potential of the Herschel herd

At any given level of management and nutrition, the productivity of the livestock system is dependent on the genetic potential of the animals used. The people who settled Herschel originally kept Nguni cattle, an indigenous breed with high natural fertility and which is well adapted to the environment and the traditional, extensive production system (Tapson 1990 and references therein). However, government schemes aimed at improving productive potential by introducing high performance breeds (e.g. dual-purpose cattle like Brown Swiss), as well as purchases of cattle from commercial farms over the years, have resulted in a highly mixed and interbred cattle population. Observations during field work and information from cattle owners on herd composition and breeding practices revealed that most cattle born in Herschel were a mixture of various breeds, and evidence of the original Nguni stock was largely confined to the relatively small size and light build of most of the cattle found in Herschel. It was therefore difficult to make any assessment of the inherent genetic potential of Herschel cattle. From their Nguni ancestry, they would be expected to be fertile as well as efficient in converting feed to productive output (Tapson 1990). How this has been altered by repeated interbreeding with cattle bred for different purposes is unclear. While the cattle introduced as part of government development interventions were chosen for particular qualities (e.g. high milk production), cattle bought from commercial farmers were often surplus stock of inferior quality, and this may have had an impact on the productive potential of the Herschel herd.

Herd composition

Table 5.8 shows the average size and composition of cattle herds in Herschel and of an "ideal" minimum herd derived for KwaZulu that would be needed to fulfill subsistence needs of four draught oxen and two milking cows, which would also enable regular sales or slaughter (Tapson and Rose 1984). Herd composition in Herschel was similar to that of this ideal minimum herd, but average herd size in Herschel was much smaller than the 18 head considered necessary for subsistence. The lack of a bull in many of the herds in Herschel was particularly noteworthy and was cited by some farmers as a limitation to their herds' breeding output. Nobody in this sample with a herd of fewer than five animals had a bull, and the maximum number of bulls in any of the herds studied was two. Small herds tended to be biased towards cows. The variance in herd composition was great, especially in small herds where a single animal contributes a high percentage of the total herd.

Table 5.8. Herd composition in the Herschel district (median of 37 herds ranging in size from 2 to 30 cattle) and the composition of the minimum "ideal" cattle herd for subsistence production according to Tapson and Rose (1984).

	Herschel (median 7 cattle)		Minimum"ideal" (18 cattle)	
	N	%	N	%
Cows (≥3 yrs)	3	42.8	7	38.9
Oxen (≥3 yrs)	1	14.3	4	22.2
Bulls (≥3 yrs)	0	0	1	5.5
Juveniles (<3 yrs)	2	28.6	4	22.2
Calves (<1 yr)	1	14.3	2	11.1

Herd composition data in Herschel were similar to findings in other South African communal areas, e.g. KwaZulu (Tapson and Rose 1984), Transkei (Bembridge 1984) and the Amatola Basin in Ciskei (Steyn 1982). The classification into age- and sex groups differed between studies, and direct comparisons were thus difficult. All of these studies found percentages of cows and calves to be lower than in "ideal" commercial systems, which have around 50% mature cows according to sources in Steyn (1982). Percentages of old and male cattle are higher in communal systems, indicating lower productivity and less offtake. The low offtake rates must however be seen in the light of the need for draught oxen and milking cows, as well as the small average herd size, all factors which are widely held to inhibit offtake in communal areas (e.g. Tapson 1990).

One farmer interviewed in Bensonvale ploughed only with cows, as he wanted to keep his herd size small (to enable him to feed them through winter if necessary) but wanted calves and milk. However, possibly as a result of poor grazing and the energy costs of ploughing, his cows only calved every four years. Among cattle owners interviewed, 80% had fewer than 4 oxen, the number considered necessary in KwaZulu by Tapson and Rose (1984), and 31% had no oxen at all. These figures are similar to those found by Tapson and Rose (1984) and Bembridge (1984). Steyn (1982) found that in the Amatola Basin in Ciskei, 61% of farmers used cows or heifers for draught because they did not have enough oxen of their own.

Herd dynamics

Median rates of calving, buying, offtake (sales and slaughter) and mortality calculated from herd transaction data are presented in Table 5.9. Herd data are mostly for the years 1997 and 1998 as most farmers did not accurately remember all transactions in earlier years. On average, there was an annual increase of 14% in the size of cattle herds during that period, but this could not be confirmed from stock census data which were unavailable for years later than 1997. The livestock data available for the 1990s did show a gradual increase in livestock numbers.

Table 5.9. Mean and median annual rates (and 25% and 75% percentiles) of additions to and deductions from cattle herds, expressed as percent of total herd size at the beginning of the year. Data are pooled for the four study areas and for the years covered by interview data. N is the number of herd-years (i.e. data for one herd over one year) used to derive means and medians.

	N	Mean	Median	25%	75%
Annual reproductive rate (per cow)	43	43.3	50	25	60
Herd crude reproductive rate	53	27.7	21.4	12.5	33.3
Buying	55	0.8	0	0	0
Mortality	55	4.8	0	0	5.7
Slaughter	55	1.8	0	0	0
Sales	55	5.3	0	0	7.1
Useful offtake (sale and slaughter)	55	6.4	0	0	8.3
Change in herd size over one year	55	116.0	114.3	100	133.3

Birth rates determined from herd transaction data were found to be variable, and reproductive indices are analysed in more detail in the next section. Mortality was low in this sample, with zero mortalities recorded in most herd-years (i.e. data for one herd over one year). A maximum of eight deaths (from heartwater, a tick-borne disease) occurred in a herd of 30 cattle in Majuba Nek in 1998. Rates of sales and slaughter and total offtake were low, and rates of buying cattle even lower, over the sample period. In more than half the herd-years recorded owners did not sell, buy or slaughter any animals. Table 5.9 shows that mean values poorly represent transactions and dynamics of the average herd in this sample, as they are biased by a few herds in which rates of purchases, sales, slaughter and mortality are high.

Most of the cattle sales took place within the district, and were mostly old cows or oxen bought for slaughter by people who own few or no cattle. Heifers in Herschel were sold less frequently, and were bought by people who needed them for starting or increasing their own herd. Tapson (1990) similarly found that 63% of cattle sales in KwaZulu were to other Zulu farmers, and less than 20% of cattle were sold through the official stockyards, which has led to a considerable underestimate of cattle offtake in KwaZulu. Thus in Herschel, not many cattle were "exported" from Herschel as a district, but they were to a large degree "exported" from the livestock-owning population within Herschel to the non-farming population.

Buying versus reproduction

Reproductive indices were obtained from progeny history interview data. Mean age at first calving across the study areas was 3.8 ± 0.2 years (n=47), mean calving interval 2.1 ± 0.2 years (n=28), and cows had on average 2.8 ± 0.2 calves in their life time (n=35). No significant differences in reproductive indices were found between the four study areas. These data agreed with the herd transaction data (Table 5.9) where median reproductive rate per cow was 50%, and were substantiated by interview information from farmers. Farmers said that on average, their cows gave birth every two years. Although this was considered to be normal in Herschel, many farmers (especially people who had worked on commercial farms, where the aim is to achieve calving intervals of one year) did not consider calving intervals of two years or more to be satisfactory.

Farmers gave two reasons for the long calving intervals: firstly, calves were usually only weaned after a year or longer (though cows under good nutrition can have their first post-calving oestrus after about a month, while still lactating) and secondly, farmers described cows as being too thin to conceive the first year after calving, as a result of poor grazing and drought. A shortage of bulls was also sometimes cited to be limiting calving rates.

Physiological stress (in this case due to poor nutrition, exacerbated by long lactation) is known to increase the anoestrus of cows. In an experimental study, Bishop and Kotze (1965, cited in Steyn 1982) found that the onset of the first post-calving oestrus averaged 184 days for nutritionally stressed beef cows, while dairy cows on a high plane of nutrition averaged 32 days between calving and first oestrus. If the cows had been mated, calving intervals would have been 15 and 10 months respectively; in Herschel, average calving interval was 2.1 years (about 25 months).

Many farmers said that if their herds were reduced through sales, slaughter or deaths and money was available, they would buy breeding stock to maintain or increase the size of the herd. People also bought cattle to start herds (e.g. upon return to Herschel after retrenchment or retirement from jobs outside the district), and for traditional needs (slaughter or lobola) if they did not have enough cattle of their own or did not want to reduce the size of their herd. Many of the purchases were from other farmers within Herschel. Of all the cattle which were added to the combined herds of all respondents (through birth, purchase and other transactions; n=358 over several years), 10.3% were bought from within or outside the district. Only 2.0% were received as lobola payments, the rest (87.7%) were born in the herd. The herd transaction data in Table 5.9 suggest an even lower ratio of buying to reproduction, which is explained by the fact that the first figure includes start-up purchases while the transactions over the last two years cover established herds. The graphs in Figure 5.2 also show that rates of buying change substantially from year to year, and it appears that the percentage of cattle bought is low except after droughts.

Offtake versus mortality in the four study areas

Figure 5.3 shows that rates and absolute numbers of deaths, sales and total offtake were significantly different in the four study areas and that useful offtake overall tended to be higher than mortality. Mortality was highest in Upper Telle, and very variable with high extremes in Majuba Nek. Useful offtake in the form of sales was highest in Bensonvale, followed by Upper Telle. While the numbers slaughtered and sold were very similar in the latter two areas, the percentages of offtake were higher in Bensonvale because of the smaller average herd size. Majuba Nek stood out with extremely low offtake rates.

The fates of all cattle that left the herds (through death, offtake or other transactions) were combined from all progeny history interviews and herd transaction data to determine the relative frequency of sales, slaughter and deaths due to different causes. The data are summarised for each study area in Table 5.10. Similar differences between study areas to those in Figure 5.3 emerge, although the data in Table 5.10 go back further in time, which may account for some of the differences. In Tugela and Bensonvale, useful offtake in the form of slaughter and sales substantially exceeded mortality, while more deaths than offtake were recorded in Upper Telle and Majuba Nek. Overall, offtake slightly exceeded deaths plus unproductive losses such as theft. It should be noted here that cattle which are going to die, especially from drought and injuries, are usually slaughtered and eaten (Gandar 1982).

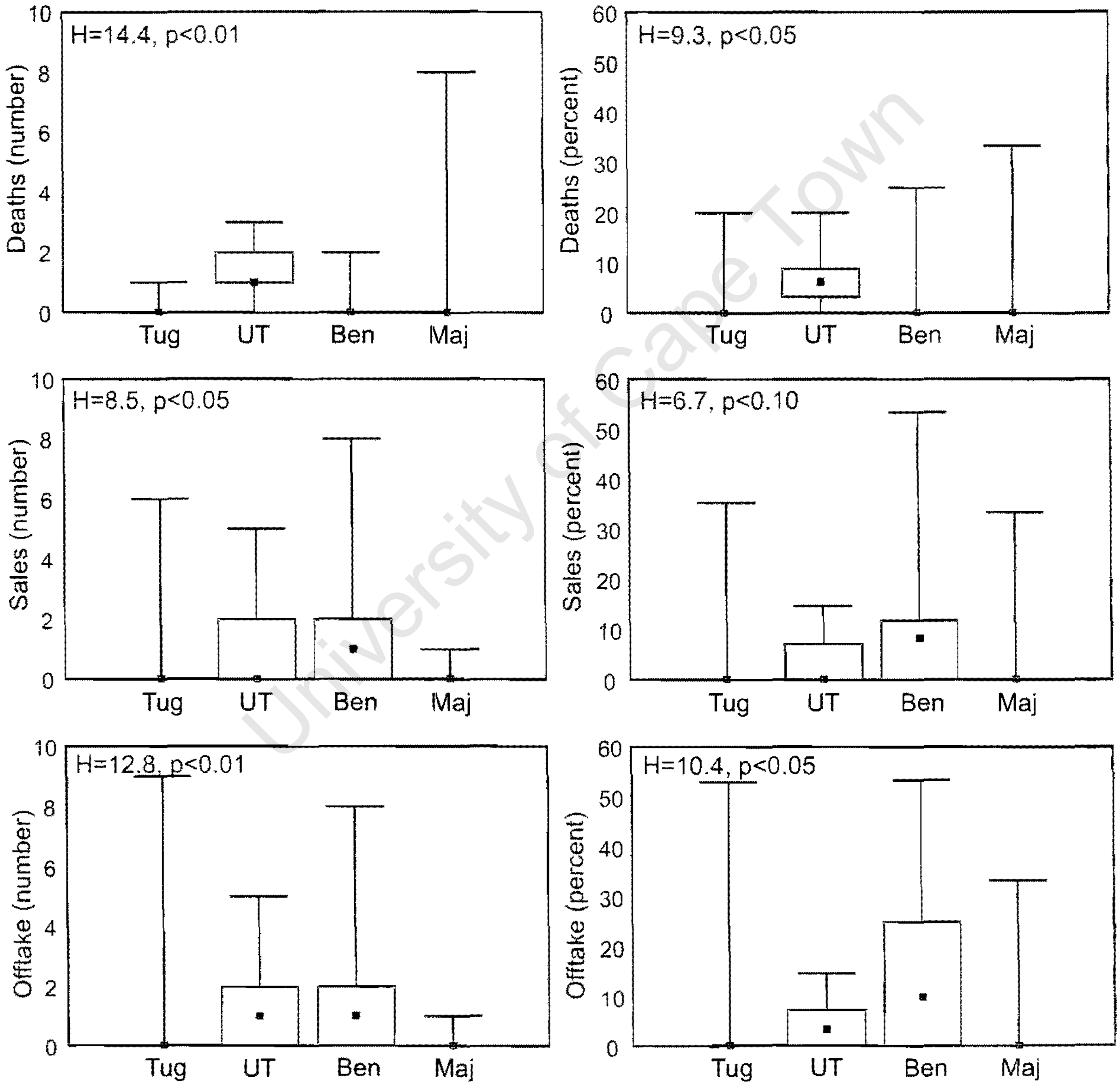

Figure 5.3. Mortality, sales and offtake (sales plus slaughter) from cattle herds in the four study areas, derived from herd transaction data (N=55). Graphs show median, quartiles and range of percent and total number per herd and significance levels from Kruskal-Wallis ANOVAs.

The high percentage of deaths due to drought and injuries in Upper Telle is noteworthy, as are the high percentage of deaths and low percentage of sales in Majuba Nek. Most of the injuries reported in Upper Telle were due to cattle falling and breaking their legs when they looked for grass, especially when they were very hungry and tried to negotiate steep sandstone boulders in their search for food. Injuries where cattle fell into dongas in search of food were also reported. The low frequency of sales in Majuba Nek was largely due to the high mortality rate and the small number of cattle owned by the average owner (average herd size in Majuba Nek was 7 compared to between 12 and 15 in other areas, which left few cattle to dispose of). Death due to disease was particularly prevalent in Majuba Nek. Unfortunately, no cause was given for many of the deaths reported in that area. Whether a proportion of the slaughterings reported in Majuba Nek (and elsewhere) was a last resort to make use of dying cattle is uncertain.

Table 5.10. The fates of 180 cattle that left the herds (through death, offtake or other transactions such as exchanges and lobola) in the four study areas, expressed as percentages.

	Tugela n = 45	**Upper Telle** n = 56	**Bensonvale** n = 42	**Majuba Nek** n = 37	**Total** n = 180
Drought / starvation	7	18	2	5	9
Disease	9	7	5	24	11
Injury	4	27	5	8	12
Pregnancy/ Birth related	7	2	5	3	4
Death, unspecified	0	4	2	27	7
Total deaths	**27**	**57**	**19**	**68**	**43**
Stolen or lost	**7**	**2**	**0**	**5**	**3**
Slaughtered	13	7	5	13	9
Sold	51	32	74	13	43
Other transactions	2	2	2	0	2
Total 'useful' offtake	**67**	**41**	**81**	**27**	**54**

Effect of herd size and inputs on offtake

The small size of individual herds is widely held to limit output and offtake rates in communal grazing systems. Bembridge (1984) found that 90% of respondents cited insufficient cattle as the main reason for not selling, and Colvin (1984, cited in Tapson and

Rose 1984) found that people selling cattle in KwaZulu stockyards owned between 28 and 36 cattle, a far greater number than that owned by the majority of Herschel farmers. Groenewald (1985, cited in Tapson 1990) found that in Bophutatswana, people with fewer than 20 head rarely sold cattle.

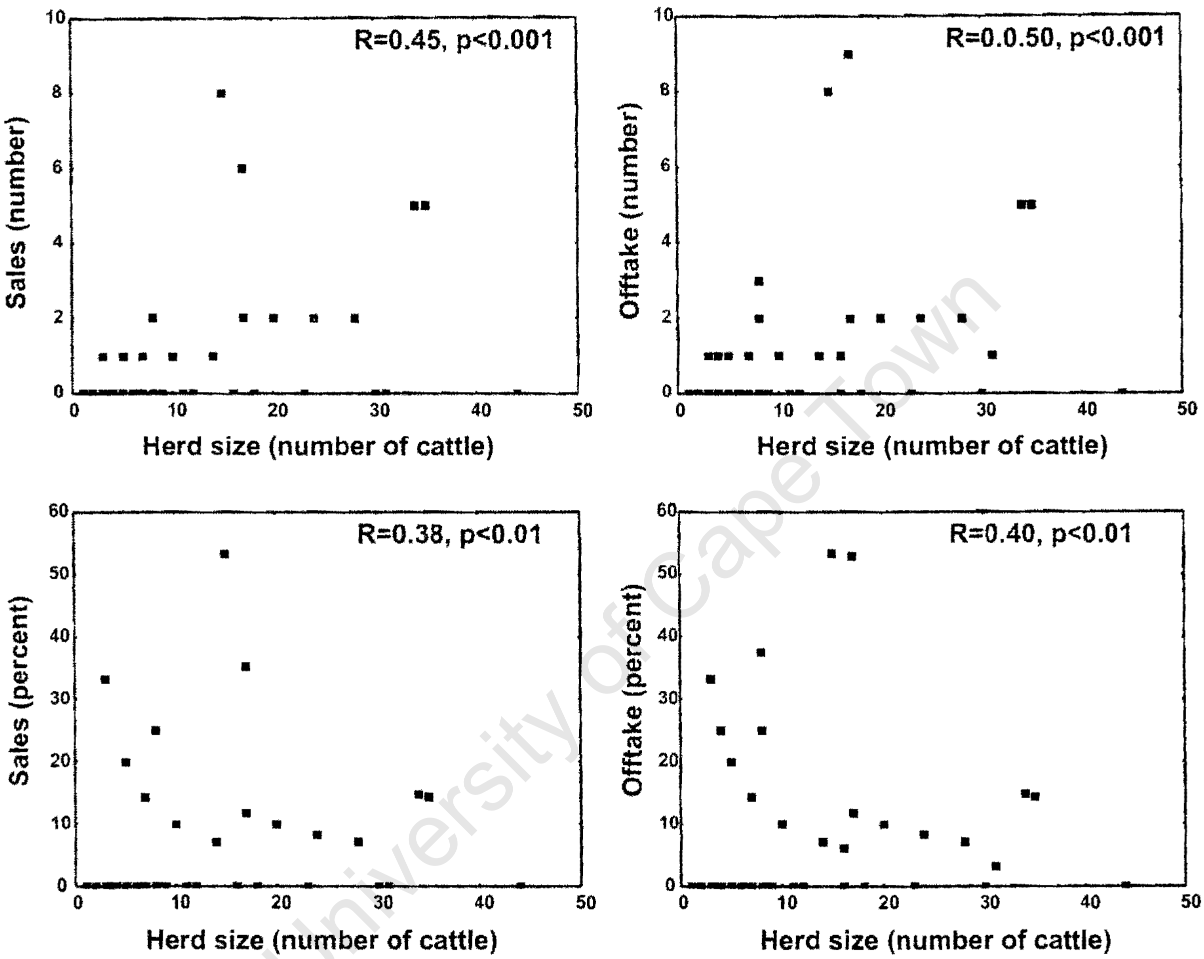

Figure 5.4. Number and percentage of sales and total offtake (sales plus slaughter) in cattle herds of different sizes. Data from the four study areas are combined, and significance levels from Spearman rank order correlations are shown in each graph (N=55).

Spearman rank order correlation analyses performed on herd transaction data showed that numbers as well as rates of both sales and total offtake (slaughter plus sale) increased significantly with herd size (Figure 5.4). Owners of bigger herds thus not only sold greater numbers of cattle, but also a bigger proportion of their herd. The high percentages of sales and offtake from small herds usually represented a single animal. From the graphs showing the number of sales and offtake against herd size, it appears that there was a threshold herd size of about 15 cattle, above which people were prepared to sell more readily, and more than one animal. Rates and numbers of slaughter showed no such correlation with herd size. Since most slaughter was done for feasts and rituals, this was likely to be driven by demand for, rather than availability of, cattle.

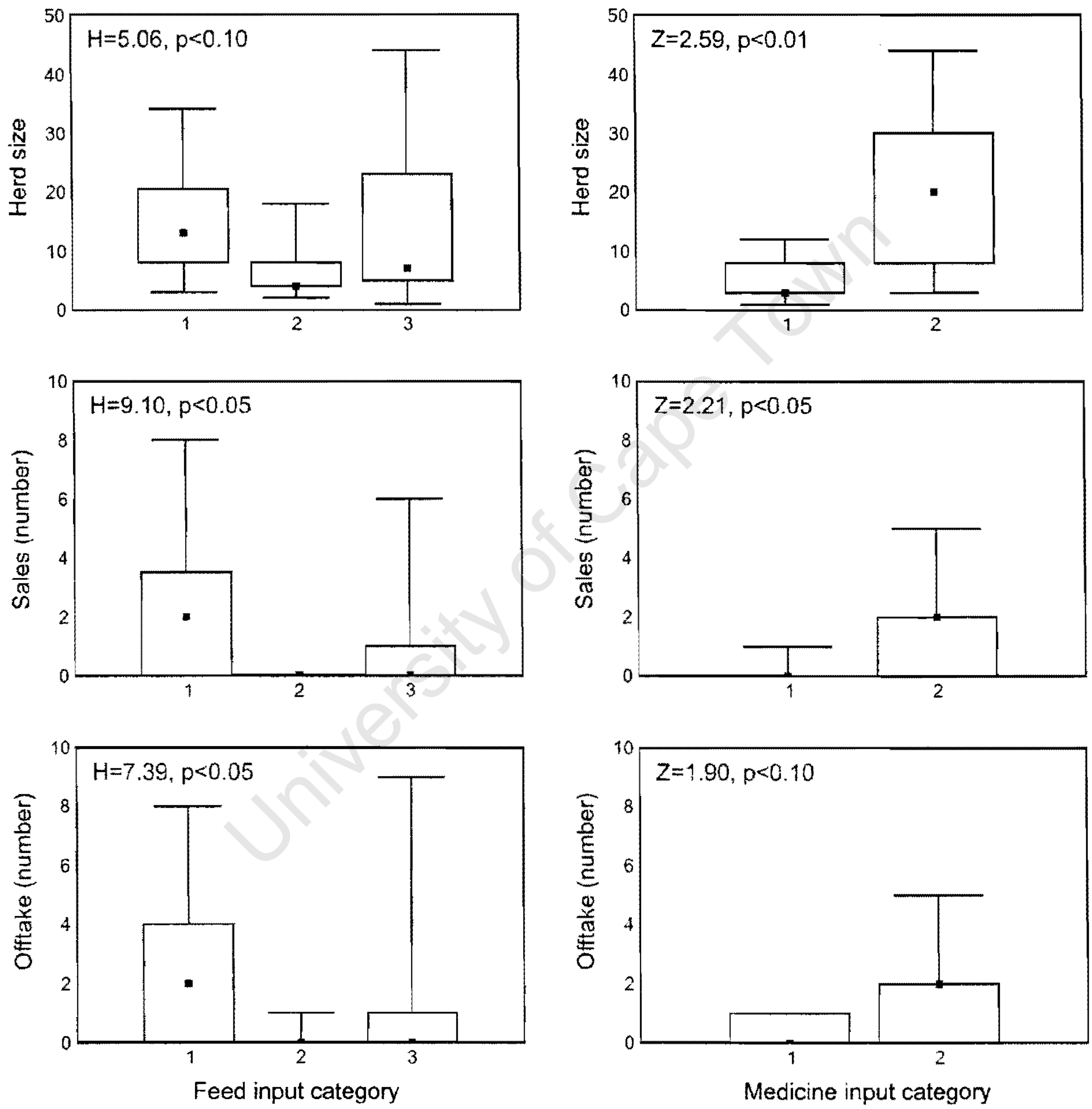

Figure 5.5. Herd size, sales and offtake (sales plus slaughter) in cattle herds with different levels of inputs of feed and veterinary medicines. Feed input categories are 1) grazing only, 2) grazing plus stover and 3) grazing plus bought or cultivated feed with or without stover (N=40). Veterinary medicine categories are 1) none or traditional remedies only and 2) bought medicines in most or all years (N=17). Graphs show medians, quartiles and range.

To investigate whether farmers who made a greater investment in feed inputs sold more cattle, feed input was divided into three classes: 1) grazing only, 2) grazing plus maize or sorghum stover and 3) grazing plus purchased or cultivated feed with or without the addition of stover. The number and percentage of sales and total offtake differed with feed input class, and appeared to be to some degree a reflection of herd size (Figure 5.5). The percentages of offtake and sales are not shown in this figure, but had the same relationship to feed input category. The number and percentage of cattle slaughtered did not differ with feed input. Herd size was largest in the "grazing only" category and smallest in the "grazing plus stover" category, although there was considerable variation, and some of the largest herds were provided with additional feed. The "grazing only" category included farmers who keep their herds at stock posts where grazing is sufficient, and thus the feed category is not necessarily correlated with the quantity and quality of nutrition available to cattle. Offtake and sales were also highest in the "grazing only" category and lowest in the "grazing plus stover" category. This suggests that additional feed inputs were not necessarily aimed at increasing commercial production. Owners of smaller herds bought feed to increase or maintain the size of their herds, and many claimed that providing feed was not an option but a necessity to keep animals alive.

Farmers who bought medicines had bigger herds, and the number of sales and total offtake was higher from herds whose owners had invested in veterinary medicines (Figure 5.5). No significant relationships were found between medicine input and the percentage of sales and offtake, nor did slaughter show any differences with medicine input. The prevalence of diseases, the higher susceptibility of nutritionally stressed animals to disease and the abandonment of government veterinary services combine to make diseases an important threat to livestock production.

Milk production

No data on milk yields were obtained in this study. Few of the cattle owners interviewed were actually milking at the time of the study, and the amounts produced were not quantified. Bembridge (1984) recorded a daily yield of 1.7 litres per cow and notes that this figure is similar to other observations in Transkei and other communal systems. Most people in Herschel who milked said that yields were low and intermittent, and milk was given mainly to babies and small children. Some cattle owners said they did not milk their cows at all as they barely produced enough milk to feed their calves. Only two people interviewed in this survey (both wealthy shop owners) sold milk. The low level of household milk production was due partly to the nutritional state of the cows (which determines fertility and hence calving, as well as the amount of milk produced), but also the number of cows owned by a household. Only 13% of the cattle owners interviewed had seven cows or more, the minimum number required to maintain two cows in milk annually (Tapson and Rose 1984).

5.3.5 Sheep production

Flock composition

Flock composition by age and sex was difficult to establish, especially for large flocks. Farmers tended to keep as many mature sheep as possible for shearing, but would often sell considerable numbers of sheep, especially castrated males and old ewes, after shearing. This, and the fact that lambs grow fast (male lambs are classified as wethers after castration and females as ewes when they have reached maturity after about a year), led to different estimates of flock composition at different times of year. Among the nine flocks for which the number of ewes was given, ewes made up between 50 and 100% of the flock, with a median of 69%. Smaller flocks tended to have higher percentages of ewes.

Flock dynamics and transactions

Lambing, buying, mortality and offtake rates were calculated for each of 26 flock-years (except for lambing as a percentage of ewes in the flock, which was only available for 11 flock-years), and are presented in Table 5.11. The median size of flocks increased by nearly 16% per year over the 1997/98 period although as with cattle data, it was not possible to cross-check these data against stock census figures, which were unavailable after 1997. Reproductive rates were higher and mortality rates lower in Herschel than in the other Ciskei and Transkei areas studied (Steyn 1982, Bembridge 1984), possibly as a result of better management practices in Herschel. As with cattle, the mean values of offtake, purchases and mortality are inflated by a few flocks with particularly high values, and the median gives a better indication of the average situation. No significant differences in flock dynamics were found between the four study areas.

Purchases of sheep contributed very little to the increase in flock size in 1998 and 1999 (Table 5.11). Almost all sheep were born in farmers' own flocks. Reproductive rates (lambs per ewe) were high overall with a median of 100%. There was no statistically significant effect of feed and veterinary inputs of reproduction and mortality. Ewes which received additional feed (bought and/or cultivated) seemed to have higher reproductive rates than ewes that only grazed (p=0.072, N=11), but the small sample of flocks which grazed only and for which reproductive rates could be calculated (N=2) makes this rather speculative.

Table 5.11. Rates of gains and losses to sheep flocks (%, mean, median and 25% and 75% percentiles), averaged for all flocks investigated in the four study areas in the Herschel district.

	N	Mean	Median	25%	75%
Annual reproductive rate (per ewe)	11	83.8	100	55.5	100
Flock crude reproductive rate	24	42.2	40.6	27.6	52.8
Buying	24	4.8	0	0	0
Lamb mortality	24	18.1	0	0	34.3
Adult mortality	24	5.1	0	0	4.8
Total flock mortality	24	9.0	6.9	0	14.9
Slaughter	21	7.8	2.9	0	7.4
Sales	21	10.7	0	0	25.0
Useful offtake (sale and slaughter)	24	18.1	14.5	2.6	29.5
Change in flock size over one year	24	117.9	115.6	94.7	131.5

Offtake rates were twice as high as mortality (Table 5.11), with sales being much more variable than slaughter. Almost all of the sales occurred within the district. Significant positive relationships were found between flock size and the numbers of sheep sold, slaughtered and total offtake (Figure 5.6). Rates of slaughter and total offtake were not correlated with flock size, while the percentage of sales was significantly correlated at the 10% level (p=0.064, N=21).

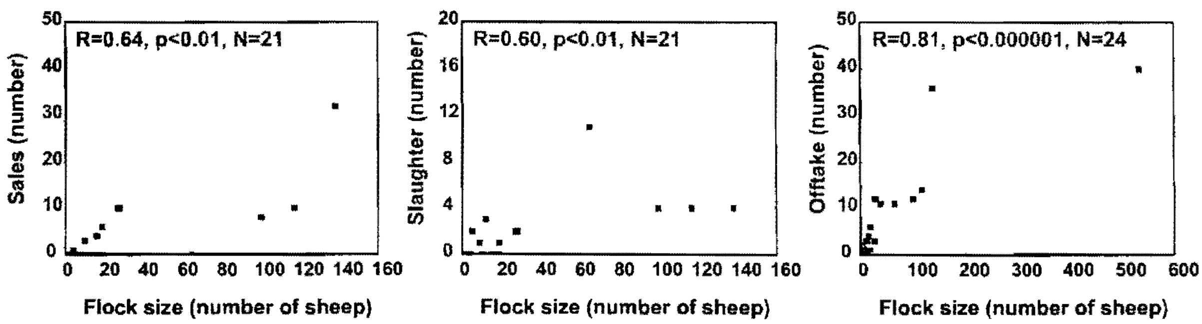

Figure 5.6. Number of sales, slaughter and total offtake (sales plus slaughter) in sheep flocks of different sizes. Data from the four study areas are combined, and significance levels from Spearman rank order correlations are shown in each graph.

Mann-Whitney U tests showed that farmers who provided additional feed had bigger flocks and sold greater numbers of sheep per year than farmers whose sheep relied on grazing alone (Table 5.12). Since maize and sorghum stover was not considered to be suitable for sheep, only two classes of feed input (grazing only and grazing plus bought and/or cultivated feed) were used. Similarly, farmers who provided veterinary medicines had bigger flocks, and only owners of very small flocks did not provide any medicines. The number of sales and total offtake are also higher from flocks of owners who provide veterinary medicines (Table 5.12). The picture that emerged was one of commercially-oriented farmers who owned large flocks, invested in feed and in medicines, and sold and slaughtered sheep regularly, in addition to making money from wool sales.

Table 5.12. Differences in sheep flock size, sales and total offtake (sales plus slaughter) between flocks receiving different feed inputs (grazing only vs. cultivated and/or purchased additional feed) and inputs of veterinary medicines (no medicines provided vs. medicines provided when needed or every year). Test statistics are from Mann-Whitney U tests.

	Feed			**Veterinary medicines**		
	Z	**p**	**N**	**Z**	**p**	**N**
Flock size (number)	2.74	<0.01	24	3.32	<0.001	22
Sales (number)	2.01	<0.05	21	1.76	<0.10	19
Total offtake (number)	2.71	<0.01	24	1.79	<0.10	22

Wool production

As in other parts of Transkei and Ciskei (Steyn 1982; Bembridge 1984), almost all of the sheep in Herschel are woolled sheep of the Merino or Döhne Merino types. Some of the bigger wool producers in Herschel invested in Döhne Merino rams to improve their flock, and many Herschel farmers regularly purchased sheep from commercial farmers. As commercial farmers usually sell surplus sheep (which may include inferior animals), and some sheep in Herschel are not pure Merino, the genetic potential of the Herschel flock to produce wool may be somewhat inferior to that found on commercial farms.

Present-day wool data were available for the years of 1994, 1995, 1996 and 1998. Over the four years, average annual wool production in Herschel was 53.7 $\pm$ 9.0 metric tonnes, with an average gross income of R 275 456 $\pm$ 50 740. Annual income fluctuates considerably as wool yield and wool price vary from year to year. The price paid for unwashed Herschel wool between 1994 and 1998 averaged at R 5.89 per kilogram. Income from wool production is sensitive to world markets which determine wool price.

Not all sheep in Herschel were shorn every year. Of the 50 000 sheep censused in 1994, 19 300 (or 40%) were shorn that year, and the fraction was similar in the other years for which stock census data and the number of sheep shorn were available. Sheep not shorn included lambs (which, according to reproductive rates calculated, would have made up about 30% of the flock at the time of shearing), sheep of unsuitable breeds, and sheep of farmers who don't shear. The latter two cases were rare: only one man interviewed said he had a few black-headed Persian sheep which weren't shorn, and one woman with a small flock said she didn't shear her sheep as the joining fee of her local shearing shed (a once-off payment of R 50) was too high for her.

Poor nutrition (as a result of high stocking rates and poor grazing) results in reductions in both wool quality and the mass of wool produced per sheep, leading to reduced income per sheep. In a grazing experiment, Donnelly et al (1983) found that fleece weight, fibre diameter and staple length decreased linearly with increasing stocking rate. The fact that the income from wool is proportional to the number of sheep in a communal system (if the overall stocking density is the same) is, however, an obvious incentive to keep more sheep, even though income per sheep (and per hectare) is compromised.

In Herschel, the average wool price per kilogram and wool production per sheep were each about half that attained by the average commercial farmer in the Eastern Cape (Table 5.13), despite high standards of shearing and sorting wool, and selling through the same brokers as commercial farmers. As a result, the income per sheep was only a quarter of that normally achieved in the commercial farming sector in the Eastern Cape.

Table 5.13. Comparing wool price, production and income per sheep in the Herschel district and the commercial farming sector in the Eastern Cape Province (Source: unpublished EDA report, 1994).

	Herschel	Norm for E. Cape
Greasy price of wool (R/kg)	6.70	12.00
Wool per sheep (kg)	2.3	4.5
Income per sheep (R)	13	40 - 50
Sheep per hectare	0.3	1.0
Wool production (kg/ha)	0.34	4.5

Wool production and income per hectare were also considerably lower in Herschel because of the lower quality and quantity of wool produced, the lower sheep densities (while commercial wool producers stock their land mostly with sheep, less than 20% of the total LSU in Herschel are sheep), as well as the fact that not all sheep were shorn annually. Dividing the average annual production in the 1990s (53 000 kg) by the available grazing area of the district (155 000 ha) gives a figure of 0.34 kg/ha, which is roughly a tenth of the annual wool production per hectare on commercial farms.

The wool produced in Herschel was slightly thinner than the wool produced on commercial farms in the region and was classified as fine wool (unpublished EDA report, 1994). While fine wool of high quality is desirable, wool value decreases if it is unevenly thin (as nutrition declines in the dry season fibre diameter decreases, resulting in an uneven and often breakable fibre). The amount of wool produced per sheep in Herschel was similar to the average values of 1.8 kg per sheep in Transkei (Bembridge 1984) and 2.6 kg per sheep in Ciskei (Steyn 1982), but the income made from wool in the latter two areas was very low, mainly as a result of poor marketing opportunities. Steyn (1982) concluded that a marketing scheme was urgently needed in the Amatola Basin where most wool was sold through local traders at half the official wool price.

5.3.6 Goat production

Flock composition and dynamics

As with sheep, flock composition by age and sex was difficult to determine for goats. Ewes made up between 34 and 100% of goat flocks with a median of 73% (N=17). Higher percentages of ewes were found in very small flocks.

Rates of reproduction, mortalities, offtake and buying are shown in Table 5.14. Kidding rates were high as goats often had twins. The high reproductive rates were offset by high rates of kid mortality. Some farmers also reported frequent abortions. The cause of these (e.g. diseases) was not known to farmers. Adult mortality was relatively low, but overall flock mortality exceeded useful offtake. Reproductive rates of goats in Herschel were found to be higher, and flock mortality lower, than in the Ciskei and Transkei studies (Steyn 1982, Bembridge 1984). Kid mortality was much higher than adult mortality. Kid mortality was also higher than lamb mortality, which contrasts with the general perception that goats are hardy and survive well.

Table 5.14. Rates of gains and losses to goat flocks in the Herschel district (%, median and 25% and 75% percentiles), for all flocks investigated in the four study areas.

	N	Mean	Median	25%	75%
Annual reproductive rate (per ewe)	17	106.1	100.0	90.0	150.0
Flock crude reproductive rate	26	60.0	50.0	33.3	75.0
Buying	25	0.3	0	0	0
Kid mortality	26	27.9	11.1	0.0	47.4
Adult mortality	27	4.0	0	0	5.3
Total flock mortality	26	13.5	8.4	0	20.0
Slaughter	28	5.9	0	0	10.5
Sales	28	2.2	0	0	0
Useful offtake (sale and slaughter)	28	8.8	0	0	13.8
Change in flock size over one year	27	124.8	122.9	98.5	150.0

Slaughter (most of it traditional) accounted for more of the offtake than sales. Several people reported slaughtering up to 10 goats for rituals, some of them associated with curing illnesses. In some years, therefore, flocks could be drastically reduced. The same could happen due to particularly high kid mortality or outbreaks of diseases. However, recovery through reproduction was usually fast, and the size of goat flocks increased by almost 23% annually. Purchases of goats by farmers were very rare, and in all cases farmers either bought a few goats to start a flock, or boer goats to improve the breed of their flock.

Numbers of sales, slaughter and total offtake were highly significantly correlated with flock size (Figure 5.7), i.e. offtake including slaughter was higher from larger flocks. The relationship between rates of offtake and flock size was similar, and is not shown in Figure 5.7 (% sales: $R=0.62$, $p<0.001$, $N=26$; % slaughter: $R=0.61$, $p<0.001$, $N=26$; % total offtake: $R=0.66$, $p<0.001$, $N=28$). The stronger relationship of offtake with flock size in goats compared to sheep could probably be attributed to the high value of wool, which compelled sheep owners to keep as many sheep as possible. By contrast, the value of goats is mainly in the form of offtake, especially in larger flocks. Of the offtake from goat flocks, slaughter far exceeded the relatively rare sales, unlike the situation found in sheep flocks. This illustrates the importance of keeping goats for ritual slaughter. However, sales, slaughter and total offtake were zero in more than half the flock-years (Table 5.14).

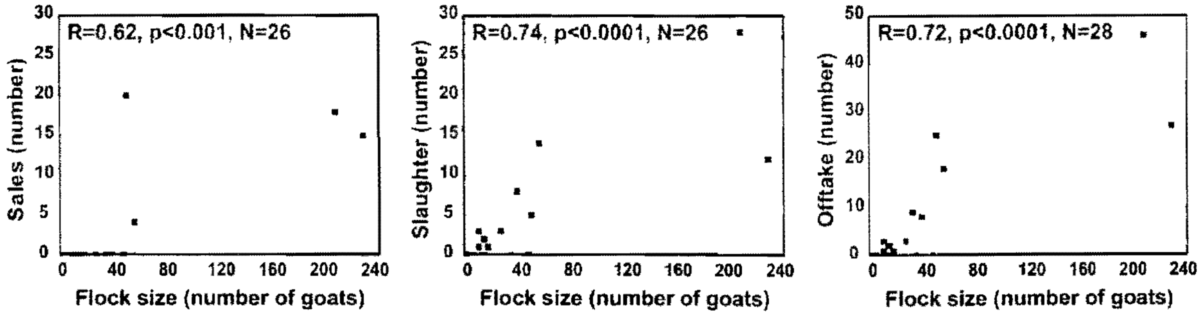

Figure 5.7. Number of sales, slaughter and total offtake (sales plus slaughter) in goat flocks of different sizes. Data from the four study areas are combined, and significance levels from Spearman rank order correlations are shown in each graph.

Given the high reproductive rate of goats and the fact that sales emerged as the second most important objective of keeping goats (section 5.3.1), the low rates of goat sales are of interest. In only six of 28 flock-years were any goats sold. Sales of goats are usually local, to people who do not have goats who need them for ritual slaughter, and it seems that the limited marketing opportunities obstruct what could be an important avenue of income generation to farmers. Since goats are almost exclusively bought for ritual slaughter, and Herschel is surrounded by white commercial farming districts and far from large urban centres, marketing goats is likely to remain a challenge.

No differences in goat flock dynamics were detected between the four study areas or with levels of feed input. From interviews on feed inputs, it became clear that few farmers make substantial investments in feeding goats, and that goats get less feed than cattle and sheep. The number of sales, slaughter and total offtake, as well as the percentage of sales and offtake, were all higher in flocks whose owners provided veterinary medicines (Mann-Whitney U test, $p<0.10$, $N=13$ in all cases). No sales and extremely few slaughters were made from flocks that did not receive any medicines.

Mohair and milk production

Of 26 people interviewed about the outputs of goat production, only three milked their goats, and three produced mohair. Of these six respondents, only two farmers respectively accredited milk and mohair production with any importance (Table 5.5). This is echoed by the socio-economic survey by Loxton Venn and Associates (1990), who found income from mohair production to be "very low" with households earning up to R100 a year from the sale of mohair, and "only a small percentage of households" to have any milking goats. With the exception of one farmer in Upper Telle who was a major wool producer in Herschel (with over 500 sheep and 150 goats, 100 of which are Angora), the few farmers who had Angora goats had small flocks and produced little mohair. No data on the amount of mohair produced or the income generated was available.

5.4 Discussion

5.4.1 Ownership patterns

Average livestock holdings in Herschel are highly variable and skewed, with most livestock owners having small herds and flocks and a few people having very large numbers of animals. A similar situation exists in other districts of the Eastern Cape (Steyn 1982, Bembridge 1984, Ainslie 2002, Kepe 2002, Ntsebeza 2002, Ntshona and Turner 2002). The percentage of the population without livestock was not established in this study, but in other recent studies in the Eastern Cape (e.g. Beinart 1992 and references therein, Ainslie 2002) it was found to be in the region of 50% and higher. This, together with the fact that livestock owners (or, at least decision makers) are men, means that development and policy which targets mainly emerging commercial farmers will represent only a small, and already relatively well-off, subset of the population. Any policies aimed at rural reform, from agricultural to land tenure policy, thus need to take into account that the needs and constraints of the majority of the population are not represented by the "typical" livestock farmer. However, the benefits from livestock are shared by people who have no livestock of their own through a variety of mechanisms, such as kin livestock sharing, livestock loaning, ploughing companies and sharing the meat of slaughtered animals with neighbours (Kepe 2002). The economic role of livestock thus extends beyond the individual owner and his or her household.

The large size of goat and particularly sheep flocks in Herschel stands out when compared to other communal areas studied in the Eastern Cape and KwaZulu (Steyn 1982, Bembridge 1984, Tapson 1990, Ntshona and Turner 2002), which is probably a factor that has resulted in so little attention having been paid to small stock in many of the other studies. The importance of large remote areas away from the crowded villages for keeping large flocks of small stock is evident when comparing ownership patterns in the small areas of Majuba Nek and Bensonvale with those in Tugela and Upper Telle, where there are several stock posts in the mountains. The need to pay a herder makes this a viable option only to relatively wealthy individuals, who effectively have exclusive user access to these grazing areas.

In terms of understanding people's objectives and management strategies in livestock production, it is important to recognize that the small size of most people's herds poses a considerable constraint on the available options. In particular, the small average size of cattle herds limits offtake in the form of sales and slaughter, and this has been reported for many communal areas in South Africa (Steyn 1982, Bembridge 1984, Tapson and Rose 1984, Tapson 1990, Ainslie 2002, Ntsebeza 2002, Ntshona and Turner 2002). Several authors (e.g. Bembridge 1984, Tapson 1990, Ainslie 2002) suggest that there is a threshold herd size above which people are prepared to start selling animals, although the estimate of this necessary minimum varies between areas and with the primary uses of cattle. Interview information and herd size and offtake data in all the studies cited above suggest that few people have managed to accumulate herds large enough to consider regular offtake. In Herschel, the threshold herd size for cattle, above which people are willing to make more than the occasional, need-driven sale of an old cow or ox, appears to be fifteen head (Figure 5.4). The positive correlations of sales and total offtake with herd and flock size for cattle, sheep and goats in this study (Figures 5.4, 5.6 and 5.7) support this conclusion that people would be willing to sell or slaughter more animals if their herds were large enough.

This makes the question of how livestock ownership patterns will change over the next decades particularly interesting. With increasing human population densities in the rural areas, the number of herds in an area may increase with a parallel decrease in average herd size. This would result in a situation where offtake remains low or even decreases. On the other hand, if the need for keeping cattle as a form of savings, for milk, draught power and ceremonial slaughter declines, the number of people keeping cattle may decrease. There is evidence (Ainslie 2002, Kepe 2002, Ntsebeza 2002, Ntshona and Turner 2002) that the younger generation is much less interested in keeping livestock. This, and factors such as stock theft, increasing production costs, a shortage of herding labour and a lack of veterinary services, which make livestock keeping increasingly expensive and difficult, may result in a future trend of fewer livestock owners and an increasing concentration of livestock among fewer owners. If this is the case, there may in time be an increase in offtake rates, and perhaps greater investment in livestock farming. However, given the current situation of increasing unemployment, the need for livestock will undoubtedly continue in the foreseeable future.

5.4.2 Reasons for keeping livestock

It became clear from interview information and production data that cattle, sheep and goats fulfill different and complementary objectives, the achievement of which cannot simply be measured in terms of livestock numbers. Cattle are primarily kept as a form of savings or security, and other utility values such as milk and ploughing are rated as more important than sales or slaughter for ceremonial or ritual purposes. When one considers that there is one bank in the entire district, the importance of cattle as a store of wealth is perhaps not too surprising. Thus the benefits from cattle are mainly derived from the live animal and occasional, need-driven offtake. This, together with the small average herd size, motivates most cattle owners to try and increase the number of cattle they own.

It is interesting to note that milk and ploughing, traditionally very important reasons for keeping cattle, are becoming less important in Herschel. The same was reported for the Peddie District of the former Ciskei (Ainslie 2002), where high population densities have resulted in small herds, reduced forage availability and low levels of secondary production. Also, greater access to employment and banks has reduced the importance of cattle for storing wealth and producing food. A person's access to other sources of food, income and security has also been shown to influence management decisions such as the number and type of animals kept, as well as willingness to sell livestock. Tapson and Rose (1984), for instance, found that communal farmers in KwaZulu who grew sugar cane for cash kept smaller herds of cattle and were more likely to buy cattle for ceremonial use when the need arose.

In contrast to cattle, benefits from small stock are mainly derived from offtake, in the form of sales, slaughter and wool. Sheep particularly are kept mainly for commercial purposes, and the inputs invested in sheep production reflect this. In a system where stocking rates can be controlled, the ideal stocking rate for these objectives would be below the ecological maximum, where productive offtake tends to zero. However, in an open access system without regulation of stocking rates, the offtake of wool in particular is proportional to herd size, and this motivates people to keep large flocks of sheep. Most people who own small stock see them as an opportunity to make a regular income, but a lack of marketing opportunities for live animals remains a big obstacle.

Overall, people interviewed in Herschel displayed a greater willingness to sell animals and animal products than has been previously reported for communal areas in South Africa (e.g. Bembridge 1984, Tapson 1990). According to the people interviewed, this was constrained by small herd size, low reproductive rates and poor marketing opportunities. More recent studies (Ainslie 2002, Ntshona and Turner 2002) also show that people who have large enough herds are often inclined to sell cattle, but that unfavourable marketing systems prevent many people from making regular sales. It is thus important to assess the success of livestock farmers in terms of factors such as reproductive rates, milk and wool yields (per hectare, not per animal), which allow people to maintain a working capital plus some food production and income.

5.4.3 Inputs

Farmers in Herschel made more frequent and substantial inputs of feed and veterinary medicines than is generally believed (e.g. Behnke and Abel 1996) and was reported in the 1980s (Steyn 1982, Tapson and Rose 1984, Bembridge 1984 and Tapson 1990). More recent work in the Eastern Cape (Ainslie 2002, Ntshona and Turner 2002), however, shows that feed and medicine inputs on a significant scale are not uncommon in the Eastern Cape in present times. Buying medicines in particular has become necessary since the phasing out of government veterinary services in most districts (Ainslie 2002). The commonly made assumption that production costs in communal rangeland systems are negligible – and hence that high stocking rates which compromise livestock productivity make economic sense in these systems – thus needs to be re-examined in many South African communal rangelands.

The levels and types of inputs, and the reasons for making them, differ between livestock species. Livestock owners who buy veterinary medicines for their cattle, sheep or goats tend to have larger herds and make higher levels of useful offtake (Figure 5.5, Table 5.12). The relationship between feed inputs, herd size and offtake is less clear. People provide feed for cattle with the primary aim of keeping them alive and in the hope of increasing the size of their often very small herds. No relationship between feed inputs for cattle and sales and offtake was observed, and offtake from cattle herds was primarily correlated with herd size (Figures 5.4 and 5.5). Some of the biggest herds with the highest offtake relied on grazing alone, though often at stockposts at the cost of hiring herding labour. In contrast, there is a trend for sheep owners with large flocks, who sell more animals, to buy more feed and medicines and to cultivate feed where possible. Whereas the costs of feeding cattle are not offset by income from sales but presumably by the benefits derived from owning and using the animals, in sheep production there is a definite aim to make a profit from sales of wool as well as live animals. With goats, this relationship was more obscure, mainly because goats are not seen to require such inputs in order to be productive. Goat flocks would generally increase without inputs, and the increase in flock size in many cases exceeded the opportunities for selling goats.

From the above, it is evident that there is a number of livestock owners who invest cash in profitable livestock production. Some of these people are primarily farmers and invest much time, effort, planning and capital in livestock farming. Others are local businessman with other sources of income, which enable them to invest in livestock. There is, however, no dichotomy between small, subsistence and large, commercial livestock owners. Many people own intermediate numbers of livestock, and many owners of small herds aspire to the more commercial style of production and are often hindered by a lack of capital. The importance of having money to be able to have large herds was also shown by Ntshona and Turner (2002) in the Maluti district, where people with higher levels of income (remittances, pensions, business) had larger herds.

The stock permit, progeny history and herd dynamics data (Figure 5.2, Table 5.9 and following pages) all suggests that buying livestock is relatively rare except after droughts, when many livestock, particularly sheep and cattle, are imported into the district. Such purchases may be made by farmers to replace drought losses in their herds and flocks, or by individuals and butcheries who would have bought these animals locally but found other stock owners reluctant to sell after the drought. This is substantiated by commercial farmers in the Lady Grey and Barkly East districts (Dick Isted and Llewellyn Gush, pers. comm.) who reported that Herschel farmers lost many livestock during the droughts of the early 1980s and 1990s, and that replacements of drought losses were made by buying stock from commercial farmers while reproductive rates were still depressed after the drought. Some commercial farmers also regularly sell their surplus sheep (mostly castrated males) to the bigger sheep farmers in Herschel who buy them for shearing. How much these transactions contribute annually to the total sheep in Herschel could not be established.

Two questions arise from the realization that people in Herschel invest in feed, veterinary inputs and buying replacement stock on what appears to be a fairly regular basis. The first is whether, given the money spent on these inputs, farmer are deriving sufficient cash income or other benefits to break even or even profit. In the case of sheep, the income from wool seems to exceed the additional production costs, although this is sensitive to international wool prices. Goats need few inputs and reproduce well, and production costs are thus unlikely to exceed the benefits gained from goats. Marketing of goats is the biggest obstacle to making an income from goat production. Cattle are becoming more expensive to keep, and there were cattle owners who said that they had reduced their cattle numbers so that they could afford to feed them. The different costs and benefits of keeping cattle, in years of high and low rainfall, need to be more carefully explored to determine whether owners of small herds in particular are operating at a loss. In the face of increased input costs, some reduction in stocking rate (however difficult to achieve in practice) would probably be economically advisable to achieve increased production to offset the rising production costs.

The second question concerns the ecological costs of maintaining high stock numbers during and after droughts by buying feed and replacement stock. Maintaining high animal numbers through drought periods may aggravate degradation as high grazing pressure is maintained during a time when plants are under stress. This can cause plant mortality and accelerated soil loss. The non-equilibrium argument that livestock numbers in semi-arid rangelands are regularly reduced by drought and thus rarely reach levels where they have an impact on the vegetation and soils (Ellis and Swift 1988, Behnke and Scoones 1993, Dikeni et al. 1996) can therefore not be applied to areas such as the Herschel district.

5.4.4 Production and herd dynamics

The data presented in this chapter show that rates of reproduction, mortality and offtake are low by commercial standards and similar to those reported in other studies of communal farming systems in South Africa. Comparison with these other studies (Steyn 1982, Bembridge 1984, Tapson 1990, Ainslie 2002, Ntsebeza 2002, Ntshona and Turner 2002) was complicated by the fact that all of these authors use mean values when presenting their data on herd size and production coefficients. It became clear from the Herschel data set that all the data, from herd size to rates of offtake, production and mortality, tend to be highly skewed by extreme cases, and the mean values are actually a poor measure of central tendency in that they are almost invariably much higher than the median. Ainslie (2002) points this out in some of his examples, but this is not discussed in any of the other studies, except that all mention the highly skewed nature of herd size which results in considerably exaggerated mean herd size estimates.

From the Herschel data, it is apparent that nutritional stress and diseases pose a major constraint on reproduction, survival (particularly of juvenile animals) and milk production, and hence the achievement of many of the stated objectives for keeping cattle, sheep and goats. This low productivity and the small average herd size result in low levels of benefits per household, which discourages people from further decreasing the number of animals owned by sales. This positive feedback cycle, which maintains the high stocking rates which caused the poor nutrition in the first place, is exacerbated by the fact that low reproductive rates and the relatively high risk of juvenile mortality make herd recovery slow and risky.

5.4.5 Differences between the four study areas

One of the aims of this chapter was to explore whether the differences in degradation levels in the four study areas translate into differences in livestock production. One would have expected a greater need for inputs, lower production and greater mortality in the more degraded areas of Majuba Nek and Tugela than in the less degraded areas of Upper Telle and Bensonvale. The data, however, show no obvious relationship between degradation and production. Degradation per se, however, is unlikely to give a direct prediction of production as this will still depend on the stocking density relative to the ecological carrying capacity (Jones and Sandland 1974, Wilson and MacLeod 1991, Behnke and Abel 1996). A degraded area stocked at its economic carrying capacity should have higher production coefficients than an area in good condition stocked at ecological carrying capacity. From the data presented here, it appears that stocking rates are at or near the ecological carrying capacity, as everybody is trying to maximise herd size. Table 4.5 in Chapter 4 shows that Tugela and Majuba Nek are becoming increasingly overstocked. This, and the data on inputs presented in this chapter, suggests that feed inputs and buying stock are allowing stocking rates to exceed the ecological carrying capacity in some areas, at least in dry years. This will be explored in more detail in Chapter 7.

Majuba Nek, the most severely degraded of the four study areas, has the highest levels of cattle mortality and low offtake (Table 5.10, Figure 5.3). The high human population density, small average herd size and the high and increasing stocking rates (see Table 4.5 in Chapter 4), with the fact that all cattle owners make feed inputs, suggests that nutrition from grazing is limiting in this area, but that people are trying hard to increase stock numbers. While Majuba Nek was stocked more or less at the recommended stocking rate in 1974, it was stocked at twice this density in 1997 (for more detail on how these recommended stocking rates were derived, see Chapter 7). By contrast, Bensonvale, which is also a small area with a high human population density, has relatively low levels of soil erosion and is generally described by people in Herschel as being in good condition. Stocking density in 1997 had decreased by about 25% from 1974, when the area was stocked at the recommended stocking rate. This area has the highest ratio of useful offtake to mortality of cattle (Table 5.10, Figure 5.3), and is also the only area studied where milk production was reported to be important and where several of the people interviewed were actually milking their cows at the time.

It is somewhat surprising that cattle mortality is high and offtake is low in Upper Telle, where human and livestock densities as well as erosion levels are the lowest of the four study areas. In contrast, livestock production in Tugela appears to be more successful (in terms of low mortality and high offtake) than in Upper Telle, despite high degradation levels and dense human population in Tugela. Clearly these relationships need to be better explored. It is possible that the harsh winters, more rugged terrain and sourveld character of the vegetation limit livestock production in Upper Telle, and that for this particular environment, the area is actually stocked at ecological carrying capacity.

5.4.6 Conclusions

This study of livestock production has left some questions unanswered which require further research over a larger area and over a longer time. Firstly, a more detailed study of the resource economics of the livestock production system would help to understand the costs and benefits currently experienced by stock owners in Herschel. This study would need to distinguish different types of livestock owners with respect to herd size, different levels of input and degree of commercialization, and would require a quantification of the different costs and benefits, including non-material ones. The data would have to be collected over a longer time to include the effects of rainfall variation, something that is lacking in this "snapshot" data set.

Secondly, the relationship between stocking rate, degradation and productivity needs to be explored more explicitly using a greater variety of study areas and, ideally, experiments. Stocking rate trials have been extensively used in agricultural research to test the relationship between veld condition, stocking rate and productivity (a good recent example is Fynn and O'Connor 2000), but a variety of logistical difficulties has thus far prevented such work in South African communal areas. In particular, the question why some areas are increasingly overstocked, while stocking rates in other areas stay stable or even decrease, begs to be answered. Do these changes reflect changing objectives and strategies on the part of the livestock owners, or environmental change resulting in changed carrying capacity? I tried to obtain some explanations from farmers in Herschel, but since most people perceived that livestock numbers everywhere had been declining (and cited small average herd size as evidence), it was not possible to get any satisfactory answers to this question.

For purposes of interpreting the livestock data over time, it is fair to assume that the actual numbers reflect the maximum possible and not some lower stocking rate aimed at maximizing offtake. What has emerged from the data gathered here, however, is that maximizing livestock numbers per se is not the primary objective of most stock owners. Instead, it is something people resort to in an open-access system where the achievement of the real production objectives is hindered by the absence of effective management structures, and small herd size in many cases. In fact, livestock owners displayed greater inclinations to use their livestock (small stock in particular) for commercial purposes than is commonly assumed. The success of the wool marketing scheme shows that commercial opportunities are readily embraced when they can be accessed by even small farmers at no, or low, cost. The fact that wool marketing does not require selling animals undoubtedly adds to the appeal of the wool marketing scheme. To what degree these maximum stocking rates are supported by inputs and resource use change will be explored in the next two chapters.

6. CHANGES IN RESOURCE USE AND PRODUCTIVITY

6.1 Introduction

This short chapter describes changes in resource use and agricultural productivity that have occurred in Herschel over the last century. It became clear in earlier chapters that stock numbers have remained the same while soil erosion has increased substantially, and that one of the ways in which this may have been achieved is through adapting resource use. There are various lines of evidence – interview information, the historical literature and unpublished reports – that livestock owners in Herschel have responded to decreased primary productivity by exploiting new food sources for their livestock, for example by using grazing areas differently, or providing extra feed. It is also possible that while livestock numbers have shown no decrease, the productivity of livestock may have declined.

This chapter relies on interview information, livestock records, unpublished reports from EDA (the NGO working in Herschel) and the historical literature to reconstruct the changes that have taken place. Much of this information is qualitative, and its sources cannot always be assumed to be objective. The aim of this chapter is to summarise and evaluate the evidence for these changes in resource use and productivity, and to discuss to what extent they are likely to be a response to declining primary productivity. Also considered in this discussion are factors other than changes in productivity which may have led to these changes.

6.2 Changes in resource use

6.2.1 Changes in the use of grazing areas

Grazing management in Herschel has undergone significant changes in the course of the 20th century, both in terms of the actual strategies adopted and the authorities in charge of it. Three distinct "phases" are recognised by livestock farmers in Herschel: before, during and after betterment planning. Overall, there has been a change from an annual cycle of resting and grazing different areas to year-round utilisation of all areas.

Until the late 1950s, grazing management was regulated by traditional authorities, primarily the chiefs. This was reported unanimously by all farmers, in all parts of the district, who were old enough to recall this. Stone beacons were used to demarcate areas which were not allowed to be grazed. The general pattern was that arable lands, areas where thatching grass grew, and some other parts of the lower lying areas were rested this way during the growing season (November/December until about May) while animals grazed mainly on the uplands. Animals were allowed to utilise the rested areas after the harvesting of crops and after the thatching grass was cut. Thus there was, in most areas, an annual movement between the uplands in summer and lowlands in winter. Some farmers reported that certain areas were rested for a whole year. The rationale behind resting grazing lands, whether for a season or a whole year, was primarily to have a forage reserve for the dry winter season in the form of tall grass and crop residues. The need to allow grasses to flower and set seed was also recognised by many informants.

Under betterment, grazing camps were fenced off with a four-camp system for each village (eight camps in bigger areas). Rotational grazing and rotational resting of one camp every four years for a whole year were strictly enforced with the aid of rangers who fined those who transgressed. Although there was rebellion against the system throughout the period it was enforced, grazing management took place according to plan at least during the 1960s.

The betterment system of grazing management slowly collapsed, and by the mid-1990s, even the most rudimentary attempts to control grazing management had faded out. There is a general feeling that people have become "ungovernable" since the shift in political authority following the 1994 elections, and that any attempts at natural resource management are hindered by a lack of effective and universally respected authorities and institutions. In some administrative areas, Tugela and Bensonvale among them, local committees still try to implement some form of rotational resting based on the old grazing camps to ensure a forage reserve for winter and to improve the condition of the grazing areas. The dilapidated state of fences, insufficient water points, lack of political authority and extreme shortage of grazing land have limited the success of initiatives such as these. Because rainfall was below average in most years during the 1990s, camps that were meant to be rested to provide a winter feed reserve were generally opened early. Overall, no case was found where grazing management had actually been carried out as planned.

Although changes in politics and management have precipitated a breakdown in grazing practices, it is generally agreed that grazing land and grass production are no longer sufficient, and this is the main reason why current initiatives are failing. Owners of large flocks of small stock in particular now keep their livestock in stock posts in the mountains year round despite harsh winter conditions, because there is not enough grass in the lowlands. Sheep are sometimes brought down to the lowlands when they lamb in winter, so that they can be fed with lucerne hay or fodder crops grown in their owner's field. People with small flocks who cannot afford to hire herders tend to keep their livestock near the village year round, and as a result, all areas are densely used throughout the year, instead of the annual cycle that allowed resting of highlands in winter and lowlands in summer.

This situation is exacerbated by the fact that over the years, grazing land has been encroached by arable land and residential areas. Bundy (1979) and Macmillan (1930) describe how in the late 19th and early 20th centuries, there was considerable conflict between livestock owners and people who wanted to expand croplands over the allocation of grazing and cropping areas. Under betterment, many croplands and residential plots were converted back to grazing land while other areas, which used to be grazing land, became the sites for the planned betterment villages. What the net gain or loss in grazing area was is not certain, although the analyses in Chapter 4 show that much of the abandoned arable lands that were converted to grazing were soon badly eroded. Over the last decades, much other arable land (i.e. the land still officially zoned as cropland after betterment) has been left fallow and is now used for grazing. Since both fallow and cultivated fields contribute to livestock feed (with either natural grazing or crop residues), expansion and abandonment of arable lands has less effect on livestock than the expansion of residential areas. The latter has been substantial in Herschel, particularly in the administrative areas close to Sterkspruit and in the more densely populated western half of the district.

It is thus evident that increasing human population, encroachment of residential areas on grazing land and the decreasing productivity of the grazing land have necessitated a much more continuous, less mobile, pattern of grazing. This in turn suggests that whereas past stocking densities may have been somewhere between the economic and ecological carrying capacities (*sensu* Jones and Sandland 1974), present-day stocking rates are likely to be at the ecological carrying capacity, or perhaps even maintained above this level by additional inputs. The effect of this would be to decrease production – weight gain, reproduction and milk and wool yields – per animal. Since production data comparable to the ones presented in Chapter 5 are unavailable for any earlier date, this can however not be tested by relating stocking rate to weight gain or some other measure of animal performance. In Swaziland, Fowler (1981) found that increasing cattle numbers and a decline in the grazing resource (partly triggered by the drought of 1964/65) had resulted in continually declining calving rates and increasing mortality. This had in turn led to reduced extraction rates, such that the increased cattle numbers had been insufficient to sustain the overall production levels of the 1960s.

6.2.2 Changes in stock composition

Although the total number of livestock in Herschel has not changed over the 20th century, the number of sheep has declined while goat numbers have increased (Figure 6.1). The number of cattle has not changed over that time period. Changes in stock composition, especially the replacement of cattle with hardier species such as camels or goats, has often been attributed to a decline in production potential (e.g. Lamprey 1983). However, care must be taken when drawing such conclusions. Other factors, such as people's production objectives or other constraints, have been found to cause changes in stock composition. In the Otjimbingwe communal area in Namibia, for example, Ward et al. (1998) found that a switch from cattle to goats reflected a changing ethnic composition with different livestock traditions, from predominantly cattle-owning Hereros to Damaras who traditionally owned few livestock and tended to keep goats.

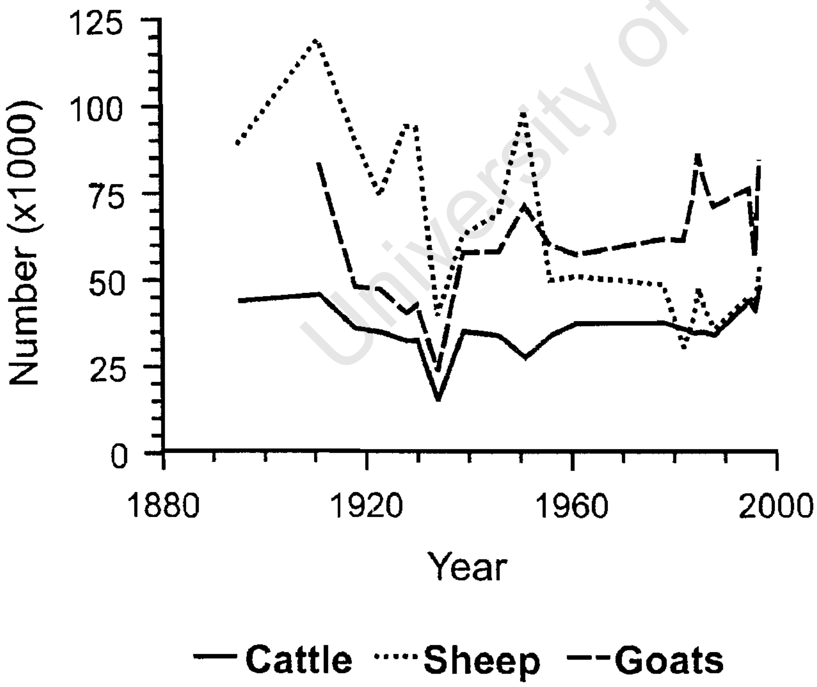

Figure 6.1. Numbers of cattle, sheep and goats in the Herschel district over a 100 year period.

In Herschel, the most important species of livestock was agreed to be cattle, and cattle numbers have not changed over time. The question is whether the decline of sheep numbers and the parallel increase in goat numbers is a reflection of changing production objectives or environmental quality. Sheep declined in importance when wool marketing opportunities disappeared in Herschel: first with the economic separation of homelands from the Union of South Africa early in the 20th century, which is held to have resulted in declines in other forms of agricultural enterprise as well (Bundy 1979), and further with the expulsion of white trading store owners when Herschel became part of Transkei in 1976. In the absence of a market for wool, sheep were considerably less important to livestock owners than they are now that a wool marketing scheme exists. This fact is echoed by other studies on livestock production in the Eastern Cape (e.g. Steyn 1982, Bembridge 1984), which found wool production to be an insignificant production objective and source of income in the absence of wool marketing structures. Until the late 1980s, when the wool marketing scheme started, the low sheep numbers may thus reflect the relative lack of priority given to keeping sheep. However, in more recent years, sheep have become desirable as a source of income, and farmers interviewed regard sheep as more desirable than goats because of their economic value. Most farmers say they would like to keep sheep, but that they are hindered by the lack of money needed for feed and veterinary medicines.

Farmers say that the reason they have more goats than sheep is because goats are hardier than sheep, and they are the only livestock species able to browse the unpalatable shrubs that now dominate the more mountainous areas. Goats are also less prone to diseases than sheep, and overall require fewer inputs of feed and medicines to survive. Only a relatively small percentage of people have sheep compared to goats and cattle, and these tend to be relatively commercially-oriented livestock owners who can afford to provide the necessary inputs. This suggests that the changing goat to sheep ratio is a reflection of environmental change rather than production objectives.

Herschel is not the only district where changes in livestock composition have taken place. Livestock data from all the former Transkei and Ciskei districts (unpublished data set compiled from stock records by Tony Palmer, ARC Range and Forage Institute, Grahamstown) show that the most common scenario is one where total livestock units have not declined, but an increase of goat numbers has been accompanied by a decrease in sheep numbers. This needs further research, for example to gain a better understanding of resource use and competitive interaction between cattle, sheep and goats in different vegetation types and in districts with different degradation coefficients

(Hoffman et al. 1999). It would also be interesting to determine to what degree goats utilise the generally unpalatable Karoo shrubs in Herschel.

6.2.3 Reliance on feed inputs

The provision of additional feed, in the form of feed and nutritional supplements bought outside the district and fodder crops cultivated in Herschel, is described in Chapter 5. It appears that buying or growing feed for cattle and sheep is fairly commonplace in Herschel. The people interviewed generally insisted that this was a new development and that in the past no such inputs were made, except for crop residues which were always fed to livestock. The decline in cropping in Herschel may be partly responsible for the increased need to buy feed from outside the district. The exact timing of this change was very difficult to determine. Some farmers said that increased buying or planting of livestock feed took place in the last ten to twenty years. Everybody agreed that their father's generation never bought feed or grew crops for animal consumption. The need to buy medicines in recent years reflects the deterioration in government veterinary services which are being officially disbanded in the communal areas of the Eastern Cape (Ainslie 2002).

6.3 Stock numbers have remained the same – but what about production?

Missionaries and visitors remarked on the diversity and extent of livestock rearing and crop production in the 1860s and '70s (Bundy 1979 and sources therein). In 1869, the missionary H. H. Dugmore referred to Herschel as "the granary of both the [Cape's] northern districts and the Free State too" (Bundy 1979). The magistrate's report for 1873 reports that Herschel produced a surplus of about 1000 bales of wool, 6000 bags of wheat and 30 000 bags of sorghum and maize, as well as livestock, which were sold outside the district. Herschel farmers used to grow wheat in winter, primarily as a cash crop in addition to subsistence cultivation of sorghum or maize in summer (Bundy 1979). In the 1920s, wheat was still the most important agricultural export, but today wheat is cultivated mainly as livestock fodder by some farmers.

The decline in agricultural production, both total and per capita, between the 1870s and the 1920s is well-documented in the work of Macmillan (1930), and interpreted by Bundy (1979) as resulting from a combination of population increase, social stratification and competition for resources, environmental degradation and undermining of economic opportunities by the South African government. The datasets cited by Macmillan appear to be the last available records of agricultural production in the Herschel District. Bundy (1979) does not cite any more recent data, and it appears that the only other data are in the form of a small household survey (de Satgé 1979), a brief and rather superficial consultants' report (Loxton, Venn and Associates 1990) and some unpublished EDA reports mainly concerned with wool production. The picture that emerges from these sources is one of low yields and insufficient livestock and crop production for subsistence. However, the lack of sufficient quantitative data on crop or livestock production makes it impossible to determine how production in the 1920s – already described as very low – compares to more recent years.

People interviewed in Herschel consistently reported reductions in crop yields, milk production, and the reproductive output, size and condition of their livestock. It is, however, difficult to obtain quantitative data to support or refute these claims. Furthermore, where production data exist (e.g. Macmillan's analysis of production, consumption, imports and exports of agricultural products between 1873, 1891 and the 1920s), the change in population size makes it difficult to disentangle per capita versus total district production when trying to compare these figures to more recent production. For example, a decrease in exports of agricultural produce may indicate a decrease in production, or merely an increase in population and hence requirement, reducing the surplus but not the total quantity produced.

Also, a decrease in production is not necessarily a direct result of (or proportional to) the productive potential of the land. For example, a common obstacle to even small-scale agricultural production is a lack of capital for buying seed, hiring tractors, and buying feed and medicines for livestock production. Much arable land lies fallow, partly because of its infertile or eroded state, but much of it because people do not have oxen or enough money for alternatives such as hiring tractors. A report by de Satgé (1978) describes these problems in detail. People in Herschel also described the distance between their homes and arable plots, and the lack of control over livestock grazing which results in stock damaging or destroying crops, as making cropping a risky investment.

In the case of livestock, Herschel farmers cite numerous ways in which productivity has declined. Milk used to be an important food source, and community dairies were established in the 1960s in the context of betterment planning. In a group interview, milk production was described as "dead", and while this may partly reflect the small number of cows owned per household (and hence the per-household deficit), interviews on livestock production revealed very low (although not quantified) milk yields and a high percentage of cows not in milk. The fact that crop production is often reported to be hindered by the poor condition of oxen at the end of winter (de Satgé 1978, interview information) is also an indication of low secondary production.

The only aspect of livestock production for which data exist in a comparable format over a longer time period is wool production. Herschel has been a wool producing district for over 100 years. In the late 1800s, about 200 000 kg of wool were sold from the district annually (Macmillan 1930; see Figure 6.2). It appears that wool production declined considerably early in the 20th century, and annual production in the 1920s averaged about 114 000 kg. No records of wool production are available between then and the 1990s, but due to the unfavourable marketing system very little wool was sold from the district for several decades until the late 1980s (Graham Frost, EDA consultant, pers. comm.).The fact that wool production was not mentioned as a reason for keeping livestock in the survey conducted by Loxton Venn and Associates (1990), whereas it is now considered to be one of the most important agricultural activities, illustrates this change. Since the introduction of the wool marketing system where wool is shorn, classed, packed and marketed collectively, and every farmer is paid individually for his or her wool, wool sales from the district have increased again. Wool sales in the 1990s averaged about 53 700 tonnes per year. This is a quarter of the production in the late 1800s from about half the number of sheep.

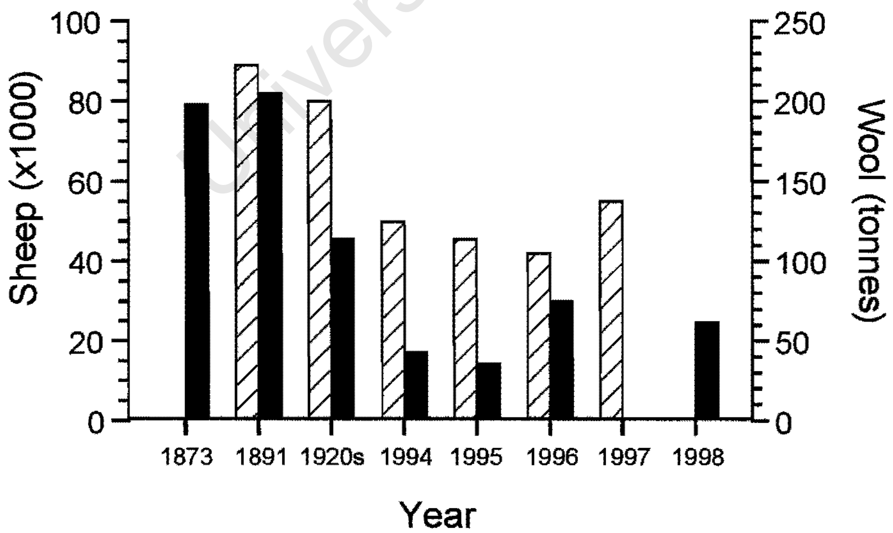

Figure 6.2. Number of sheep (hatched bars) in Herschel and tonnes of wool (solid bars) sold from Herschel in different years. Sources: Macmillan (1930) and EDA (unpublished reports).

Although it is difficult to generalise from so few data points, it appears that besides a reduction in sheep numbers, the wool production per sheep has decreased considerably over this time period. This suggests that, although total stocking rates 100 years ago were similar to today's, the same stocking rates then allowed higher production per animal than they do now, indicating that primary productivity has declined (Jones and Sandland 1974, Wilson and MacLeod 1991).

6.4 Conclusions

Data on livestock production suggest that while the same number of livestock are still present in Herschel, these are being increasingly maintained by feed inputs, and that for the same number of animals, there is less productive output than in the past. The decline in production around the turn of the century is well-documented. However, the dearth of production data between the 1920s and the late 1990s makes it impossible to reconstruct the changes in production that took place since then. There is nevertheless evidence that overall production has declined in Herschel, even though it is difficult to determine the timing of this decline.

The causal agents of resource use change and lowered agricultural output are complex, and environmental change interacts with economic risk, lack of capital, political change and the effects of increasing population size. The examples of grain and wool production illustrate the interplay of these different factors. People in Herschel have adapted in various ways to changing environmental and economic conditions, by altering grazing patterns, making new types of inputs into livestock production, and altering their production patters. The next chapter is an attempt to quantify the importance of these new contributions in compensating for losses in primary production.

7. WHAT FACTORS PREDICT STOCKING RATES IN HERSCHEL?

7.1 Introduction

In earlier chapters, it became clear that livestock numbers in the Herschel District have not declined over the last century, despite the fact that the extent and severity of soil erosion has increased considerably over that time period. The majority of farmers are trying to increase the size of their herds, and the total number of livestock kept by the many farmers can be considered to be at or close to the maximum carrying capacity. If one assumes that farmers in Herschel have always tried to keep the maximum possible number of livestock, the absence of a long-term decline in stock numbers could be interpreted as showing that the carrying capacity of the area has not declined. Since carrying capacity is closely related to primary production (McNaughton et al. 1989 and 1991, Moen and Oksanen 1991, Oesterheld et al. 1992), this also suggests that the primary productivity of the area has not been adversely affected by the observed degradation. For example, Tapson (1993) used a lack of a decline in cattle numbers in KwaZulu to argue that no loss in primary or secondary production had taken place despite apparent overgrazing and degradation.

The data presented in Chapter 5 show that farmers' inputs may contribute substantially to the maintenance of livestock numbers in the Herschel district. Many farmers buy or cultivate feed for their livestock, and purchases of livestock from outside the district to start new herds or replace drought losses are fairly common. This chapter examines to what extent stocking rates are a function of rainfall and primary productivity, and to what extent human actions play a role in supporting stocking rates at different times. Correlates of stocking rates and multiple regression analyses are used to explore which factors best explain variation in stocking rates in 23 administrative areas within Herschel between 1974 and 1997. These analyses also examine the basis for stocking rate recommendations in different areas of Herschel, and what factors characterise areas supposedly under- and overstocked. A further aim of this chapter is to explore the relationship of stocking rates and livestock population growth rate (λ) with rainfall and stock numbers in different years. This is done to explore the relative importance of density dependence and rainfall on herd productivity.

7.1.1 To what extent are stocking rates maintained by primary production? The role of rainfall and soil fertility

Rainfall is generally held to be the best predictor of carrying capacity in semi-arid rangeland systems, as rainfall is the primary determinant of plant growth and hence the quantity of forage available (Dye and Spear 1982, McNaughton et al. 1991, Illius and Hodgson 1996, O'Connor and Bredenkamp 1997, Owen-Smith and Danckwerts 1997). Positive relationships of wild and domestic herbivore biomass with rainfall at a regional scale have been found in a number of studies in Africa (Coe et al. 1976, McNaughton et al. 1989, Fritz and Duncan 1994) and in South America (Oesterheld et al. 1992). In South Africa, stocking rates in magisterial districts are also correlated with mean annual rainfall (Milton and Dean 1996, Dean and Macdonald 1994, Hoffman et al. 1999).

However, within areas of the same annual rainfall, total herbivore biomass is several times higher in areas with nutrient-rich soils than in areas with infertile soils (Bell 1982, Fritz and Duncan 1994). The more arid savannas, especially on volcanic or rift valley rock formations, are characterised by high nutrient availability and a low biomass of high quality vegetation supporting a high total biomass of large herbivores. Herbivore densities tend to be energy limited and forage quantity is limited by rainfall. Food availability fluctuates with variations in rainfall from year to year. The more humid, dystrophic savannas on old rock substrates with leached soils (such as the miombo woodlands of south-central Africa) have a high biomass of low quality forage supporting a low herbivore biomass. Plant growth is these systems is limited by nutrient availability rather than rainfall, and most plant species have high C:N ratios or produce secondary metabolites which make their tissues less digestible. Herbivore densities are limited by forage quality, and these systems tend to be dominated by very large bodied grazers such as buffalo which can digest low-quality forage, or highly selective grazers and browsers (Bell 1982, East 1984, Owen-Smith and Danckwerts 1997).

The shape of the relationship between rainfall and herbivore biomass differs between arid nutrient-rich and humid nutrient-poor savannas. On soils of volcanic origin and rift valley sediments (medium to high fertility), large herbivore biomass increases as rainfall increases from 200 to more than 1000 mm. On basement rock and sediments, granitic shields and sands of low fertility, biomass increases with rainfall up to a mean annual rainfall of about 700 mm and then appears to decline as rainfall increases further (Bell 1982). Fritz and Duncan (1994) found that relationships between the $\log_{10}$ of herbivore biomass and the $\log_{10}$ of mean annual rainfall was linear on high as well as low soil fertility but that the y-intercepts were significantly different.

The contrast between eutrophic and dystrophic systems operates even at small scales in the landscape (Owen-Smith and Danckwerts 1997). In nutrient-poor environments, wild and domestic herbivores tend to congregate on nutrient-rich patches such as drainage depressions. In Nylsvley, a well-studied South African savanna, herbivore biomass on the disturbed, nutrient-rich sites associated with former settlements was nearly four times as high as on the surrounding nutrient-poor savanna although the geological substrate was identical (Scholes and Walker 1993). Elsewhere, herbivores occur transiently, often taking advantage of recently burned areas. The influence of nutrients decreases as rainfall decreases, because less leaching of nutrients occurs (Owen-Smith and Danckwerts 1997). In more arid areas, the availability of surface water becomes the factor limiting herbivore biomass.

In Herschel, mean annual rainfall ranges from less than 500 mm to over 1000 mm, and the geological substrates differ in fertility. The effects of rainfall and soil fertility on stocking rates can thus be examined by comparing different areas of the district.

7.1.2 Limitation of stocking rates by periods of low forage availability

Mean annual rainfall or total annual forage production do not always by themselves determine how many animal units can be maintained every year. The seasonality of rainfall as well as inter- and intra-annual variations in rainfall and forage quality play a role in constraining livestock densities. Density independent periods of resource "bottlenecks" can significantly limit populations in variable environments (Wiens 1977).

A well-known example in South Africa is the "winter bottleneck" in areas with high summer rainfall, cold, frosty winters and nutrient poor soils. These areas, known in South Africa as "sourveld", are characterised by a high standing biomass of fibrous grass with a low N:C ratio (Ellery et al. 1995). Carrying capacity of these areas is limited by the extremely low digestibility of grass in winter, which prevents full utilisation of the higher quality forage in summer. Nutrient supplementation and rumen stimulants (e.g. phosphorus licks or bone meal) can greatly increase the carrying capacity by allowing livestock to utilise more of the fibrous forage in winter (Richardson 1986). Burning the grass to remove moribund material and produce more nutritious green growth is also used to improve the fodder flow through winter, although this practice is not recommended since it depletes the carbon reserves of grasses and hence their vigour (Morris 1999). All of Herschel experiences frost on an annual basis, and in the higher-lying parts the frost period is over 200 days per year (see Chapter 2). The vegetation in these high-lying areas, especially on soils derived from the nutrient-poor Clarens sandstone formation, has sourveld characteristics.

In arid and semi-arid areas, the great variability in rainfall within and between years causes considerable fluctuations in livestock reproduction and survival, resulting in variations in animal numbers with rainfall (Ellis and Swift 1988). Supplementation of feed and water is commonly used by farmers (particularly in commercial farming systems) to maintain livestock numbers through dry periods. Key resource areas, such as seep lines, vleis and river banks, can help maintain high stocking rates through winter in areas where they are available (Scoones 1993 and 1995, Illius and O'Connor 1999 and 2000). No such key resources were observed in Herschel, except for the banks of the Orange and Telle Rivers. The latter are steep and fairly stony in most places, and where there are small flood plains, these are used as arable land. Cultivated land is the most common source of winter feed (other than bought feed from outside the district) and is thus hypothesized to be a key resource in Herschel.

7.1.3 The role of degradation

Dean and Macdonald (1994) found that most semi-arid districts (mean annual rainfall <600 mm) in South Africa had exhibited long-term declines in stocking rates and attribute this to degradation. Hoffman et al. (1999) found that stocking rates were negatively correlated with indices of soil and soil plus vegetation degradation in commercial farming districts of South Africa. No correlation with degradation was however found to exist for stocking rates in districts under communal tenure, nor in the whole dataset using all districts of the country. In Chapter 6, I found livestock densities in the four administrative areas that were studied in some detail to be unrelated to degradation levels.

Recommended stocking rates in Herschel (Winston Trollope, unpublished data, 1974) are a reflection of veld condition, based on grass composition, basal cover and extension officers' experience of agricultural production (see the Methodology section of this chapter for details). In the absence of erosion or veld condition data for each administrative area, the recommended stocking rates are used as a surrogate of the condition of different areas within Herschel.

7.1.4 The influence of Karoo shrubs

Apart from reduced basal cover and soil erosion, the encroachment by Karoo shrubs is a widespread feature of Herschel grasslands. This is viewed, in the agricultural literature as well as by farmers in Herschel, as undesirable. Bush encroachment in savannas reduces grass yields (e.g. Dye and Spear 1982, O'Connor 1985), mainly due to shading and competition for water, although the effect on animal performance is less pronounced because of the availability of browse as well as effects on soil fertility (Teague and Smit 1992). The effect of the small Karoo shrubs on grass yields is uncertain; they reach densities of 15% of aerial cover in Herschel, particularly in the Afro Mountain Grassland vegetation type. They are unpalatable and contribute little to livestock production, although this needs to be researched. There is also evidence that Karoo shrubs have an allelopathic effect on grasses (Squires and Trollope 1979).

Since sufficiently detailed shrub data for the whole district were unavailable, shrub cover is not included in the analysis of determinants of stocking rates. It would be interesting to determine experimentally what the impact of Karoo shrubs on grass production and total available forage is.

7.1.5 The influence of livestock management

The nature and frequency of management inputs can affect livestock densities in an area. Oesterheld et al. (1992) found that at a regional scale, pastoral areas in South America supported ten times the herbivore biomass per unit area than wildlife areas with comparable primary production, which they calculated from rainfall. They attribute this to the effects of husbandry practices such as herding, stock selection and veterinary care (but not supplementary feed) in reducing mortality and increasing fecundity and production efficiency. Livestock breeding has resulted in higher production efficiency factors worldwide (Richardson 1986). On the other hand, Fritz and Duncan (1994), using data from southern and eastern Africa, found no difference between the carrying capacities of areas grazed by wild and domestic herbivores, and they suggest that the advantages of livestock management practices may be matched by the effects of species diversity in wild ungulate communities, which are able to exploit the forage resource more effectively.

Neither of these studies considered systems where additional feed is provided, and the results in Chapter 5 show that many farmers in Herschel buy or cultivate feed for their livestock at least in some years. Arable lands are likely to function as key resources for both stover and feed crops. Purchases of livestock from outside the district, especially to replace drought losses, are also fairly common. It may therefore be possible that high livestock densities in Herschel are at least partly maintained by the provision of feed and other management inputs which would be correlated to human population density or the availability of arable land in an area.

7.1.6 Livestock population dynamics: density dependent or climate-driven?

One of the ongoing debates in range ecology is that regarding the relative importance of density dependent interactions and annual rainfall in determining annual herd productivity, reproduction and mortality (Ellis and Swift 1988, Sullivan 1996, Illius and O'Connor 1999, Sullivan and Rohde 2002). In grazing systems with very high climatic variability, forage availability varies to such a great degree with rainfall that livestock population dynamics are driven by rainfall (*via* its effect on forage availability) rather than density-dependent interactions such as competition for resources (Wiens 1977). Livestock numbers build up during series of wet years, but mortality is high – and independent of livestock density – during severe droughts, particularly droughts lasting longer than one year (Homewood and Lewis 1987, Ellis and Swift 1988, Oba 2001). Population size thus fluctuates dramatically, although it may not track rainfall closely because of the time it takes populations to recover from crashes. In a grazing system with relatively predictable rainfall and hence forage production, livestock populations are regulated in a density-dependent manner via competition for food resources. A sign of density-dependence is that population growth rates decrease with increasing population size because of the effects of competition on reproductive and mortality rates.

The above dichotomy is an oversimplification of the range of situations found in the real world. For example, density-dependent dynamics in non-drought years can alternate with density-independent mortality during droughts and subsequent recovery (e.g. Scoones 1990 in southern Zimbabwe). Also, describing livestock population dynamics simply in terms of density-dependence or a lack thereof ignores the underlying mechanisms of the consumer-resource dynamics and how they are affected by seasonal variability and spatial heterogeneity in forage quality and quantity (Owen-Smith 2002).

This chapter nevertheless includes a simple analysis to distinguish whether changes in livestock numbers and herd growth in the Herschel district are rainfall-driven or density-dependent. This is of interest because non-equilibrium grazing systems, where livestock populations fluctuate with rainfall, are thought to be less prone to grazing-induced degradation than systems where livestock populations are in density-dependent equilibrium with the vegetation (Ellis and Swift 1988, Behnke and Scoones 1993). Environments with a rainfall coefficient of variance (c.v.) of more than 33% are hypothesized to experience mostly non-equilibrium dynamics (Ellis et al. 1993, Ellis 1994). The rainfall c.v. calculated from rainfall records in Sterkspruit is 28%. Since the 33% boundary between equilibrium and non-equilibrium environments has not been empirically tested, I considered it worth exploring whether the c.v. of 28% in Herschel was high enough to induce non-equilibrium dynamics.

7.1.7 Hypotheses considered

From the above discussion, a number of hypotheses emerges regarding factors determining the ecological carrying capacity of an area, and how livestock densities might be maintained in Herschel. Table 7.1 sums up the hypotheses on determinants of stocking rates in different parts of the district, which were examined using a multiple regression approach with cattle, sheep, goat and total livestock densities over two decades (1974 - 1997) as dependent variables. Stocking rates are assumed to be the maximum possible. The main question is whether stocking rates are determined by ecological carrying capacity (and hence environmental factors), key resources (arable lands[6] in the case of Herschel), people and the inputs they make, or a combination of these factors.

The second set of hypotheses concerns temporal patterns in livestock numbers and productivity. If carrying capacity in a given year is primarily determined by rainfall, one would expect animal numbers (which in Herschel are at or close to n_{max}) to be positively correlated with rainfall in different years. Similarly, if herd productivity is driven by rainfall, one would expect herd growth[7] to be correlated with rainfall. If on the other hand herd growth is density-dependent, one would expect a negative correlation of herd growth with population size in the previous year.

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[6] The term "arable land" in this study refers to areas zoned under betterment planning as fields for cultivation. Many of these are marginal and whether they are arable in terms of climatic, edaphic and topographical criteria is open to debate.

[7] $\lambda = N_{t+1}/N_t$ where λ is population growth from year 1 to year 2, N_t is population size in year 1 and N_{t+1} is population size in year 2.

Table 7.1. Summary of hypotheses on factors predicting stocking rates (S.R.) in different areas within Herschel. The relationship between stocking rates (dependent variables) and different independent variables predicted by each hypothesis is listed.

Hypothesis	Predicted relationships with stocking rates
1. S.R. is determined by primary production.	Positive with mean annual rainfall Positive with higher winter temperatures and less frost.
2. S.R. is limited by soil nutrient status (and hence forage quality).	Negative with % on Clarens sandstone. Negative with % on altitudes above 2000 m (higher rainfall: more leaching).
3. Variable rainfall reduces S.R.	Negative with standard deviation of mean annual precipitation.
4. More inaccessible terrain reduces overall S.R.	Negative with steeper slopes.
5. S.R. is higher in areas with good veld condition.	Positive with recommended S.R.
6. S.R. is maintained by key resources	Positive with % arable land.
7. S.R. is maintained by management inputs including the cultivation and purchase of feed.	Positive with human population density. Positive with % arable land.

7.2 Methodology

7.2.1 Calculation of stocking rates

The dependent variables used in the correlation and multiple regression analyses are stocking rates (cattle, sheep, goats and livestock units per hectare, see below) in 1974, the 1980s and 1997. Stocking rates were calculated as the number of livestock per hectare of grazing area. Since all areas in Herschel are stocked continuously (see section 6.2.1), stocking rate ($N.ha^{-1}.yr^{-1}$) is equal to stocking density ($N.ha^{-1}$).

The numbers of cattle, sheep and goats in each of the 23 administrative areas (AA) in the years 1982-1987 and in 22 of the 23 areas in 1997 were obtained from the Department of Agriculture office in Sterkspruit. To convert all livestock to Large Stock Units (LSU, the metabolic equivalent of a 450kg steer), I used detailed census data, which divided livestock into age and sex classes (see Table 7.2 for weights used and conversion to

LSU). Detailed census data were only available for the years 1983-1987. To calculate stocking rates, stock numbers were averaged for the years 1982-1987 (1983-1987 for LSU), and LSU in 1997 were calculated by multiplying the number of cattle by 0.8 while numbers of sheep and goats were multiplied by 0.17. Animal mass used in these conversion was based on unpublished data (Theunis de Bruyn, then Department of Livestock and Pasture Science, University of Fort Hare) collected in communal areas near Alice, Eastern Cape, where livestock composition and condition is similar to that in Herschel.

Table 7.2. Mass and conversion to LSU of different age and sex classes of cattle and small stock.

	Mass (kg)	LSU
Bulls	450	1.00
Cows	400	0.91
Oxen	450	1.00
Heifers	200	0.54
Calves	100	0.32
Rams (goat or sheep)	55	0.21
Ewes (goat or sheep)	45	0.18
Wethers (goat or sheep)	50	0.19
Lambs or kids	20	0.10

Total Animal Units (AU), but not numbers of cattle, sheep and goats separately, were available for each AA in 1974 from unpublished data compiled by Winston Trollope (Department of Livestock and Pasture Science, University of Fort Hare) from Department of Agriculture records (Trollope 1976). In these records, one AU is equivalent to one unit of cattle or six small stock. Recommended stocking rates for the same year use the same conversion. I converted the later stocking rates using the same ratio for use in analyses comparing stocking rates in later years with those of 1974 and investigating the correlations between recommended and actual stocking rates.

To determine the available grazing area in each AA, I digitised its boundaries and the outlines of residential areas from 1:50 000 topocadastral map sheets (Department of Mapping and Survey 1982). Total grazing areas were calculated using ArcView GIS by subtracting residential area from the total area of each AA. Arable land, road verges and woodlots are thus included in the grazing areas, as livestock graze everywhere except on people's residential plots. In areas where arable lands are cultivated, livestock are kept out during the growing period, but the stover provides extra forage after the harvest. In all areas I visited, I observed livestock grazing in harvested or fallow fields.

This analysis assumes that livestock are confined to the boundaries of the administrative area they are counted in. While people agree that livestock usually are herded within the owner's administrative area, there is at present nothing to prevent livestock and their herders from crossing most AA boundaries since fences became increasingly dilapidated or were destroyed since the mid-1970s. The potential effect of this on the difference between calculated and effective stocking rates in an area is not obvious, as movement across boundaries may occur in either direction. Quite possibly, the two cancel each other out in many cases. The magnitude of the potential "edge effect" is higher in small AAs, and lowest in AAs which border on neighbouring districts from which they are separated by fences or large rivers. Bearing this in mind when interpreting the results, the analysis should nevertheless be a useful tool for exploring correlates of stocking densities in different parts of the district.

7.2.2 Independent variables – climate, topography, geology, arable land and human population

The following data were obtained from the South African Atlas of Agrohydrology and Climatology (Schulze 1997). These data are at a resolution of 1' by 1', and mean values for each AA were extracted using a GIS.

- Mean annual precipitation, MAP (mm)
- Standard deviation of mean annual rainfall (mm)
- Mean maximum temperature in January (°C)
- Mean minimum temperature in July (°C)
- Average duration of frost period (days)
- Average number of days with heavy frost

Mean slope (degrees) and the percentage of the area on slopes exceeding 40° were calculated from the contour line themes of digital 1:50 000 topocadastral maps obtained from the Department of Land Affairs. The same map coverages were used to obtain mean altitude and the percentage of area above 2000 m altitude. The 2000 m contour more or less coincides with the layer of Clarens sandstone which forms the border between the two vegetation types, as well as the Karoo sediments below and the basalt layer above.

Soil data were not available at a suitable scale. A soils map for Herschel exists (AOC Technical Services 1967), but this covers only physically arable land which makes up 23 % of the total area in Herschel (Loxton, Venn and Associates 1988). Geological data were used instead as they provide information on soil nutrient status (Bell 1982) and an indication of soil texture and erodibility (Weaver 1988b). Geology was divided into three classes: Clarens sandstone, other sedimentary rock (Karoo formations and alluvium) and igneous rock (dolerite, basalt and pyroclastic material). The percentages of each AA on different geological formations were determined from a 1:250 000 geological map (Geological Survey 1980; see Figure 2.2) which I digitised using ArcInfo. Soils derived from Clarens sandstone are very nutrient poor and support sourveld. The soils derived from Karoo sediments are more susceptible to soil erosion (see Chapter 4) than those derived from igneous rock and have intermediate soil fertility. Soils derived from igneous rocks have a relatively low erodibility (Weaver 1988b) and a relatively high cation exchange capacity, resulting in higher availability of mineral nutrients.

The human population density for each AA was calculated from 1991 census data (Central Statistics Office 1994) in the absence of any census data with sufficient resolution closer to the 1982-1987 period covered by detailed livestock data. I used 1996 population census data (Statistics South Africa 1998) in the analysis of 1997 stocking rates. Not all enumerator boundaries used in the 1996 population census were consistent with the AA boundaries used for the livestock and 1991 population censuses, and only nine areas were suitable for comparison with stock and 1991 human population census data. Similar problems with the spatial format of census data in different years – and apparent population decreases between 1991 and 1996 which have variously been ascribed to movement from rural areas to cities and problems with the methodology used for the earlier census - have been encountered elsewhere in the Eastern Cape (e.g. Fox 1999). Some doubts exist about the reliability of census data collected in the former homelands as these often used extrapolations from hut counts and exaggerated conversion factors based on presumed household size (Orkin 1998). However, the 1991 census in Transkei was based on *de facto* population counts and not population models as was done in other censuses in the former homelands; the methodology is described in detail in the census report (Central Statistics Office 1994).

The percentage of arable land in each AA was obtained from the original betterment planning maps kept by the Department of Agriculture in Sterkspruit. This was the best information source available, but is not entirely accurate because the extent of arable land cultivated has changed since the early 1960s and also varies from year to year. Some arable lands have been permanently abandoned, for example as a result of erosion, and this is not accounted for in the data. Mapping arable lands in the entire district from aerial photographs would have been very time consuming. Also, the fact that the actual extent of the land cultivated varies between years would have prevented an accurate assessment of the arable area using this method as it is very difficult to determine from the photos which lands are cultivated.

I obtained recommended stocking rates for Herschel (Winston Trollope, unpublished data, 1974), which were estimated by agricultural officers in the Planning Section of the Department of Bantu Administration and Development located at King William's Town in Ciskei. The estimated carrying capacities were based on field experience and reflect forage production potential, which is a function of botanical composition and basal cover (Winston Trollope, pers. comm.). The recommendations were intended to permit the maximum number of livestock, taking into account the high human population owning and wanting to own livestock, without deterioration of the natural veld. The recommended stocking rates are expressed in AU/ha, where one bovine or six small stock are equivalent to one AU. These recommended stocking rates are included in the analysis as a measure of veld condition (basal cover and botanical composition), and to determine how well they predict the actual stocking rates in the different administrative areas. For this analysis, the actual stocking rates were converted to AU using the same conversion.

7.2.3 Stocking rates and rainfall

Rainfall in Sterkspruit between 1944 and 1998 was obtained from the Department of Agriculture office in Sterkspruit. For the correlations with livestock numbers and herd growth, I used the total rainfall in the season (July to June) preceding the stock census, which is taken in March. The running mean of the two summer seasons preceding the livestock census was also used in case there is a carry-over effect in forage production and availability between years. Livestock numbers used in the analysis were the numbers of cattle, sheep, goats and LSU in the whole district (using ratios 1 bovine = 0.8 LSU and 1 sheep or goat = 0.17 LSU) for all years available within the period covered by rainfall data. To calculate herd growth, the number of livestock in the present year was divided by the number of livestock in the previous year ($\lambda=N_{t+1}/N_t$). The census data have many missing years, and λ could thus only be calculated for some of the years.

7.2.4 Data analysis

To determine factors influencing stocking rates, and to explore relationships between the independent and dependent variables, a Pearson's Product Moment correlation matrix using all variables was generated. This was used to explore correlations between different environmental variables, relationships between recommended stocking rates and environmental variables, relationships between stocking rates of different stock types, and to select variables for inclusion in the multiple regression analysis.

I then performed a stepwise multiple regression (using the statistical software JMP) to determine the variables that best predict actual and recommended stocking rates. Before proceeding to a stepwise regression analysis to identify significant variables, I eliminated variables found by an initial standard least squares analysis to have variable inflation factors (VIF) exceeding 10. This was done to avoid using variables that are closely correlated with others and hence redundant. I retained variables with $p<0.05$ in the final model.

To determine the effect of rainfall over time on stocking rates and productivity, I performed Pearson's Product Moment correlation analyses of stock numbers (N_t) and λ against the previous season's rainfall as well as the mean of the previous two seasons' rainfall. A correlation analysis using λ and N_t of different livestock species and total LSU was used to test for density dependent effects of conspecific livestock, other livestock species and total livestock.

7.3 Results

7.3.1 Correlations between all variables

Relationships between independent variables

Most of the climatic and geomorphological variables showed a high degree of correlation with one another (see Table 7.3; full variable names are listed in Appendix A at the end of this chapter). Areas at higher altitude have higher percentages of igneous rock and Clarens sandstone, steeper slopes, higher rainfall, lower temperatures year round and more frost.

Table 7.3. Pearson's Product Moment correlation matrix showing relationships between all variables (N = 21). Significant r values (p<0.05) are highlighted.

	AU 74	Cattle 80s	Sheep 80s	Goats 80s	LSU 80s	Cattle 97	Sheep 97	Goats 97	LSU 97
Cattle 80s	**0.59**								
Sheep 80s	0.26	**0.55**							
Goats 80s	0.15	0.10	0.25						
LSU 80s	**0.54**	**0.75**	**0.71**	**0.61**					
Cattle 97	0.22	**0.71**	0.39	0.31	**0.49**				
Sheep 97	0.07	**0.46**	**0.74**	0.14	0.39	**0.49**			
Goats 97	0.23	-0.02	0.09	**0.91**	**0.43**	0.16	0.14		
LSU 97	0.27	**0.60**	0.48	**0.62**	**0.61**	**0.89**	**0.63**	**0.55**	
Recomm	0.39	-0.06	-0.25	-0.18	-0.09	-0.25	-0.40	-0.09	-0.30
Res 74	0.21	**0.44**	0.43	0.29	**0.44**	0.40	**0.47**	0.24	**0.49**
Res 80s	0.07	**0.51**	**0.57**	0.40	**0.56**	**0.53**	**0.57**	0.27	**0.62**
Res 97	0.07	**0.51**	**0.47**	**0.50**	**0.48**	**0.81**	**0.65**	0.41	**0.89**
People 91	0.37	**0.71**	**0.43**	0.13	**0.55**	**0.53**	0.35	0.07	**0.49**
% arable	**0.44**	0.42	**0.49**	-0.22	0.28	0.00	**0.46**	-0.12	0.06
% sediment	0.24	0.30	0.28	0.42	0.42	0.21	0.22	0.37	0.35
% igneous	-0.22	-0.20	-0.15	**-0.48**	-0.35	-0.21	-0.09	-0.43	-0.35
% Clarens	-0.18	-0.42	**-0.47**	-0.08	-0.42	-0.12	**-0.44**	-0.06	-0.21
%slope>40	-0.16	-0.25	-0.35	-0.02	-0.20	-0.05	-0.42	-0.06	-0.16
Meanslope	-0.07	-0.23	-0.36	0.09	-0.15	0.01	**-0.45**	0.04	-0.08
MAP	0.11	-0.05	-0.28	-0.19	-0.09	-0.11	**-0.45**	-0.22	-0.27
MAP STD	-0.34	-0.30	**-0.45**	-0.12	-0.39	-0.03	-0.31	-0.15	-0.15
JUL Tmin	0.43	0.35	-0.04	0.32	0.32	0.26	0.04	0.34	0.33
JAN Tmax	0.03	0.20	0.26	0.07	0.14	0.11	0.39	0.09	0.20
Frostdur	-0.30	-0.35	-0.16	-0.22	-0.30	-0.23	-0.25	-0.23	-0.31
Frostdays	-0.34	-0.36	-0.08	-0.27	-0.31	-0.27	-0.17	-0.28	-0.34
Altmean	-0.13	-0.26	-0.23	-0.10	-0.20	-0.13	-0.35	-0.12	-0.22
%alt>2000	-0.34	-0.42	-0.37	-0.24	-0.42	-0.27	-0.34	-0.19	-0.35

	Recomm	Res 74	Res 80s	Res 97	People 91	% arable	% sediment	% igneous	% Clarens
Res 74	**-0.81**								
Res 80s	**-0.84**	**0.94**							
Res 97	**-0.68**	**0.76**	**0.86**						
People 91	-0.13	0.37	0.42	0.43					
% arable	-0.16	**0.45**	0.36	0.15	0.35				
% sediment	-0.43	**0.61**	**0.56**	**0.45**	0.42	0.38			
% igneous	0.39	**-0.55**	**-0.48**	-0.42	-0.40	-0.23	**-0.96**		
% Clarens	0.34	**-0.48**	**-0.51**	-0.32	-0.26	**-0.57**	**-0.67**	0.42	
%slope>40	**0.51**	**-0.64**	**-0.57**	-0.37	-0.33	**-0.58**	**-0.74**	**0.58**	**0.82**
Meanslope	**0.55**	**-0.63**	**-0.56**	-0.32	-0.38	**-0.65**	**-0.71**	**0.57**	**0.78**
MAP	**0.66**	**-0.64**	**-0.61**	**-0.51**	-0.25	-0.37	**-0.76**	**0.66**	**0.68**
MAP STD	0.22	**-0.45**	-0.39	-0.22	**-0.49**	**-0.70**	**-0.58**	**0.53**	**0.45**
JUL Tmin	-0.05	0.33	0.25	0.28	0.29	0.23	**0.75**	**-0.69**	**-0.56**
JAN Tmax	**-0.52**	**0.58**	**0.53**	0.39	0.34	**0.47**	**0.79**	**-0.65**	**-0.79**
Frostdur	0.30	**-0.50**	**-0.44**	-0.38	-0.37	-0.39	**-0.82**	**0.70**	**0.75**
Frostdays	0.21	**-0.44**	-0.38	-0.36	-0.32	-0.32	**-0.79**	**0.69**	**0.70**
Altmean	**0.46**	**-0.58**	**-0.52**	-0.39	-0.39	**-0.49**	**-0.82**	**0.69**	**0.79**
%alt>2000	0.37	**-0.61**	**-0.56**	**-0.45**	**-0.47**	**-0.46**	**-0.84**	**0.72**	**0.77**

	%slope>40	Meanslope	MAP	MAP STD	JUL Tmin	JAN Tmax	Frostdur	Frostdays	Altmean
Meanslope	**0.95**								
MAP	**0.91**	**0.88**							
MAP STD	**0.54**	**0.60**	**0.43**						
JUL Tmin	**-0.52**	-0.42	**-0.48**	-0.26					
JAN Tmax	**-0.93**	**-0.91**	**-0.93**	-0.42	**0.66**				
Frostdur	**0.79**	**0.71**	**0.75**	0.35	**-0.91**	**-0.90**			
Frostdays	**0.68**	**0.58**	**0.65**	0.30	**-0.97**	**-0.81**	**0.98**		
Altmean	**0.92**	**0.90**	**0.90**	**0.47**	**-0.74**	**-0.99**	**0.93**	**0.86**	
%alt>2000	**0.86**	**0.78**	**0.80**	**0.44**	**-0.79**	**-0.91**	**0.95**	**0.90**	**0.93**

It must be borne in mind that the climatic data are modelled (Schulze 1997 and references therein) and topographic data are often among the input variables when modelling climate. As a result of the correlations between topography, altitude, geology and climate, it is not always easy to differentiate between the effects of the individual variables.

The percentage of arable land is substantially lower in high-altitude areas with steep slopes and high percentages of the infertile Clarens sandstone. The density of human population is lower in areas with a higher percentage at altitudes above 2000 metres, where steep slopes and low temperatures make habitation more difficult.

Relationships between stocking rates of different stock species and in different years

Stocking rates were lowest in 1974 and highest in 1997, despite the low rainfall throughout the early 1990s (see Figure 2.4). Total stocking rates in different AAs (AU/ha calculated as in 1974 where 1 AU equals one unit of cattle or six small stock units) were correlated in different years, as summarised in Table 7.4.

Table 7.4. Pearson Product Moment correlations between stocking rates (AU/ha) in different AAs in Herschel in different years.

	N	r	p
AU/ha 1974 vs. AU/ha 1980s	23	0.94	<0.001
AU/ha 1980s vs. AU/ha 1997	22	0.79	<0.001
AU/ha 1974 vs. AU/ha 1997	22	0.67	<0.01

The stocking rates of different stock types were often correlated with one another and total LSU per hectare in different years (Table 7.3), suggesting that areas with high densities of one livestock species tended to have high densities of other stock species and overall high stocking rates. The number of cattle per hectare was generally positively correlated with the number of sheep per hectare as well as total LSU per hectare, in the same year and in other years. Goat densities are not correlated with densities of cattle and sheep, but are correlated with total livestock densities.

Recommended vs. actual stocking rates

Recommended stocking rates are strongly correlated with mean annual rainfall (Figure 7.1) and are greater at higher altitudes (Table 7.3). A multiple regression analysis retained mean annual rainfall ($p<0.0001$) and minimum temperature in July ($p<0.05$) in the final regression model, which explained 54 % of the variation in recommended stocking rates across AAs (N = 23). The relationships between actual stocking rates and independent variables are presented in the next section.

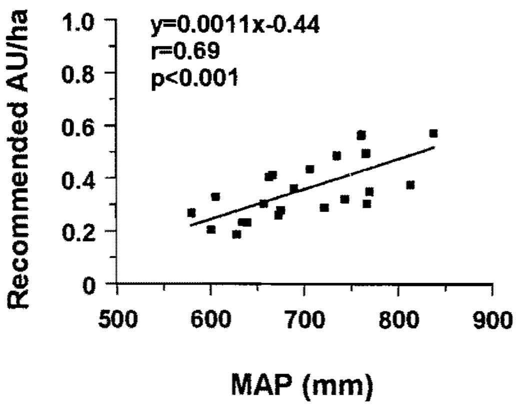

Figure 7.1. Relationship between recommended stocking rate and mean annual precipitation in 23 administrative areas of Herschel.

Compared to the recommended stocking rates, 14 of the 23 administrative areas were understocked in 1974, while 9 of 23 and 8 of 22 areas were understocked in the 1980s and 1997 respectively. Actual stocking rates (AU/ha) in 1974 were positively correlated with recommended stocking rates (Figure 7.2). No significant relationship exists between actual and recommended stocking rates in the 1980s and 1997. Figure 7.2 shows that areas with low recommended stocking rates have shown an increase in stocking rates from 1974 to the 1980s, and to 1997. Areas with high recommended stocking rates in 1974 remain understocked through to the 1990s. The same areas are under- or overstocked in the different years. Pelandaba consistently has the highest recommended and lowest actual stocking rates with actual stocking rates in different years at between 41 and 49 % of the recommended stocking rate. This is followed by Upper Telle (55-75 % of recommended stocking rate) and other high-altitude areas. According to Table 7.3, overstocking occurs in areas on sediment, at lower altitudes and in flatter, warmer and drier areas. Figure 7.3 shows that areas with high population densities tend to be overstocked, while areas with higher rainfall tend to be understocked relative to recommended stocking rates.

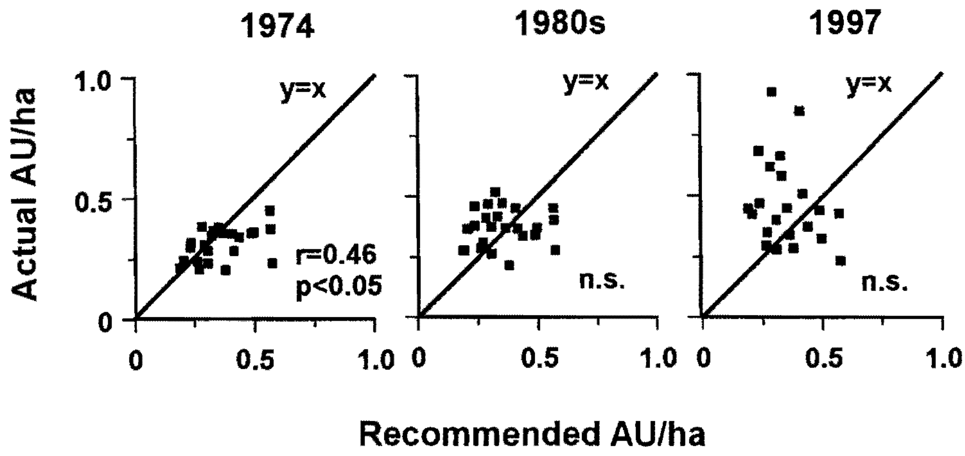

Figure 7.2. The relationships between actual and recommended stocking rates in different administrative areas of the Herschel district in 1974, the 1980s and 1997. Points below the line y=x represent understocked, points above the line overstocked, areas in terms of the 1974 recommendations.

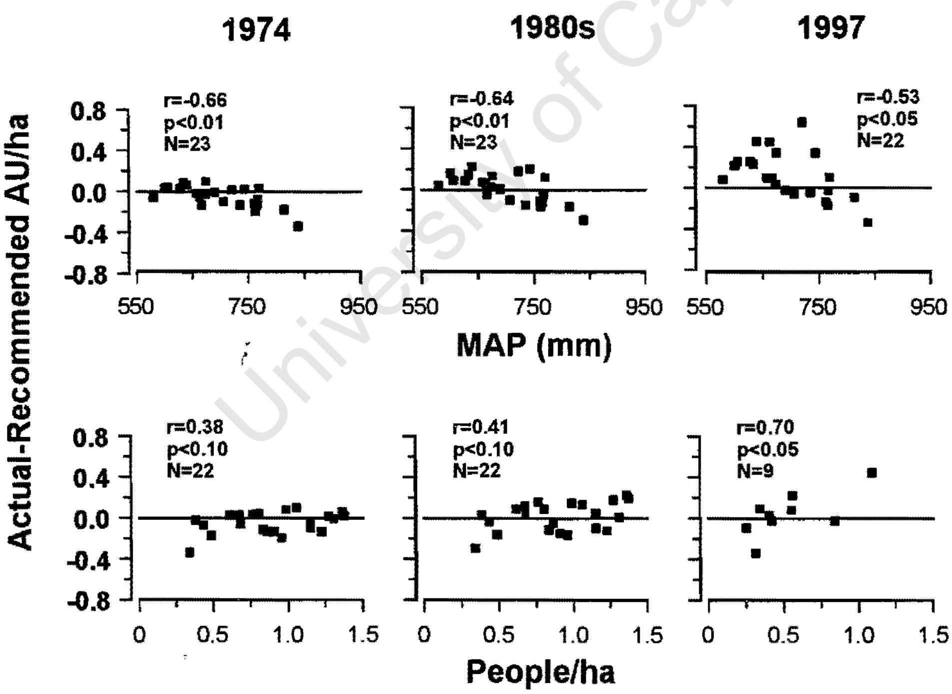

Figure 7.3. Level of over- or understocking (actual minus recommended stocking rate) in different administrative areas of the Herschel district, plotted against mean annual rainfall and human population density in 1974, the 1980s and 1997. Population census data from 1991 are used in the 1974 and 1980s analyses, while 1996 census data are used for the 1997 analysis.

7.3.2 Relationships between stocking rates and independent variables

The correlation matrix formed the basis for the selection of variables for the multiple regression analysis. I retained eight variables (recommended stocking rate, people/ha, % arable, % on Clarens, % on igneous rock, % on slopes >40°, MAP, July minimum temperature) to derive multiple regression models for each independent variable. The remainder were eliminated from the analysis due to high collinearity (VIF > 10). The administrative area of Sterkspruit was excluded from the analysis because of the presence of the town of Sterkspruit and the area's high urban population. The results of the regression analysis are summarised in Table 7.5.

From Table 7.5, it is clear that the factors which best explained variations in stocking rates in different areas of the district changed from the 1970s to the 1990s, with an increasing influence of human population density on stocking rates and a decreasing influence of environmental factors.

In 1974, stocking rates were best predicted by mean annual rainfall, in combination with slope and winter temperature. These are all factors affecting primary production and hence ecological carrying capacity.

In the 1980s, human population density became more important in predicting livestock densities, especially of cattle and sheep. The percentage of an area on Clarens sandstone – indicating sourveld vegetation - was negatively correlated with cattle, sheep and total livestock densities in the 1980s. Separate multiple regression analyses for each year between 1982 and 1987 showed the same relationships of cattle and sheep stocking rates with human population density and % Clarens sandstone in all years, regardless of rainfall.

In 1997, human population density was the sole significant predictor of cattle, sheep and total livestock densities. The strong relationship of sheep density with human population density is particularly striking. Variations in goat densities across AAs were poorly explained by any of the independent variables in the 1980s and in 1997.

Table 7.5. Summary of regression results for stocking rates in different years. All variables contributing significantly to the final model ($p<0.05$) are included. R^2 values are adjusted for results with more than one independent variable.

Dependent variable and regression coefficient	Independent variables		
	Variable	**Slope**	**p**
AU/ha 1974			
$R^2_{adj} = 0.67$	MAP	+	<0.0001
N = 22	% Slope > 40°	-	<0.01
	July T_{min}	+	<0.05
	People/ha 1991	+	<0.05
Cattle/ha 1980s			
$R^2_{adj} = 0.67$	People/ha 1991	+	<0.0001
N = 22	% Clarens	-	<0.01
	MAP	+	<0.01
Sheep/ha 1980s			
$R^2_{adj} = 0.73$	People/ha 1991	+	<0.0001
N = 22	% Clarens	-	<0.001
	July T_{min}	-	<0.001
	MAP	-	<0.01
	% Slope > 40°	+	<0.05
Goats/ha 1980s			
$R^2_{adj} = 0.23$	% igneous	-	<0.05
N = 22			
LSU/ha 1980s			
$R^2_{adj} = 0.54$	People/ha 1991	+	<0.01
N = 22	% Clarens	-	<0.01
	MAP	+	<0.05
Cattle/ha 1997			
$R^2_{adj} = 0.46$	People/ha 1996	+	<0.05
N = 9			
Sheep/ha 1997			
$R^2_{adj} = 0.90$	People/ha 1996	+	<0.0001
N = 9			
Goats/ha 1997			
$R^2_{adj} = 0.14$	% igneous	-	<0.05
N = 22			
LSU/ha 1997			
$R^2_{adj} = 0.48$	People/ha 1996	+	<0.05
N = 9			

When only relationships between stock and human population densities are considered, all stocking rates show some degree of positive correlation with human population densities in all years (Figure 7.4). These relationships become stronger in the later years, except in the case of goats. The increases in sheep numbers between the 1980s and 1997 are particularly striking, and may reflect the fact that the wool marketing system, which was developed in the late 1980s, encouraged more people to keep sheep and make inputs to sustain them. Areas with large increases in livestock numbers are the areas with high population densities.

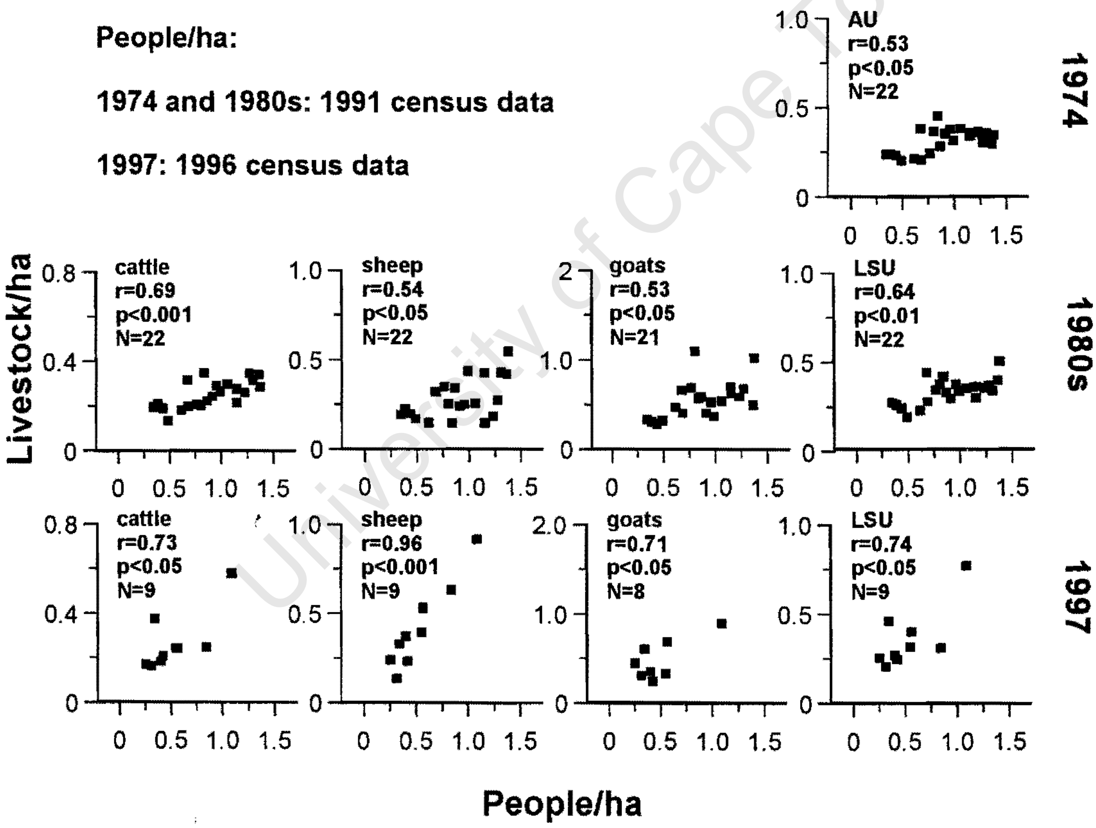

Figure 7.4. Densities of different livestock species against human population densities in different AAs. For 1974 and the 1980s, population census data from 1991 are used; the 1997 stocking rates are plotted against 1996 population densities.

7.3.3 Carrying capacity and herd growth: influence of rainfall and density dependent effects

The correlations of livestock numbers with the previous season's and the average of the two previous seasons' rainfall were similar, and they are presented in Figure 7.5 using the two-year running mean of seasonal rainfall. Sheep and goat numbers show no relationship at all with rainfall over time, even after a conspicuous outlier (1951 with nearly 100 000 sheep) was removed from the sheep data. This is unlike results from a more arid (MAP = 139 mm) communal rangeland in Namaqualand (Todd and Hoffman 2001), where small stock numbers were found to be strongly correlated with annual rainfall over time. Surprisingly, numbers of cattle and total LSU are negatively correlated with rainfall, i.e. lower in times of high rainfall and higher during and immediately after dry years.

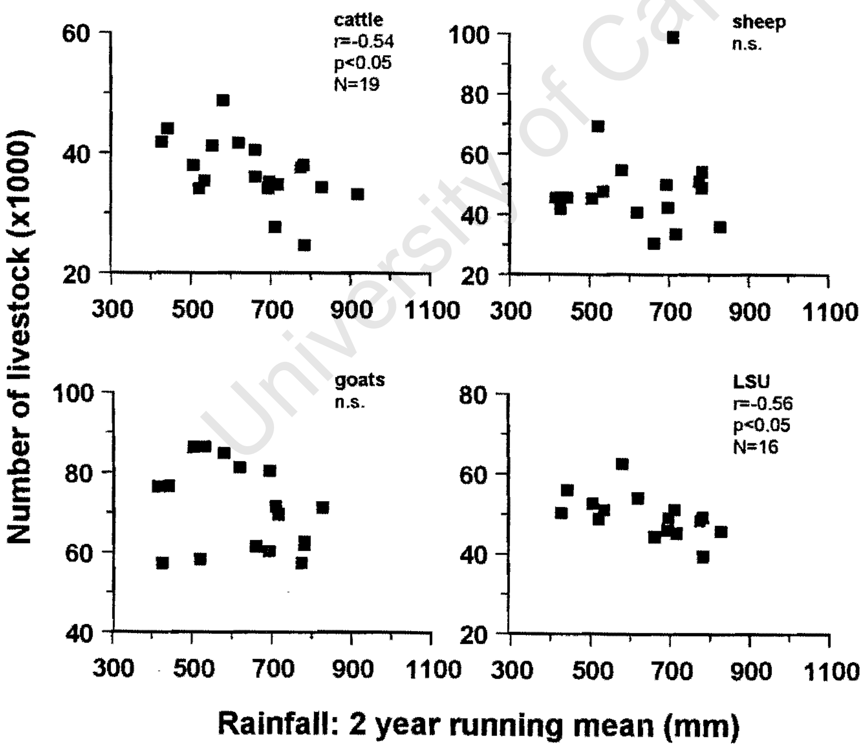

Figure 7.5. Total livestock numbers in the Herschel District for a given year plotted against 2-year running mean of annual rainfall (measured July to June) in Sterkspruit.

No correlations were found between herd growth (λ) and rainfall. When examining the relationships between λ of different livestock species with the numbers of livestock of the same species, total LSU and livestock of different species, the only significant correlations were between λ, of all species and total LSU, with goat numbers in the first year (N_t) (Figure 7.6). It appears from this result that high numbers of goats have a negative effect on herd productivity, not only of other goats but of all livestock species. This is possible because goats have a broad spectrum of feeding habits which allows them to offer maximum competition to cattle and sheep at high stocking rates, when they are forced to utilise all available forage, both grazing and browse.

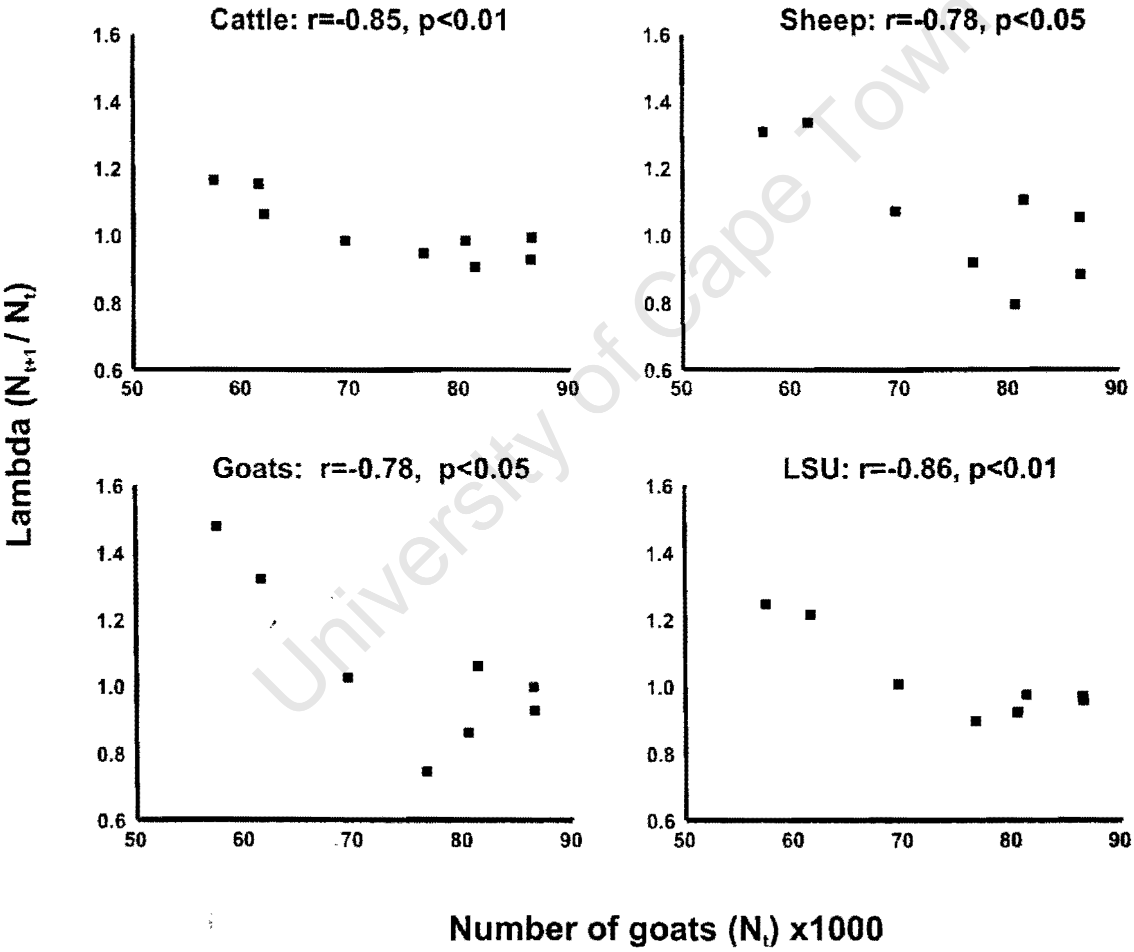

Figure 7.6. Herd growth (λ) of cattle, sheep, goats and total livestock against goat numbers in the Herschel district.

7.4 Discussion

7.4.1 How are stocking rates maintained – primary production, nutrients, key resources or inputs?

The positive relationship of stocking rates with rainfall, and their negative relationship with the dystrophic soils derived from Clarens sandstone (Table 7.5) in 1974 and the 1980s show the role of rainfall and soil nutrient status in determining an environment's carrying capacity. These findings agree with those described by Coe et al. (1976), Bell (1982), McNaughton et al. (1989) and Fritz and Duncan (1994) at the regional level. The fluctuations in livestock numbers over time, particularly in response to droughts (Figures 1.3 and 6.1) show that annual rainfall also affects stocking rates over time. Thus the data in this chapter show that calculating carrying capacities at the scale of hundreds of hectares from environmental data makes sense scientifically, but in planning and implementation at the local level, one also needs to take into account spatial heterogeneity caused by differences in topography, soil nutrient status and edaphic factors. In addition, adaptive management in response to annual rainfall is more appropriate than attempting to maintain constant stocking rates – especially if, as in Herschel, the stocking rates aimed for are very high.

From the data presented in Table 7.5 and Figures 7.3 and 7.4, it is clear that the factors predicting livestock densities in different parts of the district change between 1974 and 1997. Stocking rates in 1974 were best predicted by a combination of environmental factors which reflect the interaction of the positive effects of rainfall and the negative effects of the winter bottleneck on stocking rate. In the 1980s, the influence of people on stocking rates became increasingly important. While human population density already showed a positive relationship with stocking rates in the 1970s, in the 1980s it became the most significant predictor of cattle, sheep and total stocking rates, with environmental variables having a significant but weaker influence. In 1997, human population densities became the sole significant predictor of cattle, sheep and total stocking rates. This suggests that livestock numbers were increasingly being maintained by feed and other inputs made by people. The fact that livestock numbers actually increased over that period (despite the 1990s being a dry decade), suggests that people are not only maintaining livestock numbers, but are actually increasing them above the environment's ecological carrying capacity.

This has important economic and ecological implications. For the livestock owner, it is becoming increasingly expensive to keep less productive livestock (see Chapters 5 and 6). From an ecological viewpoint, keeping livestock numbers high during and after droughts poses risks of increased degradation. The idea that degradation is less likely to occur in rainfall-driven nonequilibrium systems relies to a large extent on the fact that grazing pressure is relieved after droughts because of high, density independent livestock mortality (Ellis and Swift 1988, Behnke and Scoones 1993). Even in less strongly climate-driven grazing systems, adjusting stocking rates to rainfall is recommended as an appropriate management strategy which reduces the risk of rangeland degradation (Danckwerts et al. 1993). In Herschel today, drought mortality is increasingly prevented (or prevented for longer) through the provision of feed, and drought losses are replaced by buying replacement stock after the drought breaks. As a result, the vegetation is heavily grazed during and after drought, when plants are most stressed. The interaction of drought and high grazing pressure has been shown to increase plant mortality and reduce recovery (O'Connor 1994 and 1995, O'Connor and Roux 1995), leading to reduced basal cover and increased risk of soil erosion.

The increasing rates of overstocking appear to be a phenomenon most common in the drier, low-lying parts of Herschel, and absent from high-altitude areas such as Pelandaba and Upper Telle. The lower-lying areas have the lowest recommended stocking rates (because of the lower rainfall and poorer veld condition), yet show the greatest increase in stocking rate over the years (Figure 7.2). The increasing stocking rates in these areas can partly be accounted for by the higher human densities, which mean that the average herd size is small, and people try to maintain and increase the size of these many small herds to satisfy their basic needs.

The low actual, relative to recommended, stocking rates in the high altitude areas also suggest that the extension officers' estimation of carrying capacities did not take into account factors such as soil nutrient status and temperature that influence the slope of the rainfall-herbivore biomass relationship. Figure 7.3 shows that the wetter areas consistently remain understocked from the 1970s to the 1990s, and Table 7.5 shows the negative relationships between stocking rates with the percentage of an area on Clarens sandstone and minimum winter temperatures. These data support the idea that livestock numbers are kept low in the more cold, eutrophic sourveld areas by a nutritional winter bottleneck.

There is no evidence from the data presented here that livestock numbers in Herschel are controlled by the resources available in key resource areas in the form of croplands. This is probably due to the very variable contribution that the different fields make to total available forage. Areas zoned as "arable" under betterment ranged in their suitability for crop production, and now comprise highly eroded patches, fallow fields with grass and weeds, fields cultivated with maize or sorghum, and fields used for the production of winter feed crops for livestock. Also, crop failure in dry years means that even arable lands which are regularly cultivated cannot provide a key resource when it is most needed. The role of river banks as key resource areas similarly varies. It differs between eroded and vegetated banks, and depends on whether the river bank is stony or a flood plain. Some areas, such as Upper Telle which lies along the Telle River, have among the lowest stocking rates in the district. Others, like N'Dofela and Wittebergen, which lie along the Orange River, have very high stocking rates. However, these areas are no more densely stocked than areas like Majuba Nek and Tugela which have no major rivers flowing through them.

A more systematic study of spatial heterogeneity, and seasonal variations in primary production and forage quality in different patches, is needed to understand the nature of key resources in Herschel, and whether they exist at all. The fact that most of the drainage lines and bottomlands in Herschel are eroded as a result of injudicious ploughing and heavy grazing (Chapter 4) may mean that areas which acted as key resources in the past have been lost. A comparative study of spatial heterogeneity in areas with different levels of soil erosion within Herschel, or even a communal-commercial comparison, could be used to investigate this. A knowledge of the nature and role of key resources in Herschel would be of great value from a management point of view.

It would also be worthwhile to do similar studies of correlates of stocking rates in communal areas in different vegetation types, to determine how representative the situation in Herschel is. In the semi-arid succulent shrublands of Namaqualand, Todd and Hoffman (2001) found that mean maximum summer temperature explained over 80% of the variance in stocking rates of goats plus sheep. They concluded that the main source of forage in this heavily stocked communal grazing area had shifted from palatable perennial shrubs to annual herbs. Annuals are more responsive to the effect of growing season, which is a function of temperature extremes in winter and summer in this area. It thus appears that not only the response of the vegetation to heavy grazing, but also the effects on secondary production and carrying capacity, differ with rainfall and vegetation type.

7.4.2 Are livestock populations regulated by rainfall or density-dependence?

The analysis of livestock numbers and herd growth rate against rainfall and initial livestock numbers is, of necessity, rather simplified. Both livestock numbers and changes in herd size are not only a function of reproduction and mortality, but also of buying, selling and slaughtering. In the absence of detailed herd dynamic data over a long enough time, the livestock census data and the herd size changes calculated from it were used as a crude measures of carrying capacity and herd productivity respectively.

From the data presented in section 7.3.3, there is no evidence that livestock numbers change in direct response to rainfall. In fact, Figure 7.5 shows exactly the opposite, namely that cattle and total livestock numbers are negatively related to the previous two seasons' rainfall. No explanation for this can be gained from the available data. It is possible that high inputs during droughts, and purchases of livestock after droughts, maintain stock numbers high in dry years. People are reluctant to sell livestock during and after dry years (Chapter 5), and if slaughter and sales occur primarily in wetter years, this may account for the observed pattern. Clearly, however, this surprising result needs further investigation.

Herd growth (λ) is unrelated to rainfall, although one would expect higher birth rates and lower mortalities in years of high rainfall. Grass production in semi-arid grasslands and savannas is correlated with rainfall, and grazing trials over a ten-year period in a semi-arid savanna (mean annual rainfall 568 mm) showed that cattle performance was more responsive to rainfall than herbaceous biomass and stocking rate (Fynn and O'Connor 2000). In Herschel, the factors causing the apparent negative correlations between stock numbers and rainfall (buying of stock, supplying of feed inputs, different rates of slaughter and sales in wet and dry years) would undoubtedly obscure the relationship between herd growth and rainfall which may have existed in the absence of these confounding factors.

Of interest, then, is the significant negative correlation between goat numbers and herd growth of all livestock species. The fact that herd growth of all livestock species, individually and combined, is lower when numbers of goats are high suggests that goats are strong competitors which have a significant impact on other livestock species. Goats are highly selective feeders and are generally classified as browsers. They are, however, opportunistic feeders able to shift to a grass-dominated diet if grasses are nutritionally superior to browse (Pfister and Malechek 1986; Rutagwenda et al. 1990, Grünwald *et al.*

1994). Grasses were found to have higher digestibility values than shrubs in a study of livestock diets in Karoo vegetation (Zeeman et al. 1983), and I found little evidence in the field of goats browsing Karoo shrubs. Goats would thus be expected to compete with cattle and sheep for grass in Herschel. While goats are useful in *Acacia* savanna in controlling bush encroachment, and stocking with cattle and goats allows more complete utilisation of the available forage (Aucamp et al. 1984, Trollope 1980, Beckerling et al. 1995), this does not apply in grassland areas where browse is scarce.

Considering the struggle of many people to maintain sheep and cattle numbers with feed inputs while their goat flocks grow (see Chapter 5), it is important to investigate the competitive relationships between the different livestock species. If goats really have a strong negative impact on other livestock species, then controlling their numbers (preferably through an accessible marketing system) would make more forage available to other, more preferred, livestock species.

Appendix A. Descriptions of abbreviated variable names used in Table 7.3.

Variable name	Variable description
Cattle 80s	Cattle per hectare (mean 1982-1987)
Sheep 80s	Sheep per hectare (mean 1982-1987)
Goats 80s	Goats per hectare (mean 1982-1987)
LSU 80s	Total LSU per hectare (mean 1982-1987)
Cattle 97	Cattle per hectare (1997)
Sheep 97	Sheep per hectare (1997)
Goats 97	Goats per hectare (1997)
LSU 97	Total LSU per hectare (1997)
Recomm	Recommended stocking rate, AU per hectare (1974)
Res 74	AU/ha (1974) - recommended AU/ha
Res 80s	AU/ha (mean 1982-1987) - recommended AU/ha
Res 97	AU/ha (1997) - recommended AU/ha
People 91	People per hectare, 1991 census
% arable	% of area zoned as land for cultivation
% sediment	% of area on Molteno and Elliot sediments and Alluvium
% igneous	% of area on basalt, dolerite and pyroclastic material
% Clarens	% of area on Clarens sandstone
%slope>40	% of area on slope exceeding 40°
Meanslope	Mean slope of area (degrees)
MAP	Mean annual precipitation (mm)
MAP STD	Standard deviation of mean annual precipitation
JUL Tmin	Mean minimum temperature in July (°C)
JAN Tmax	Mean maximum temperature in January (°C)
Frostdur	Average duration of the frost period (days)
Frostdays	Average number of days with heavy frost
Altmean	Mean altitude of area (metres above sea level)
%alt>2000	Percentage of area above 2000m altitude

8. SYNTHESIS AND CONCLUSIONS

This study set out to understand the costs of environmental degradation to communal livestock farmers in South Africa, using a case study of the Herschel district. This was done against the background of a debate among researchers and policy makers about appropriate ways of assessing degradation in communal rangelands. The non-equilibrium arguments that degradation rarely occurs in semi-arid rangelands, and that there is little evidence that vegetation changes and soil erosion associated with rangeland degradation materially affect people's livelihoods, have influenced South African agricultural policy (Dikeni et al. 1996). The lack of a decline in livestock numbers in many communal farming districts in South Africa has been used as evidence that there had been no loss of the land users' ability to fulfil their objectives (e.g. Tapson 1993). The conclusion that concern about overgrazing and rangeland degradation is thus unfounded in most communal rangelands in South Africa provided the starting point for this research.

This study attempted to uncover changes in rangeland degradation and agricultural productivity in the Herschel district over time, against the socio-economic, political and population changes that took place from the late 19^{th} to the end of the 20^{th} century. This was coupled with an attempt to explore variations in degradation, agricultural productivity and ecological dynamics within the same communal district. Studies in South African communal rangelands linking degradation indices such as botanical composition and soil erosion to livestock production and the achievement of people's production objectives were almost non-existent when this study was initiated. Exceptions are the study of cattle production by Tapson (1990) in KwaZulu, and the detailed analysis of historical changes, livestock dynamics and household economy by Scoones (1990) in southern Zimbabwe. Little work of a comparable depth has been done since, and there is still a need for a better understanding of these interactions than these few studies can provide.

This final chapter revisits the questions asked in the first chapter, namely whether the nonequilibrium paradigm provides a useful framework for understanding South African communal rangelands, and what kinds of criteria are appropriate for assessing degradation in communal rangelands in South Africa. It concludes with a discussion of appropriate policy and interventions in Herschel and other South African communal rangelands.

8.1 How well does the nonequilibrium paradigm describe the dynamics of South African communal rangelands?

The primary aim of this study was not to provide a comprehensive test of nonequilibrium theory, which would have required data to be collected over several years to reveal the effect of rainfall on the vegetation and livestock populations. However, the nonequilibrium debate and policy implications form the background to this research, and one of the key questions was whether livestock populations in Herschel are so strongly driven by annual rainfall that they seldom if ever have an impact on vegetation and soil resources. I found that in the Herschel district, neither the vegetation, soil erosion nor livestock data support this theory.

The nonequilibrium prediction that long-term grazing impacts on the vegetation are negligible is refuted by the data in Chapter 3, which show that plant composition differs significantly between the heavily grazed Herschel district and the more lightly grazed commercial farms, with higher proportions of less palatable and productive grass species in Herschel. Soil erosion, shrub density and bare ground are also significantly higher in Herschel. Soil erosion increased substantially between 1950 and 1995 (Chapter 4). While high erosion levels in the lowlands can partly be attributed to the ploughing of marginal land and the extremely erodible nature of the soils, soil erosion in areas used solely for grazing shows that ongoing, grazing-induced soil erosion is a costly risk which cannot be ignored. The observed response of the grass community and soils to sustained heavy grazing in Herschel was consistent with predictions of the "mainstream" rangeland succession model, although this does not prove that succession is the underlying mechanism for these responses.

South Africa is an ecologically diverse country, with communal rangelands inhabiting a range of environments from semi-arid succulent shrublands to subhumid cool grasslands. The Herschel district is an area falling on the wetter and colder end of the spectrum from semi-arid to subhumid, and its duplex soils and steep topography make the area extremely vulnerable to soil erosion. In fact, the Herschel district was chosen as a study area because it represented a worst-case scenario. Great care must thus be taken when trying to apply the findings of this work to other communal rangelands in South Africa.

Evidence from arid environments (e.g. Ellis and Swift 1988, Ward et al. 1998, Sullivan 1999) suggests that these systems are well described by the nonequilibrium paradigm. Arid rangelands appear to be resilient to long-term intensive grazing, because the grass sward is dominated by annual grasses which do not germinate or establish in the absence of rainfall. Grasses grow from a seed bank in subsequent wet years, with biomass production more or less proportional to the amount of rainfall. As Sullivan and Rohde (2002) argue, there may be literally no grass to overgraze in a drought year. In systems dominated by perennial grasses, on the other hand, heavy grazing can exacerbate drought mortality of grass tussocks and hinder post-drought establishment of seedlings (O'Connor 1994). Compositional changes and local extinction of grass species such as *Themeda triandra* following drought are greater under heavy grazing than under light or no grazing (O'Connor 1995, Fynn and O'Connor 2000). Perennial grasses invest less in reproduction from seed than annual grasses, and their dispersal, recruitment and establishment is therefore often seed-limited. As grass tufts die and grasses fail to re-establish, more soil becomes exposed and hence vulnerable to erosion. O'Connor and Roux (1995) found that the long-term response to grazing was most pronounced in longer-lived plants, whereas the growth of annual grasses directly responded to rainfall from year to year. More research is needed to gain a predictive understanding of the response of different environments to heavy communal grazing.

The livestock census data show that livestock numbers in Herschel do not track rainfall, nor do they drop dramatically after droughts or take a long time to recover after droughts. Livestock numbers showed no positive response to rainfall at any stage of the livestock census data series, and neither did population growth rates (Chapter 7). Chapters 6 and 7 indicate that livestock numbers in Herschel are increasingly maintained by farmers through resource use changes, feed inputs and buying replacement stock after droughts. An important consequence of this is that a high grazing pressure is maintained during and after droughts, which further increases the risk of rangeland degradation.

8.2 What are appropriate measures of degradation in South African communal rangelands?

Herschel is an area supporting over 130 000 people, many of whom face chronic financial and food insecurity. In areas such as this, the most appropriate and justifiable criterion in assessing degradation is the sustained ability of the land to support livestock production and other goods and services towards people's livelihoods. This study has focused on livestock production, which is the primary land use in Herschel, and found that people's ability to sustain livestock and yields of livestock products has declined in parallel with declines in the natural resource base. Reconstructing this in any detail proved to be difficult due to a lack of production data over time. Many strands of evidence had to be drawn together to infer changes in productivity, and much of this relied on available, sufficiently detailed stock census records, historical information, and people's recall. This proved to be a time-consuming approach which may not be conducive to replication over many sites. There is thus a need for developing a more time- and cost-effective protocol for assessing degradation and its costs to land users in other communal areas in South Africa to obtain a broader, more representative picture of degradation in South African communal rangelands.

It became clear in this study that livestock numbers alone are a poor indicator of degradation. There are two main reasons for this. Firstly, the numbers themselves did not reveal the changes in productivity, reproduction, purchases and offtake which had taken place over time. Secondly, maximizing livestock numbers at the expense of offtake is not really an objective of livestock owners in Herschel, but rather something people aim for under the constraints of the overpopulated, open-access system that they try to farm in. In Herschel, people aim to maximise livestock numbers to maximise the benefits derived in a system where offtake and production are proportional to livestock numbers because of the individual's lack of control over stocking rates. The small average herd size further discourages people from reducing the number of livestock they own.

Since livestock numbers and performance are of greater interest to livestock owners than veld condition *per se*, ways of assessing and monitoring degradation should ideally be based on livestock variables. Fowler (1981), for example, used a continuous series of cattle census data from 1954 to 1980 in Swaziland to compare calving, death and offtake rates over time. Scoones (1990) used data on livestock numbers, sales, births and deaths covering more than 60 years to explore the ecological and economic dynamics of cattle in southern Zimbabwe. These studies illustrate the great value of accurate, long-term livestock records for monitoring the productivity of rangelands over time, and exploring the relationships of productivity with rainfall, livestock densities and external factors. One of the greatest obstacles to assessing the productivity and sustainability in communal rangelands, in South Africa and elsewhere, is the lack of reliable livestock census data. More detailed data on reproduction, mortality, offtake and livestock ownership (e.g. the number of herds in an area, the average herd size, and herd composition) are usually unavailable. With the phasing out of state-provided dipping services and the accompanying collection of livestock census data in South Africa, even the continued availability of data on total livestock numbers is uncertain.

A key finding of this study was that degradation, in the form of soil erosion and vegetation cover and composition, had in fact resulted in reduced livestock production. The effects of denuded vegetation cover on livestock production were recognized by many livestock owners in Herschel. In contrast to livestock data, aerial photographs covering the whole of South Africa are available for different years and go back to the 1930s in most parts of the country. Compared to measuring livestock productivity, measuring botanical variables and soil erosion is relatively simple to carry out, especially in a communal system where actual stocking rates at any time are hard to determine, livestock are relatively mobile, and there are many constraints to experimental work involving animals (ILCA 1990). Thus there are strong incentives for establishing whether there are predictable relationships between livestock production and more easily measured indicators of vegetation condition and soil erosion. Methods of assessing rangeland condition which give a relevant measure of the potential for livestock production under communal systems would be very valuable tools for monitoring sustainability in these areas. These should be developed in collaboration with the land users, using criteria which they recognize to be indicators of grazing value and as having a positive or negative impact on livestock production.

There is a need for studies to understand how communal farmers assess the grazing value of different areas, and the empirical basis of these assessments. Issues worth investigating are the criteria people use, the scale at which grazing value is assessed, and how these assessments correlate with forage production and quality. Goqwana (unpublished data) found that livestock herders in Herschel used high standing biomass and the availability of green grass as indicators of good veld condition, rather than botanical composition. The green grass seen as a valuable resource in Herschel was often *Eragrostis plana* and *Cynodon dactylon*, both rated as having very low grazing value by commercial farmers (e.g. van Oudtshoorn 1999, Beckerling et al. 1995). Conventional range assessment views these species as indicators of degraded vegetation, because they thrive under heavy grazing. Livestock owners in Herschel, on the other hand, view these species as dry season key resources, as their contribution to forage flow at a crucial time of the year compensates for the low total biomass production of *C. dactylon* and the tough stems and low digestibility of *E. plana*. Clearly, there is a need to review our understanding of the relationship between grass composition, biomass and productivity and livestock production under communal rangeland conditions. This should aim at an understanding of the contribution of different patches in the landscape to forage flow at different times of the year, and identifying the crucial forage bottlenecks in different types of rangeland systems.

8.3 Options for grazing resource management in Herschel

South Africa has a long history of research, extension services and incentives aimed at reducing soil and vegetation degradation. This has, however, largely served the commercial farming sector. In situations where veld management strategies have been enforced in communal areas (e.g. during betterment planning), they were unpopular and soon abandoned. However, many livestock owners in Herschel are dissatisfied with the condition of the grazing resource, and many attribute this to a lack of management. The main options available for managing grazing are manipulating the demand for forage, by controlling animal numbers (e.g. by selling livestock), and manipulating the forage supply by regulating the use of different grazing areas and providing alternative sources of feed. Different potential management strategies are discussed below.

8.3.1 Controlling livestock numbers

For as long as excessively high livestock numbers have been held responsible for land degradation in communal rangelands, destocking has been the most commonly proposed and enforced solution, often in conjunction with rotational grazing. Destocking has always met with resistance in communal rangelands, and is still unpopular today. None of the farmers I interviewed felt that destocking was an acceptable solution, even those people who judged Herschel rangelands to be degraded because of the excessive human and livestock densities. Destocking is difficult and expensive to implement, practically and politically, as the loss of livestock would come at a cost to the land users, who are already among the poorest people in the country. Thus, although reduced stock numbers would most probably result in better veld condition and higher livestock productivity, destocking is not a recommended intervention to improve the condition and productivity of Herschel grazing land, unless the farmers themselves agree that it is necessary. Even then, care must be taken to ensure that such decisions represent the whole spectrum of land users, and that the interests of some farmers do not compromise the livelihoods of poorer people who are most vulnerable to changes in policy which limits access to natural resources.

An interesting finding of this study was the apparent density-dependent effect of goat populations on the productivity of other, more preferred, livestock species. The competitive interactions between goats and other livestock species are worth investigating, especially since a trend of increasing goat numbers accompanied by declining sheep numbers has been observed in Herschel and other communal farming districts in South Africa (see Chapter 6). If reducing goat numbers were to benefit cattle and sheep production and to reduce the need for expensive inputs, regulation of goat numbers through marketing might be an acceptable strategy to livestock owners. Most goat owners were willing to sell more goats but were unable to find enough buyers.

8.3.2 Controlling livestock movement

Livestock grazing patterns in the grasslands and savannas of South Africa were traditionally based on seasonal transhumance between eutrophic savanna (sweetveld) in winter and dystrophic grassland (sourveld) in summer. This was done by Xhosa-speaking agropastoralists in the Eastern Cape (Ainslie 2002 and references therein) as well as by white trekboers (Rowland 1937, cited in Coughenour 1991) until settled farming put an end to this practice. In Herschel, the annual pattern of grazing the lowlands in winter and the mountains in summer was based on a similar notion: utilizing the high-altitude areas in the growing season while the grasses are palatable and nutritious, and moving into the lowlands at the end of summer, where the forage retains its palatability year round. Crop residues and grasses which had accumulated during the growing season provided a crucial dry season forage reserve.

Rotational grazing systems were first proposed in the late nineteenth century in the U.S.A. (Smith 1895, cited in Coughenour 1991), when the open ranges in the western U.S.A. became increasingly restricted by homesteaders from 1912 to 1925. The resulting dense, settled livestock populations were observed to lead to rangeland degradation (Coughenour 1991). The aim of rotational grazing is to mimic the intermittent, relatively heavy defoliation patterns imposed by native ungulates under which the grasslands had evolved. Rotational grazing also aims to avoid area-selective grazing by livestock, which leads to the under-utilisation of less favoured patches while preferred patches are overgrazed and degraded (Danckwerts et al. 1993). The benefits of rotational grazing are however still debated, both for the grass sward (O'Connor 1985) and animal performance (Coughenour 1991, O'Reagain and Turner 1992, Danckwerts et al. 1993).

Rotational resting, on the other hand, has been advocated as an effective way of storing forage for the dry season and allowing grasses to accumulate carbon reserves and/or to set seed. Under rotational resting, a different part of the range is rested for a length of time every year, while the remainder may or may not be used continuously. The season and duration of rest is determined by the environment and the farmer's objectives, e.g. whether it is aimed at storing forage, ensuring seed set or restoring the vigour of the grass sward. Resting is an effective way of buffering the effects of variable rainfall in semi-arid areas (Danckwerts et al. 1993). Rotational resting was also found to lead to improved veld condition in the False Thornveld of the Eastern Cape, while allowing the maintenance of relatively high stocking rates (Trollope 1984). This has led to recommendations that rotational resting should be implemented in communal areas of the Eastern Cape as a more realistic alternative to reducing livestock numbers (Trollope 2000).

A rotational resting system in Herschel could make use of the existing fences, although most of these need repair. There are several areas in the former homeland areas which have maintained a simple rotational resting system based on the grazing camps established during Betterment Planning. This was found in some villages around Alice in Ciskei (Goqwana 1998), where rotational resting had led to a more even use of the resource, less variability in veld condition and an overall higher grazing capacity. In the Herschel district, farmers in the Tugela and Madakana administrative areas are trying to implement rotational resting using the betterment grazing camps, with the aim of maintaining a forage reserve and improving the condition of grazing areas.

People in Herschel face several problems in their attempts to rest grazing camps. The fences are in disrepair and cannot prevent livestock from crossing camp boundaries. Some camps do not have water points and therefore cannot be used in winter, while camps that have water points are used every winter for the same reason and are therefore never rested for a whole year. Livestock theft, which has increased dramatically throughout South Africa over the last decade, necessitates herding and kraaling of livestock. For this reason, livestock cannot simply be left in grazing camps over night, and a shortage of herding labour prevents many livestock owners from accessing pastures far from the village. There is no recognized authority to regulate the use of grazing areas, and thus a lack of co-operation by livestock owners. It is important to address these factors, particularly the institutional aspect.

The planning of a grazing system must be done in consultation with livestock owners, and should take into account the need to access water and palatable grasses in winter, as well as the kraals where animals are kept at night. Perhaps the failure of present-day attempts to use the camp system for grazing management is partly due to the fact that existing fences and grazing rules do not allow access to water, kraals and key grazing resources when they are needed. This, and the expense of fencing, will probably necessitate alternative and more innovative ways of regulating grazing and resting patterns in many areas. Possibilities for concentrating grazing in some areas while resting others include the use of herding, regulating water supply or even fire to manipulate grass palatability (Danckwerts et al. 1993).

One of the decisions to be made is whether the resting system should be based on the traditional transhumance pattern of using highlands in summer and lowlands in winter, or whether certain areas should be rested for an entire year on a rotational basis. Perhaps the two systems can be combined, incorporating transhumance and resting small areas for the whole year. According to some informants, this used to be part of the traditional system – the transhumance was aimed at ensuring a forage reserve for winter, while some areas were rested for longer to allow grasses to set seed. A better understanding of the traditional and present patterns of exploiting spatial heterogeneity would be very useful in designing an acceptable and effective grazing management system in Herschel and other communal rangelands.

8.3.3 Reclamation of eroded areas

One of the questions that arises when working in a severely eroded area such as Herschel is whether reclamation of the enormous erosion gullies is a feasible and worthwhile option, given the great investment of time, labour and resources required. At present, the low returns from agriculture make a major investment on the part of livestock owners in Herschel unlikely. From interviews with people in Herschel it became clear that while people found dongas to be undesirable, spending time and money on donga reclamation ranked as a low priority. This was partly due to the fact that dongas were not seen as a direct threat to livestock production, except for times when animals fall into the gullies while looking for food. Also, the magnitude of the problem appears overwhelming to people in Herschel, who feel that the state should take responsibility for donga reclamation (as it did in the betterment era) and pay people for their labour. Several people I interviewed saw donga reclamation as an opportunity for job creation, but not something that they would initiate themselves.

There are exceptions to this – in Sunduza, a village which had a resident EDA field worker for several years and has been active in development initiatives, people showed me a donga which had been blocked and which had filled with silt. Kikuyu grass (*Pennisetum clandestinum*) now grows on the reclaimed area. This points to the potential of reclaimed dongas to provide key resources in the form of patches of green grass. It was impossible to reconstruct from the aerial photographs what the lowlands looked like before dongas were initiated, as the major gully systems were already in place by 1950. It is quite likely, however, that dongas removed key resources such as wetlands or riverine vegetation. Experimental reclamation of some dongas, accompanied by monitoring of the quantity and quality of forage produced by the area before and after reclamation, would reveal how much the reclamation of dongas would contribute to forage production. Donga reclamation would also reduce the loss of topsoil from Herschel to the Orange River, where it contributes to the silting up of major dams. Once the total economic value of donga reclamation is apparent, it may be worth allocating state funding to soil conservation works. This would provide the dual benefit of creating temporary employment and increasing the productivity of the land. It is important to bear in mind, however, that the long-term success of donga reclamation depends on people's willingness to participate in the long term, as well as management of the vegetation and soils upstream.

8.3.4 Suitable government interventions and support

Government interventions in the South African communal rangelands have moved from a system of government control and centrally planned interventions without consultation, to a policy of seemingly minimal intervention and support. This policy is not limited to communal areas. The subsidies which commercial farming enjoyed under the National Party government were abandoned since the change in government in 1994, and as the then Minister of Agriculture Derek Hanekom put it[8], "the government will not pay people to be farmers". For example, the stock permit system and compulsory free dipping against ticks is being phased out under the new agricultural policy, and along with it the collection of livestock census data. While it is understandable that the state faces budgetary constraints, financial and extension support is urgently needed in the neglected former homeland areas, where shortage of land, labour and capital is hindering agricultural production.

From the point of view of natural resource management and investment in farming activities, access to markets, information and extension advice is likely to achieve more than regulations and restrictions. Interventions by government extension services or non-governmental organizations should be perceptive to the objectives and constraints of rural people, and developed and implemented in consultation with land users. Interviews with farmers in Herschel have revealed a greater than expected inclination to produce some commodities commercially, and this is borne out by the large quantities of wool produced and sold annually. Access to markets has great potential to improve the economic situation in Herschel, which may lead to greater investment in farming and natural resource management. Marketing has focused on cattle, and still does today; yet cattle

[8] In an opening speech at a symposium on policy-making for the sustainable use of Southern African communal rangelands, held at Fort Hare University, Alice, South Africa, July 6-9, 1998.

are the species of livestock people are most reluctant to sell, because of their great value as a store of wealth, and the small number owned by most people. The data collected in Herschel suggest that marketing of small stock would have a greater chance of success than cattle sales. Access to markets does not only mean more livestock auctions – it also includes better roads and other infrastructure, better and more readily available information, and better access to financial services. At this point, there is a single bank serving the entire district, and the roads in most of Herschel are in such bad condition that trucks cannot or will not use them.

People in Herschel are generally aware that the human and livestock numbers in Herschel are far too high, and that this causes the poor condition of the vegetation and soil. Even in the 1920s, when the population of Herschel was less than a third of its present size, Macmillan (1930) commented that

> "In Herschel itself 'overstocking' is a fact, but it is also only a relative term. For a people who are supposed to be entirely dependent on the land and must have cattle for ploughing and transport, as well as for food, it is doubtful if an allowance of less than one head of cattle per unit of population is at all excessive – even with two or three head of small stock in addition. [...] It is really the population which is excessive and more than the district can hope to support under present conditions." (p. 150).

This was also emphasised by the Tomlinson Commission (Union of South Africa 1955). For future land management, it is important to note that an awareness of degradation and its causes exists, and that there is evidence that community members in some areas are interested in better livestock and veld management in particular. Unfortunately, overpopulation and poverty are serious obstacles to achieving improved management which involves the entire community. Overgrazing in Herschel is a reality, which can only be overcome with commitment from the state towards supporting agriculture in the communally farmed areas, as well as improving access to land, education and employment. Taking the stance that "agriculture has to pay for itself" in areas where the state has interfered for decades with policies aimed at undermining the self-sufficiency of the people, is not only unjustified but will leave an even greater legacy of poverty, degradation and underdevelopment in South Africa.

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