IMPACTS OF LIVESTOCK ON REHABILITATING POST-MINING DUNE FOREST IN ZULULAND

BY

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DECLARATION

I **THAMSANQA DOCTOR EMPIRE MPANZA** declare that the work contained in this thesis is my original work except where reference has been made. This work has not been submitted nor will be submitted for an award in another university or institute of higher learning.

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DEDICATION

This work is wholeheartedly dedicated to my beloved parents Cynthia Vivace Hlengiwe Linda (Nsele kalinda kaMkhonto) and Mandlakapheli Bhekuyise Mpanza (Thabekhulu, Sandanezwe, Mavundla, Siwela, Donda).

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I shall not forget the contribution made by Richard's Bay Minerals (RBM) for allowing me to work in their rehabilitating area with the help of Mr B Mkhize (employee of Dune Rehab Service) and Mr Mthiyane (RBM employee as cattle guard).

I would like to thank Almighty God for giving me strength, energy and ability to develop myself through this study. He has always been wonderful to me, "***for great is his love towards us, and the faithfulness of the Lord endures forever***" Psalm 117: 2.

I also like to thank my grandmother, for being helpful and supportive to me through this study. Furthermore, I would also like to thank my late aunt and uncle who passed away in 2001 and 2002 respectively may their soul rest in peace. They have been supportive to me.

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ABSTRACT

Richard's Bay Minerals (RBM) disturbs the natural vegetation by mining heavy minerals (zircon, rutile and ilmenite) along the northern coast of KwaZulu-Natal province of South Africa. The disturbed area has to be rehabilitated in order to be reused by the future generation. RBM initiated a rehabilitation program in 1978 where the mining commenced, and that has resulted in stands of different ages, however, little is known about the impact of cattle from neighbours grazing in this rehabilitating forest. The study of the impact of cattle grazing on the oldest stand which has been under ecological rehabilitation for 28 years (during the time of the study) was conducted in order to assess the effect of cattle grazing. The following questions were addressed.

- What is the impact of cattle on the structure and functioning of rehabilitating forests on the coastal sand dunes?
- What impact do grazing cattle have on the micro-environment of the rehabilitating forest?
- Do communal cattle disperse some exotic tree species from the community to the rehabilitating forest?

The study comprised of two components which are field and laboratory experiments. Field experiment was conducted on the 28 years old rehabilitating stand (see figure 2.2 in chapter two) and lab experiment was conducted at the University of Zululand in KwaZulu-Natal Province of South Africa. Field experiment addressed the impact of livestock grazing in the rehabilitation. Therefore a one-hectare plot was demarcated and divided into two halves. One half was fenced (exclosure) to prevent cattle grazing and the other half was unfenced (control) to allow cattle grazing. Eight transect belts of 80 m^2 each were marked per subplot and three

markers were pinned (one on each end of the transect belt and one in the middle) per transect belt. Transect belts were 5 m apart. A total of sixteen 0.25 m^2 quadrats were clipped between the markers per subplot (exclosure and control). Clipped biomass was oven dried and weighed and further analysed for NDF and CP. Seed germination surveys was also conducted per subplots around each marker in a complete randomised design with four replicate.

Laboratory experiment was conducted at the University of Zululand as a multi-factorial experiment which evaluated the external (possible damaging) factor(s) on *Acacia karroo* and the experiment was arranged in complete a randomised design with four replicate. A total of 972 *Acacia karroo* seeds were sown in 324 pots which were filled with sandy soil and each pot was planted with three seedlings. Seedlings were subjected to the following treatment: damage, water, fertilizer and shade each having three levels. At the termination of the experiment seedling height was measured and seedlings were oven dried at 60^0C for 48 hours, after which shoot and root dry mass were recorded separately.

Another experiment was proposed based on findings that guava was a dispersed tree species in the rehabilitating forest. Therefore a pot experiment was conducted in order to check the effects of grass, damage and water in guava establishment in the rehabilitating forest.

The *Psidium guajava* experiment differed from the *Acacia karroo* experiment because shade was standardised (all pots were shaded by 80% shade cloth) and fertiliser was replaced by grass competition, making three factors. Another difference was that treatments were replicated eight times with one pot per treatment. Guava seeds were sown in 216 pots and seeds were not counted, but before guava was sown LM grass was sown in two thirds of the pots and it was given two months for establishment prior guava seeds being sown. One month after germination, seedling height was measured and three of eight replicates per factor was terminated prior to infliction of damage treatment. The remaining seedling height was measured weekly until the experiment was terminated month later. Seedlings were oven dried at 60^0C for 48 hours, and thereafter root and shoot was weighed separately and in three out of five remaining replicates seedling leaf was weighed separately.

Statistical significance was considered at the 5% level ($P < 0.05$). Cattle grazing in the rehabilitating forest was found to reduce seedling establishment significantly ($P = 0.041$) by 49.8%. Communal cattle which grazed in the rehabilitating forest reduced herbaceous biomass by 51.8% ($P < 0.001$). There was no significant difference in NDF and CP between the subplots ($P = 0.165$ and $P = 0.453$ respectively). Cattle consumed guava seeds and they dispersed them in rehabilitating forest which was the most preferred for gazing. Germination tests done on guava seeds that had passed through livestock alimentary canals as compared with fresh seeds (from tree), showed that the passage of guava seed in the digestive track did not trigger germination. Livestock play a major role in the livelihood of Kwa-Mbonambi communal farmers, however livestock mortality and shortage of grazing land were their major constraints in livestock operation. Communal farmers in Kwa-Mbonambi keep livestock for cultural activities and to support their families since they are unemployed. Their cattle invade the rehabilitating forest where they disturb the rehabilitation programme. Therefore cattle grazing in the rehabilitating forest hinders seedling establishment and herbaceous cover and that disturbed the micro-environmental condition of the forest.

Damage in the form of clipping significantly reduced height of *Acacia karroo* seedlings ($P < 0.001$), by 75.9%. There was no significant effect on seedling height due to factor interactions ($P = 0.338$). Shades decreased shoot mass of seedlings by 19.9% ($P < 0.001$). Moreover there was a significant effect of interaction of three factors namely fertiliser, water and damage ($P = 0.020$). Daily watering reduced shoot mass in the absence of fertiliser. Shade reduced root mass significantly ($P < 0.001$) by 33.1%. Clipping also reduced root mass significantly ($P < 0.001$), however watering daily increased root mass of clipped seedlings in the absence of fertiliser.

Grass had a significant effect on guava seedling establishment ($P < 0.001$). Irrigation also had a significant effect on growth of guava seedlings ($P < 0.001$). Grass reduced the growth rate of guava seedlings. Clipping reduced root mass significantly ($P < 0.001$). The highest interaction had a significant ($P.< 0.028$) effect on root mass, where as in seedling height and shoot mass the highest interaction of three factors had no significant effect ($P = 599$ and $P = 0.186$).

Damage in the form of clipping significantly reduced seedling height, in other words it hinders growth rate and the establishment of tree species. *Acacia karroo* is known to allocate more nutrients in root growth, however clipping reduced root growth in order to compensate shoot regrowth after clipping. Though guava is dispersed by communal livestock grazing in the rehabilitating forest their establishment is hindered by grass.

In conclusion *Acacia karroo* was found to be suitable for the rehabilitating programme with low supervision. *Acacia karroo* is regarded as an invasive tree species, and since it is a legume it has nitrogen fixing bacteria in roots hence it enriches soil with nitrogen and it has a competitive ability in nitrogen poor soil. Though guava found to be dispersed by cattle in the forest, its establishment was found to be hindered by grass, therefore it is very rare for guava to invade the forest. The follows recommendations are proposed for the smooth operation of rehabilitation. There is a need for research on the long-term impacts of livestock. The two communities of Kwa-Mbonambi and RBM need to reach a point where they agree on the importance of rehabilitation.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 BACK GROUND

In South Africa the public's growing interest in the environment as associated with nature conservation has been changing from an idealistic philosophy to a serious technology, with ecology firmly established as the science of environmental conservation (Van Aarde *et al.* 1996). An inevitable result of urban expansion and development is increased pressure on natural resources and biodiversity (Scogings *et al.* 1999). Urban expansion is generally accompanied and also driven by industry and commerce, which both largely depend on natural resources. For example, along the coast of the KwaZulu-Natal province of South Africa, Richard's Bay Minerals (RBM), in its pursuit of raw materials, disturbs the natural coastal vegetation by employing a wet mining process (Figure 1.1a) to extract heavy minerals (zircon, rutile and ilmenite) from sand dunes (Figure 1.1b). Figure 1.1c shows the same area after rehabilitation which was initiated in 1978 (Kumssa *et al.* 2004 and Van Aarde *et al.* 1996). In this case, one-third of the mined area is being rehabilitated to indigenous vegetation by sweet thorn trees (*Acacia karroo*), while the remaining two-thirds is re-vegetated by the introduction of exotic beefwood (*Casuarina equisetifolia*) (Figure 1.1c) for the development of a local charcoal industry (Figure 1.2) (Van Aarde *et al.* 1996b and Weiermans and Van Aarde, 2003).

The rehabilitating programme has resulted in the development of a series of "known age stands" (Foord *et al.* 1994 and Van Aarde *et al.* 1996). This has given rise to a plethora of research and published papers about the area in question and focused on different aspects of rehabilitation (see Davis *et al.* 2003, Ferreira and Van Aarde 1996 & 1997, Foord *et al.* 1994, Kumssa *et al.* 2004, Lubke *et al.* 1996, Lubke and Avis 1998, Mentis and Ellery 1994 & 1998, Van Aarde *et al.* 1996, Wassenaar and Van Aarde, 2001, Wassenaar *et al.* 2005 and Weiermans and Van Aarde 2003).

The mining area abuts on the local community of Kwa-Mbonambi tribal authority, which falls within the developing node of Richard's Bay (Wassenaar and Van Aarde 2001). As a result, the area experiences large influxes of people originating from rural communities, and these people come with their livestock. As indicated before, urban expansion and development inevitably results in increasing pressure being exerted on natural resources and biodiversity (Scogings *et al.* 1999).

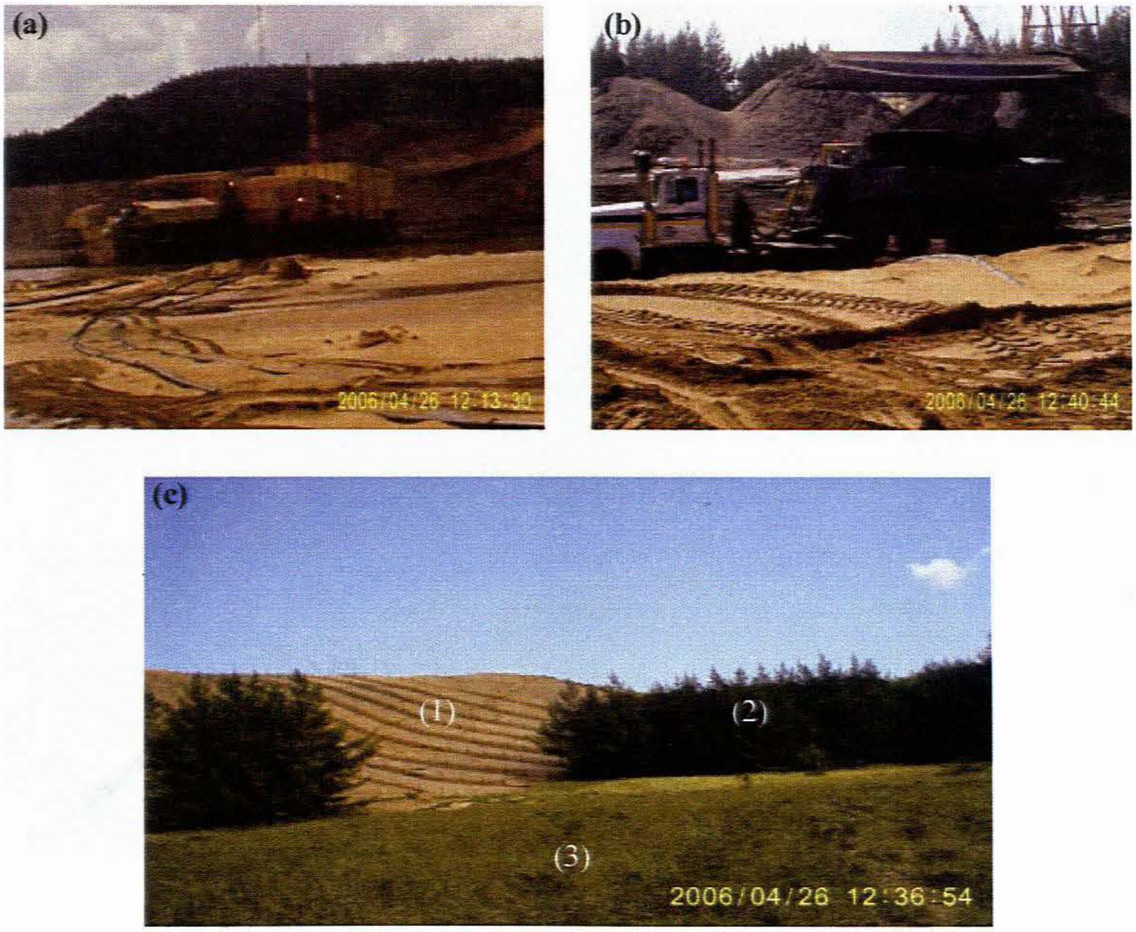

Figure 1.1: Mining and rehabilitation of dunes at Richards Bay, KwaZulu-Natal by RBM (a) The mining pond with dredger extracting heavy minerals. (b) Extracted heavy minerals are loaded in a truck. (c) A rehabilitated stand with different ages (1) bare sand with nets which stabilize soil, (2) three-year old *Casuarina equisetifolia* (beefwood) and (3) open grass land dominated by *Dactyloctenium australe* (LM grass).

Figure 1.2: The local charcoal industry consumes beefwood, which is burned after being cut.

Communities resided in the Kwa-Mbonambi area long before RBM started mining heavy minerals in 1977 (Van Aarde *et al.* 1996). Mr B. Mkhize, who has been in personal communication with the researcher in the course of this study, is an employee of Dune Rehab Services. His forefathers have been living in this area since early times, as evidenced by the grave of Inkosi Mbuyazi, who was buried around 1925 approximately 200 meters from the seashore, and the Lutheran Church that was built in 1948 (Figure 1.3).

Figure 1.3: The Lutheran Church, which was built in 1948

1.2 THE IMPORTANCE OF LIVESTOCK TO COMMUNAL FARMERS.

Indigenous livestock breeds contribute substantially to the livelihoods of people that make up the communities of the humid subtropical coastal thorn veld of Zululand in northern KwaZulu-Natal. Communal farmers traditionally keep livestock for various reasons, including food security, draught power, social status, cultural rituals and financial security (Tapson and Rose 1984 and Kunene *et al.* 2003). Among certain communities living in northern KwaZulu-Natal rangelands, 86% of the farmers keep indigenous livestock, namely Nguni cattle, goats and sheep, from which they derive 20% of their annual income, while 93% of the livestock are used directly for domestic purpose (Kunene and Fossy 2006). The livestock in such communities, therefore, represent a form of investment, and the death of livestock due to disease and starvation during dry winter months is therefore a major loss to them (Kunene *et al.* 2003).

In African communities livestock owners have diverse objectives and their herds therefore range widely in terms of size (Scogings *et al.* 1999). Whereas many livestock owners hold few animals and do not depend on them for income, some own significant numbers of animals and livestock farming can, therefore, be considered as their source of income (Tapson and Rose 1984). According to Zulu tradition, large herds of livestock (cattle) are a sign of wealth, therefore, it is not strange to find that in communal areas, such as Kwa-Mbonambi, the community experiences not only an influx of people, but also of livestock (Wassenaar and Van Aarde 2001).

1.3 FORAGING BEHAVIOUR OF LIVESTOCK

1.3.1 Forage intake and diet selection by livestock

While the feeding value of forages is mostly influenced by the intake of the animal in question (Tainton 1999), it is necessary to understand the principles of forage intake by animals in order to address the following questions related to why animals eat what they do eat, and why they do not eat constantly (Givens *et al.* 2000). In general terms, animals eat certain forages depending on the amount of nutrients available and the animals' requirements in terms of nutrient intake. Forage intake by ruminants is controlled by sets of feelings which include desire (appetite) and the decision that enough is eaten (satiety) (Chesworth 1992). According to principles of diet selection of grazing animals, which have already been formulated, these animals eat certain forage in order to satisfy their nutrient demands (Forbes 1995). An illustration of how animals select forage in order to meet their nutrient requirements is presented in Figure 1.4.

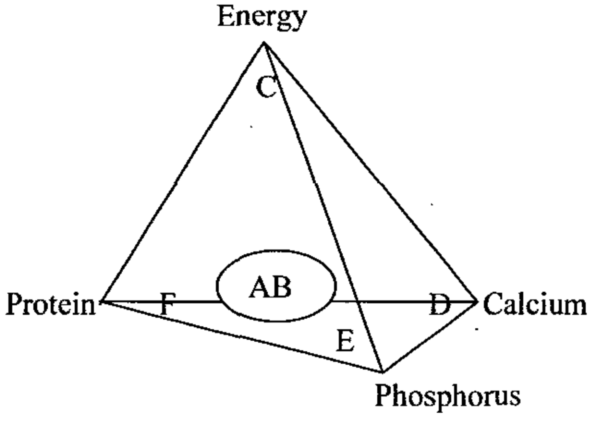

Figure 1.4: A model of food selection to satisfy animal nutrient requirements (modified from Forbes 1995).

Key: letters C to F, with their respective names, represent foods available to animals, while the letters AB within a circle represent what is required by animals. The foods represented by F and D are therefore more likely to be selected by animals due to the fact that they provide the requirements of the animals, as compared to other food combinations.

A shortage of nutrients that reduce the activeness of rumen micro-organism is liable to reduce forage intake by the ruminants (McDonald *et al.* 2002 and Forbes 1995). Animals, therefore, stop foraging in order to limit metabolic discomfort (Givens *et al.* 2000). Hence, their forage intake is controlled by satiety rather then appetites.

1.3.2 Habitat selection by livestock

In order to understand the grazing behaviour which includes habitat selection of an animal, it is important to consider abiotic and biotic factors involved. Abiotic factors refer to the slope of the grazing area and the animal/s distance from water, while biotic factors refer to forage quality and quantity, including palatability and availability (Bailey *et al.* 1996). Distance from water, topography (slope), forage palatability and availability have all been considered as the most important parameters that modify grazing behaviour (Roath and Krueger 1982 and Smith *et al.* 1992). Because cattle spend more time next to water, there is inclined to be higher grazing pressure around water (Mpinyane and Rethman 2006) and hence soil nitrogen is three times higher around water than in areas that are far from water (Tainton 1999) due to urea and dung deposition. Distribution patterns of grazing cattle together with the reasons for habitat selection and utilization of forage within habitat provide a basis for grazing management and range improvement (Smith *et al.* 1992).

1.3.3 Forage defoliation

Defoliation is defined as the removal of plants shoots/laminae by means of grazing or cutting (Humphreys 1987 & 1991 and Wade and Carvalho 2000). Defoliation stimulates tillering by reducing the influence of apical dominance (Gorder *et al.* 2005). Selectivity of grazing livestock results in a shortage of palatable species forcing animals to graze whatever is available, instead of what is required. Forage defoliation may be due to the high stocking rate in a grazing area or to non-rotational grazing (typically found in heavily grazed areas). Defoliation may rapidly or drastically reduce the leaf elongation rate (Schyder *et al.* 2000).

Animals prefer younger shoots to older ones, which affects the potential photosynthetic output of the sward (Humphreys 1991). As a result, stored resources in roots will be used for recovery. Defoliation is characterised by frequency (how often grass is removed), intensity (how much pasture is removed), and by selectivity (what is removed) (Humphreys 1991). Therefore the amount of forage an animal can consume and the number of times that forage is grazed depends on the palatability of the species.

1.4 PURPOSE OF THE STUDY

As a result of the influx of people and their accompanying livestock (Wassenaar and Van Aarde 2001), the community's livestock are forced to graze in the rehabilitating forest as there is no alternative grazing space available in the densely populated community (see Chapter two). Little is known about the impact of livestock grazing in the rehabilitating forest of Zululand. Large herbivores can influence the organization of almost every plant community at many different scales and on all hierarchical levels (Wassenaar and Van Aarde 2001). It is known that frequent, severe grazing caused by high stocking rates applied over prolonged time periods, reduces forage production and alters botanical composition (Morris *et al.* 1999). The influx of livestock in the rehabilitating forest has raised concern among those who face the challenge of rehabilitation that grazing may have an impact on the dispersal and establishment of tree species in the rehabilitating forest.

Among the studies and reported impacts of short-term cattle grazing in regenerating forest areas, is the negative effect that it has on plant species richness, cover and abundance of under-storey vegetation (Wassenaar and Van Aarde 2001). A study on the impacts of long-term grazing on the floristic composition and physiognomy of the under-storey vegetation is needed in order to improve knowledge and understanding of cattle impacts on rehabilitating forest. Since the cattle that graze in the rehabilitating forest originate from the neighbouring high-density community of destitute people, the main objective of this study was to monitor the impact of livestock on the rehabilitating coastal dune forest by: (1) the effect of cattle on germinating seed and young plants in the forest, (2) the effect of seed dispersal by cattle, since nothing is known about the effect of cattle on recruitment processes of trees in this rehabilitating forest. It is however, known that vervet monkeys disperse seed in the rehabilitating coastal dune forest, especially from un-mined to mined areas (Foord *et al.* 1994), and cattle disperse seed from savanna to grassland (O'Connor 1995).

1.4.1 Aims and outline of thesis

This study investigated the impacts (negative or positive) that communal livestock may have in the rehabilitating coastal dune forest of northern KwaZulu-Natal province of South Africa. The study therefore consist of two components – the first being field work and the second laboratory work, which were both conducted in order to provide answers to the problem statement.

Chapter 2 Comprises a community livestock survey and documentation of the effects of cattle grazing, seed dispersal and seedling establishment in the coastal dune forest that is being rehabilitated by Richard's Bay Minerals (RBM) as part of their mining operations.

Chapter 3 Develops from chapter 2, and follow up the effects of the trampling of seedlings in the rehabilitating forest during cattle grazing in relation to changing environmental conditions. Chapter 3 more specifically documents a multi-factorial laboratory experiment that was conducted in a horticultural tunnel at the University of Zululand to evaluate the effects of external (possibly damaging) factors on *Acacia karroo* seedlings in November – December.

Chapter 4 In the experiment described in this chapter, fertilizer levels were adjusted, otherwise it is the same multi-factorial experiment that examines possible external factors as conducted in chapter 3, except that is was conducted under a rainout shelter in March – April.

Chapter 5 This chapter developed from the result of chapter two, this section deals with the recruitment of dispersed guava species (*Psidium guajava*) and their competitiveness in shady area. Chapter 5 more specifically documents a multi-factorial laboratory experiment which was conducted in a rainout shelter at the University of Zululand to address the effect of grass on guava establishment in the forest as it is dispersed by communal livestock grazed in rehabilitating forest.

Chapter 6 Contains the general conclusion and recommendation, which summarises the three experiments which were conducted and interprets the results in the context of communal livestock impacts on rehabilitating coastal sand dune forest.

Chapters 2 – 5 are written as separate manuscripts for submission to a peer-reviewed journal, after some minor changes; therefore, there is some unavoidable repetition among these chapters.

CHAPTER TWO

LIVESTOCK OWNERSHIP PATTERNS AND IMPACTS OF CATTLE GRAZING ON POST-MINING REHABILITATING COASTAL DUNE FORESTS, ZULULAND

2.1 INTRODUCTION

The social status of rural communities in developing countries is determined principally by the number of livestock owned by each household (Chesworth 1992 and Schwalbach *et al.* 2001). Communal farmers keep livestock for various reasons which include self respect (dignity), draught power and cultural rituals. Livestock forms an integral part of communal farmers' household food security and fulfill a suite of important socio-economic roles (Tapson and Rose 1984). The sale of livestock and its products provides income and is a major source of wealth for the rural communities. Communal farmers in northern KwaZulu-Natal derive 20% of the annual income from livestock (Kunene and Fossy 2006). Livestock also play an important socio-cultural role such as slaughtering for the ancestors and serving as payment for bridal dowry (*Ilobolo*). In communal areas of northern KwaZulu-Natal it is very rare to find properly managed land for livestock grazing, hence livestock roam around. Common problems experienced by communal farmers with livestock include diseases and poor grazing resources (Kunene *et al.* 2003). Kwa-Mbonambi is in the developing node of Richard's Bay (Wassenaar and Van Aarde 2001) and the area experiences a large influx of people with their accompanying livestock originating from rural communities of destitute people. Under an increasing human population the cultivated areas take up communal grazing lands which results in a shortage of grazing land for livestock, hence livestock will be left to graze on marginal land (Kassa 2000). Kwa-Mbonambi community abuts the mining area of Richard's

Bay Minerals (Wassenaar and Van Aarde 2001 and Wassenaar *et al.* 2005), hence the communal livestock (cattle) invade the rehabilitating dune forests (Figure 2.1) due to the shortage of grazing land within the community as it is mentioned above.

Figurer 2.1: Community livestock grazing in the rehabilitating forest

Forage resources around Kwa-Mbonambi settlements are limited to commercial forestry plantation on one side, and rehabilitating coastal sand dune forests on the other side. The prosence of cattle grazing in dune forests of northern KwaZulu-Natal (South Africa) is anomalous because few vertebrate herbivores inhabit these forests (Wassenaar and Van Aarde 2001). Forests are not considered to provide a major forage resource for livestock, though they can provide useful forage when other forages are limited (Tainton 1999), which constitute a key forage resource (Illius and O'Connor 2000). The influx of livestock (cattle) in the rehabilitating dune forests has raised a concern to those who face a challenge of post-mining rehabilitation; that grazing may have an impact on the seed dispersal and establishment of tree species in rehabilitating sand dune forests. The impact of grazing and seed dispersal by livestock has been reported elsewhere (see Kauffman *et al.* 1983, Campos and Ojeda 1997, Tews *et al.* 2004, Ash and McIvor 1998, Morris *et al.* 1999, Yates *et al.* 2000, Wassenaar and Van Aarde 2001, Roberson 1996 and Fuhlendorf *et al.* 2002). Livestock grazing in the forest results in the disturbance of the forest under-storey (Smith *et al.* 1996) and this influences plant diversity (Adler *et al.* 2001). Livestock grazing often leads to changes in vegetation structure, species composition and abundance, plant productivity and plant nitrogen cycling (Van Staalduinen *et al.* 2005).

Grazers carry seeds from one place to another, by means of dung dropping. Native grassland is colonised by exotic plant species due to seeds transported via cattle dung (Gardener 1993). Cattle are reported as a major means by which a number of seeds can reach a new site (Grice 1996, Malo and Suarez 1995a, 1995b and Milton and Dean 2001), hence they are an effective dispersal agent of seeds (Barrow and Havstad 1992). Seed dispersal may be beneficial or not, depending to the dispersed plant species. Seeds dispersed by animals are known to contribute to the spread of desirable and undesirable plants (Ocumpaugh *et al.* 1996) which then promotes shrub encroachment (Tews *et al.* 2004).

A major question which arose due to cattle grazing in the rehabilitating forests was; what is the impact of cattle on the structure and functioning of rehabilitating forests on the coastal dunes forest of Zululand? Short term impact of cattle grazing in this rehabilitating forest has been reported to affect plant species composition and abundance (Wassenaar and Van Aarde 2001), but nothing is known about the effect of cattle on recruitment process of plant species (trees) in this rehabilitating forest. The main aim of this research was, therefore, to create knowledge about the impacts of communal livestock in rehabilitating coastal dune forest that will inform future management of the forest. Hence this research addresses the following predictions:

- The influx of people in Kwa-Mbonambi reduces communal grazing area
- Cattle disperse exotic plant species in the rehabilitating forest from the community.
- Cattle have an impact on the micro-environment of the rehabilitating forest in which woody species germinates.
- There will be less grass biomass as a result of grazing.
- There will be less tree seedling establishment (germination) as a result of grazing.

2.2 MATERIALS AND METHODS

2.2.1 Community livestock survey

2.2.1.1 Surveyed area

A livestock survey was conducted at Kwa-Mbonambi tribal authority (communal area) under Chief Mbuyazi, from February 2005 to March 2005. The area abuts the mining area of Richard's Bay Minerals abbreviated as RBM. Kwa-Mbonambi is divided into the following wards namely; Current, Mzingazi, Nzalabantu, Sabokwe, Nhlanzini, Nkunzebomvu

(Ntshingimpisi), Mankwathini and Ndlabeyilandula, and the survey was conducted in each ward. The first five wards are on the boundary of RBM mining area. Kwa-Mbonambi area is under lower uMfolozi district located at 28^0 44' S and 32^0 14' E situated north of Richard's Bay harbour and stretched to Sokhulu south of Umfolozi River (see Figure 2.2). It is about 12.5km from Meer-en-see suburbs at an altitude of 60 to 80m above sea level. The area receives rain mostly in January up to March with the highest precipitation received in February.

2.2.1.2 Data collection

Community livestock survey data were collected by interviewing 78 farmers which comprised 15 farmers at Mzingazi, 10 farmers at Nzalabantu, 7 farmers at Sabokwe, 14 farmers at Nhlanzini, 8 farmers at Nkunzebovu, 14 farmers at Mankwathini and 10 farmers at Ndlabeyilandula. The interviews were conducted on the following dates; 19, 20, 27 of February 2005 and 12 and 19 March 2005, using structured questionnaires (see appendix 1). Farmers were informed through their local iNduna about the meeting for the interviews, and the farmers in each ward were gathered in one place for the surveys. The problem experienced during the survey was that of unavailability of farmers for two wards and a small number of farmers in other wards, probably the methods which was used here might be the cause, however it is subjected to corrections. During the survey, information which included age and sex of farmers, types of livestock owned, constraints (perceived by farmers) on livestock operation, shrubs or trees available as forage, poisonous and medicinal plants and type of livestock diseases treated by the farmers was collected.

2.2.2 Exclosure experiment

2.2.2.1. Study site

The exclosure experiment was conducted in a post-mined area which is situated about 16 km north-east of Richard's Bay town in KwaZulu-Natal province of South Africa on coordinates 28° 43′S and 32° 12′E (Figure 2.2) and it has been under rehabilitation for 28 years (Van Aarde *et al.* 1996a; 1998 and Weiermans and Van Aarde 2003). Richard's Bay Minerals (RBM) uses a wet mining process (dredger pond) to extract heavy minerals (ilmenite, zircon and rutile) from coastal dune forests (Figure 2.3). Rehabilitation has resulted in different stands of known age (Van Aarde *et al.* 1996a). The study site was stand 1 which is approximately 83 ha (Ferreira and Van Aarde 1996). This stand is dominated by senescent *Acacia karroo* woodlands replaced by a variety of secondary dune forest tree species (Weiermans and Van Aarde 2003, Van Aarde *et al.* 1996a and Ferreira and Van Aarde 1998) which include *Trichelia emetica, Trema orientalis, Mimusops caffra, Vepris lanceolata* and *Celtis Africana* (Ferreira and Van Aarde 1997). As it has been stated, the study site has been under ecological rehabilitation for 28 years (at the time of study), hence it is the oldest stand (Van Aarde *et al.* 1998 and Ferreira and Van Aarde 1997).

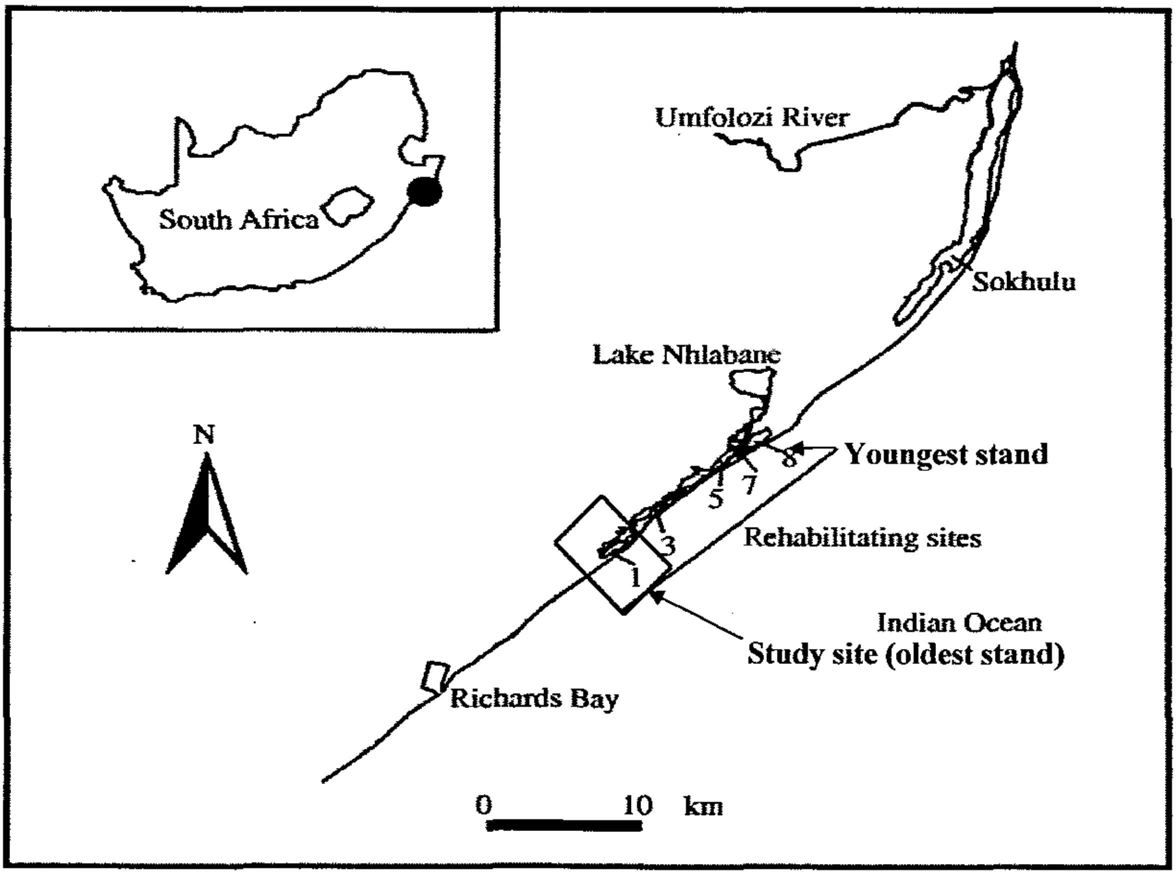

Figure 2.2: A map showing location of the study site amongst four rehabilitating stands and benchmark (undisturbed) site modified from Kumssa *et al.* (2004)

Figure 2.3: A dredger during process of extracting heavy minerals in mining area

2.2.2.2 Climate and soil

The study area forms part of the summer rainfall area in South Africa. The climate around Richard's Bay is subtropical and the area receives the mean annual precipitation of 1650 mm (Lubke *et al.* 1996), of which 70% is received from January to March. The area experiences hot and windy weather conditions in summer. Daily maximum temperature ranges from 22.6°C to 30.0°C and minimum temperatures from 10.0°C to 20.0°C in June and January respectively (Wassenaar and Van Aarde 2001 and Ferreira 1996). The soil is sandy with small clay particles and it is covered by decomposed logs of dead *Acacia karroo*, snail shell and leaves of trees therefore nutrients are concentrated on top (Kumssa *et al.* 2004), which might have leached due to rainwater. Pre-mining vegetation is Coastal Forest and Thornveld (Acocks 1988).

2.2.2.3 Experimental design

The exclosure experiment was conducted in stand 1 (Figure 2.2), where a 1 ha plot was demarcated and divided into two equal halves. One half was fenced off (exclosure) with 3m long treated timber poles and three wire strands and the other half was left unfenced (Control see Figure 2.4). Eight transect belts of 2 m wide and 40 m long were marked in each plot modified from Yates *et al.* (2000). Each transect belt was 80 m^2 and the transect belts were 5 m apart and 5 m from boundaries of the plots on both sides. Three pegs (markers) were pinned (one on each end of the transect belt and one in the middle) in each transect belt on the exclosure sub-plot and control sub-plot, making a total of 24 pegs pinned per sub-plot.

Figure 2.4: Visual illustration of the exclosure trial conducted in RBM rehabilitating forest

Due to theft of exclosure material (poles and fence) the exclosure sub-plot only lasted for four months from August 2005 to December 2005 in the rehabilitating dune forest. To determine spatial distribution and relative densities of cattle in the rehabilitating forest, the road network inside the forest was used twice a month for cattle counts. Cattle numbers were recorded and Global Positioning System (GPS) was used to record a geographical location of cattle in the rehabilitating forest. In order to determine the types of seeds dispersed by cattle during grazing, fresh cattle dung was collected for examination of any seeds available (Foord *et al.* 1994). Dung was air dried in order to remove visible seeds and the remaining dung was spread on seedling trays which were half filled with vermiculite.

2.2.2.4 Data collection

Seed germination (seedlings) data were first recorded on 20th of October 2005 two months after the exclosure plot was set up. Seedling surveys were done around each of the three pegs (markers) per transect belt of each sub-plot (exclosure and control). The surveyed seedlings were mainly *Acacia karroo* which is abundant because they are used for rehabilitation by RBM. However, some other seedlings beside *Acacia karroo* were recorded during the survey. A radius of 30 cm was measured with a ruler from each peg in order to standardise the surveyed area per peg (marker). A protractor was used to measure the angle of each seedling relative to the transect line during the survey, and the distance of each seedling from the peg was also measured; which was done once a month for three months (October to December 2005).

Rainfall was recorded daily for three months from October to December 2005 (Figure 2.5). Due to theft of the exclosure material (poles, rain gauge and fence) more data could not be collected. Quadrats were clipped between the pegs (markers) during November 2005 for which herbaceous biomass was estimated. Therefore two quadrats of 0.25m^2 were clipped per transect belt which made a total of 16 quadrats per sub-plot. Clipped herbaceous biomass was oven dried for 48 hours at 60^{0}C after which dry weight was recorded per sample. As mentioned above that the exclosure materials were stolen, therefore herbaceous biomass data was not collected again. Dried forage samples were milled using a milling machine to pass through 1 mm sieve, and were further analysed for nitrogen (N) according to Kjeldahl technique from which crude protein (CP) was calculated as N x 6.25 (AOAC, 1990). Neutral detergent fibre

(NDF) analysis was performed by the sequential procedure of Goering & van Soest (1970), NDF was expressed as dry matter per sample by using the following formula.

$$\%NDF = \frac{((\text{crucible} + \text{dry Residue}) - (\text{crucible} + \text{ash})) \times 100}{\text{Sample mass (mg)}}$$

Cattle distribution in the rehabilitating dune forests was counted twice a month using the road network inside the forest. To standardise the cattle count data, the same route in same direction was used every time for cattle counts. Cattle numbers were recorded and Global Positioning System (GPS) was used to locate the co-ordinate where cattle were seen. Cattle distribution data were collected from February 2005 to October 2005. During the survey sometimes cattle were not found in the rehab due to the fact that RBM cattle guards had already chased cattle out of the forest, therefore, they were our source of information about the area which is most likely to be grazed by livestock. Cattle counting in the forests were done in collaboration with dung collection in the forests. Collected cattle dung was air dried at the University of Zululand in the Department of Botany drying room after which visible seeds were manually removed for identification by germinating them separately. The remaining dung was spread on seedling trays which were half filled with vermiculite to see any germination of less visible seeds for identification. Vermiculite was used as the germinating media as it is characterised by high water holding capacity.

Student's t-Tests for two tail tests was used to test differences between grazed and ungrazed plots based on exclosure experiment, and all statistical tests were done at 5% level of significance ($P \leq 0.05$).

2.3 RESULTS

2.3.1 Community livestock survey

Livestock survey results indicate that farmer's age ranged from 20 to 85 years. In a total of 78 interviewed farmers 55.1% of them were older than 51years old. The majority (80.8%) of the farmers were males of which 76.7% of the male farmers were older than 50 years. The remaining 19.2% of 78 interviewed farmers were female, and large proportions (40%) of the female farmers were widows older than 50 years while 6.7% of total females were wives of the migrant workers. Most of the respondents (35.8%) had a primary education. Illiteracy is the common problem in rural areas, 32.1% of the respondents were illiterate. Some of the respondents (29.4%) had high school education. A very small percentage (2.6%) of respondents went to tertiary though they did not complete their tertiary studies. Most of the respondents (43.6%) depended on pensions as the source of income for their living, and some received their income from both pension and sale. Farmers who responded as workers (30.8%) in this survey included only 5.1% who were RBM employees.

In a total of 78 interviewed communal farmers 51.3% kept indigenous cattle (Nguni breeds) for reasons such as adaptability, and it is highly preferred as a dual purpose breed (produced both milk and meat). Some farmers (12.8%) reported that instead of keeping Nguni they keep

Brahman breeds, and 35.9% of the total farmers prefer Brahman for meat consumption. The considerable number of farmers reported to keep a mixed type of cattle breeds. Besides keeping cattle, some communal farmers (ten of them) reported to have goats and most of them preferred indigenous breeds for cultural activities (slaughtering for ancestors). Sheep farming in this area is not familiar, to such an extent that only two farmers in two wards out of seven surveyed wards, reported to keep sheep.

Kwa-Mbonambi community had an increase of livestock (cattle) numbers from 1975 to 2000, but in 2005 there was a drastic decrease of about 56.7% of cattle numbers as compared to year 2000. At the some time goat populations in this community seemed to decrease from 1975 to 2005 (Figure 2.5). Livestock mortalities at kwa-Mbonambi community from 2002 to 2004 are presented in Figure 2.7. In 2003 livestock mortality was low in contrast with 2002 and 2004, in fact in 2004 more than half (54%) of cattle died, which was double that in 2002 and 2003 (Figure 2.6).

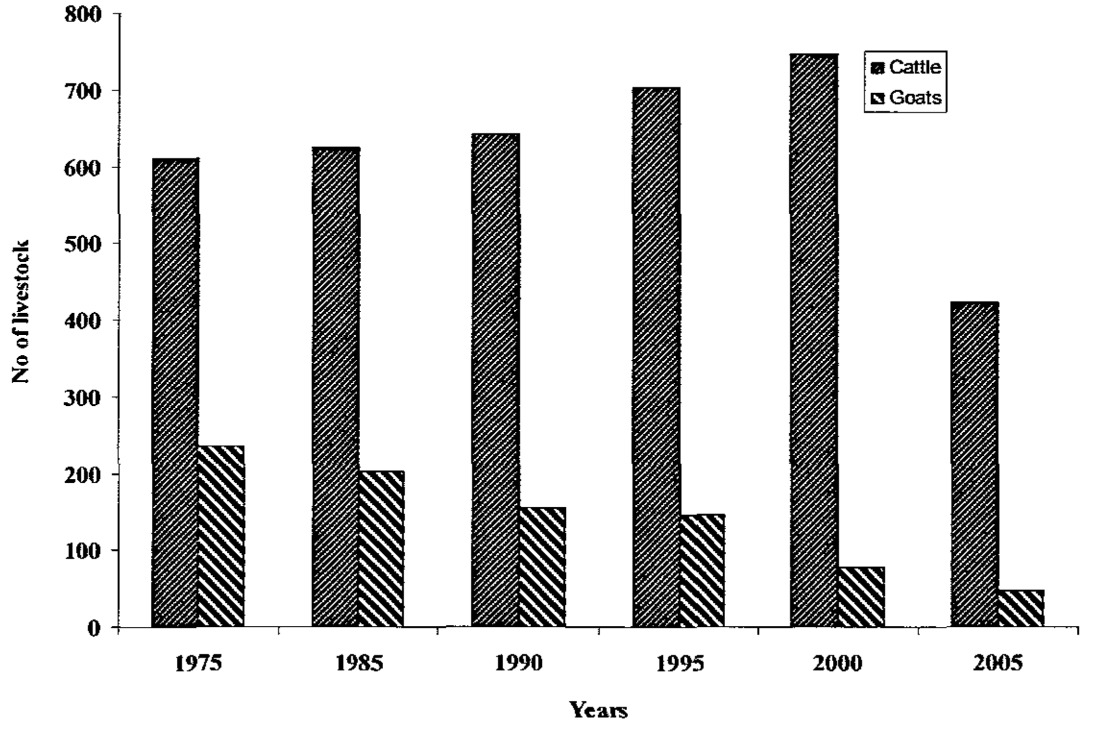

Figure 2.5: Variation of livestock at Kwa-Mbonambi communal area

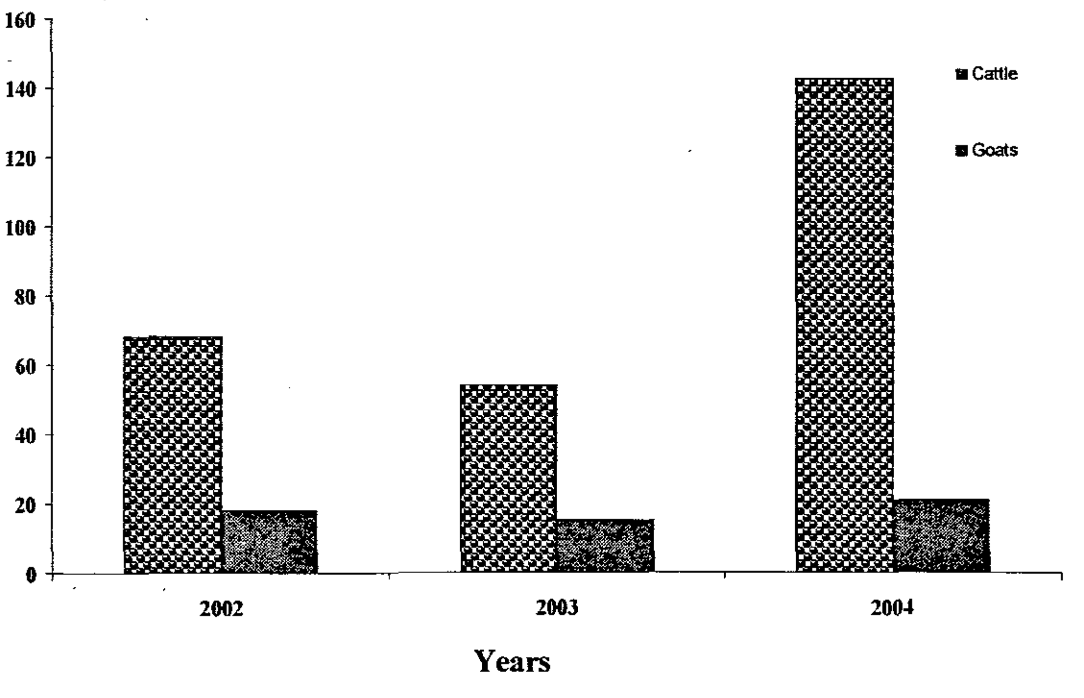

Figure 2.6: Livestock mortalities in the past three years (2002 to 2004)

Kwa-Mbonambi communal farmers encountered various problems related to livestock grazing. These problems included, grass shortage, shortage of grazing land, and no dip availability (Table 2.1). In wards like Ndlabeyilandula dip is there but it was vandalized so it should be renovated (Figure 2.7a), where as in other wards there are no resources. The invasion of guava (*Psidium guajava*) in the community grazing land reduces grazing quality (Figure 2.7b).

Table 2.1: Problems encountered by farmers and their possible solutions

Problems	Possible solutions	Respondents %
Grass shortage	Building Camps	76.9
Increase of *Aristida junciformis*	No solution	9.0
Ticks	Dipping	38.5
Diseases	Doctor (vet)	15.4
No space for grazing	Claiming land	69.2
Increase of Gum trees	Should be reduced	1.3
Theft of Cattle	Provide Place	6.4
Water shortage in winter	Dam building	12.8
Worms	Telemysin	1.3
Fire	Make Pathways in pasture	3.8
No dip	Dip construction	51.3

Figure 2.7: (a) Community unused dip at Ndlabeyilandula ward (b) grazing land invaded by *Psidium guajava* abutting commercial plantation at Nhlanzini

Increasing livestock numbers is the primary aim for Kwa-Mbonambi communal farmers. Other farmers reported that they want to sell their livestock with the aim of generating an income since they are unemployed, while other farmers reported that they want to support their families in terms of food security, school fees etc. Culture has a major role to play in rural areas, hence they also reported that they keep livestock for cultural activities such as slaughtering for the ancestors and bridal dowry (ilobolo) particularly for their son (Figure 2.8).

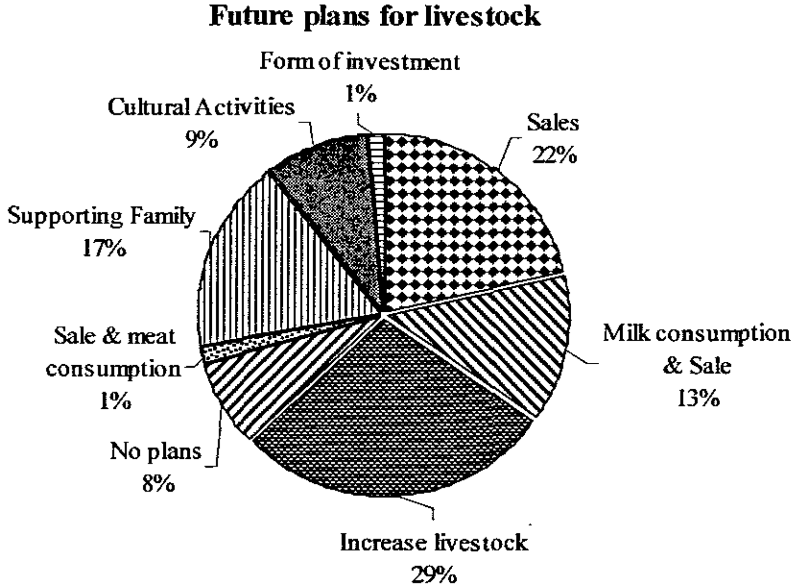

Figure 2.8: Major reasons given by farmers for livestock farming at Kwa-Mbonambi

Scientific names of local grass species which are reported by communal farmers to be consumed by their livestock and their consumption rate (preference) are presented in Table 2.2. *Aristida junciformis* (ingongoni) was reported to be the most dominating grass species in this area, though it is unlikely to be consumed by livestock. *Panicum schinzii* (ubabe) was reported as the highly preferred grass species by livestock and it was the second dominating grass species after *Aristida junciformis*.

Table 2.2: Grass species reported by Kwa-Mbonambi communal farmers and their levels of consumption by livestock

Scientific Name	Common Name	Zulu Name	Animal	Respondents (%)
Aristida junciformis [C]	Ngongoni bristlegrass	iNgongoni	Cattle & Goats	79.5
Chloris gayana [A]	Rhodes grass	uMnyankomo	Cattle	1.3
Cynodon dactylon [A]	Couch grass	iNgilazi	Cattle	7.7
Dactyloctenium australe [A]	LM grass	iSikhukhukhu	Cattle	11.5
Digitaria eriantha [A]	Common fingergrass	iSikhokho	Cattle	7.7
Hyparrrhenia dregeana [C]	Giant thatchgrass	iSiqunga	Cattle	2.6
Imperata cylindrica [C]	Cottonwool grass	uMthente	Cattle	3.8
Panicum ecklonii [C]	Buffalo grass	___	Cattle	1.3
Panicum schinzii [A]	Blue panic	uBabe	Cattle	41.0
Pennisetum clandestinum [A]	Kikuyu	___	Cattle	1.3
Sporobolus africanus [B]	Rastail dropseed	uMtshiki	Cattle	10.3
Stenotaphrum secundatum [A]	Coastal buffalo grass	uNgwegwe	Cattle & Goats	3.8
Themeda triandra [B]	Red grass	iNsinde	Cattle	6.4
Urochloa pancoides [C]	Annual signalgrass	iMbubu	Cattle	1.3

[A] =highly consumed; [B] =moderate consumed; [C] =low consumption
Translation of Zulu names were taken from Hutchings *et al* (1996), Pooley (1993)

Scientific names of shrubs and trees which were reported by Kwa-Mbonambi farmers to be consumed by their livestock and their estimated consumption rates are presented in Table 2.3. *Psidium guajava, Persea americana* and *Citrus annum* were the tree species which were most preferred by livestock in their respective order. Kwa-Mbonambi communal farmers traditionally use some of these trees and shrubs for medicinal purposes for their livestock (Table 2.4). *Melia azedarach, Prunus persica* and *Clerodentarrhiza glabrum* were common (11.5%) medicinal trees for treating worms, wounds and diarrhea.

Table 2.3: Shrubs and trees browsed by livestock at Kwa-Mbonambi

Scientific name	Common name	Zulu name	Animal	Part used	Respondents (%)
Acacia karroo [1]	Sweet thorn	uMunga	Goats	Leaves	3.8
Afzelia quanzensis [3]	Lucky bean	uMhlakuva	Cattle	Leaves	1.3
Brachylaena ilicifolia [3]	Bitter- leaf	iPhahla	Cattle	Leaves	1.3
Citrus annum [3]	Orange	uMwolitshi	Cattle	Fruits & leaves	37.2
Citrus lemon [3]	Lemon	uLamula	Cattle	fruits	19.2
Citrus nirtjie [3]	Nartjie	aManatshi	Cattle	Fruits	1.3
Colocacia esculentas [3]	Taro	aMadumbe	Cattle	Leaves	1.3
Erythrina caffra [2]	Coral tree	uMsinsi	Cattle	Leaves	11.5
Ficus ingens [3]	Wild fig	uMgonswana	Cattle	Leaves	1.3
Ipomoea batatas [3]	Sweet potatoes	uBhatata	Cattle	Leaves	1.3
Lantana rugosa [1]	Birds brandy	uKhwebezane	Goats	Leaves	3.8
Malus pumila [2]	Apple	aMahhapula	Cattle	Fruits & leaves	1.3
Mangifer indica [2]	Mango	uMango	Cattle	Fruits	12.8
Maytenus heterophylla [1]	Pendoring	iSihlangu	Goats	Leaves	1.3
Melia azedarach [2]	China berry tree	uMsilinga	Cattle	Leaves	19.2
Moraea spathulata [2]	Tulp yellow iris	iNdlolothi	Goats	Leaves	1.3
Musa [2]	Banana	uBhanana	Cattle	Leaves	14.1
Obedia tenax [2]	Mountain nettle	iMbati	Goats	Leaves	2.6
Passiflora coccinea [1]	Granadilla	__	Cattle	Leaves	2.6
Persea americana [3]	Avocado	uKotaphela	Cattle	Fruits	47.4
Psidium guajava [1]	Guava	uMgwava	Cattle	Fruits & leaves	71.9
Rhus gueinzii [1]	Thorn karree	iNhloboshiyane	Goats	Leaves	1.3
Rubus rigidus [3]	Bramble	uMjikijolo	Cattle	leaves	1.3
Solanum incanum [2]	Bitter apple	iNtuma	Cattle &Goats	Fruits & leaves	1.3
Trichilia dregeana [1]	Natal forestmahogany	uMkhuhlu	Cattle	Leaves	2.6

[1]=Highest consumption, [2]=Moderate consumed; [3]=Low Consumption

Translation of Zulu names were taken from Hutchings *et al.* (1996) and Pooley (1993)

Table 2.4: Medicinal shrubs, trees which are used by Kwa-Mbonambi communal farmers for their livestock

Scientific name	Common name	Zulu name	Animal	Part used	Ailment	Preparation	Respondent %
Albuca setosa	Albuca baurrii bak	iNgcino	Calves	Leaves	Diarrhea	Grind & Mix with water	1.3
Aloe maculata	Soap aloe	iCena	Chicken	Leaves	New castle	Grind & Mix with water	1.3
Aloe spectabilis	Mountain aloe	iNhlaba	Cattle	Leaves	Worms	Grind & Mix with water	3.8
Clerodendrum glabrum	Bitter blaak	uMqaqongo	Cattle	Leaves	Worms	Grind & Mix with water	11.5
Elephantorrhiza elephantina	Baswortel	iNtolwane	Cattle	Leaves	Worms & diarrhea	Grind & Mix with water	5.1
Erythrina caffra	Coral Tree	uMsinsi	Cattle	Leaves	Miyosis & worms	Grind & Mix with water	7.7
Gunnera perpensa	River pumpkin	uGobho	Cattle	Roots	Removes placenta	Chopped & Mix with water	1.3
Melia azedarach	China berry tree	uMsilinga	Cattle	Leaves	Diarrhea	Grind & Mix with water	11.5
Musa	Banana	uBhanana	Cattle	Flower	Abortion	Grind & Mix with water	1.3
Prunus persica	Peaches	uMpetshisi	Cattle	Leaves	Wound & diarrhea	Grind & Mix with water	11.5
Psidium guajava	Guava	uMgwava	Cattle	Leaves	Diarrhea	Grind & Mix with water	1.3
Sarcostemma viminale	Bush vine	iNgotsha	Cattle	Stem	Increase milk	Chopped & Mix with water	2.6
Tetradenia riparia	Ginger bush	iBozane	cattle	Leaves	Increase milk	Grind & Mix with water	1.3
Rhoicissus tridententa	Wild/bitter grape	iSinwazi	Cattle	Roots	Increase milk	Chopped & mix with water	1.3
Ficus sur	Cape fig	uMkhiwane	Cattle	Leaves	Increase milk	Grind mix with salt, sugar and boiled	1.3

2.3.2 Exclosure experiment

2.3.2.1 Cattle impact in rehabilitating forest

Seedling surveys showed that seed germination in the rehabilitating forest was mostly of *Acacia karroo* and very few seedlings of other species. Seedlings recorded in the exclosure plot were more then seedlings recorded in the control plot (mean = 41.4 m^{-2}; SE = ± 10.61 and mean = 20.6 m^{-2}; SE = ± 4.14 respectively). Grazing reduced seedling survival by 49.8% which was significantly different (t = 2.04, DF = 30, P = 0.041). Livestock grazing in the rehabilitating dune forests reduced herbaceous biomass per quadrat significantly by 51.8% (t = 2.13, DF = 15, P<0.001) with the herbaceous biomass of mean = 28.2 g; SE = ± 2.23 and mean = 54.3 g; SE = ± 4.14 (Figure 2.11). Herbaceous biomass were further analysed for Crude Protein (CP) and Neutral Detergent Fiber (NDF). There were no significant differences between the NDF (t= 2.13, DF = 15, P = 0.165) with the following mean percentage and standard error of 65.5 ± 1.33 and 63.0 ± 1.33 respectively per plot (control and exclosure). There was no significant different between the plots for CP analysis (t = 2.13, Df = 15, P = 0.453) with the mean percentage and standard error of 7.0; ± 0.84 and 8.4; ± 1.01 respectively per sub-plot.

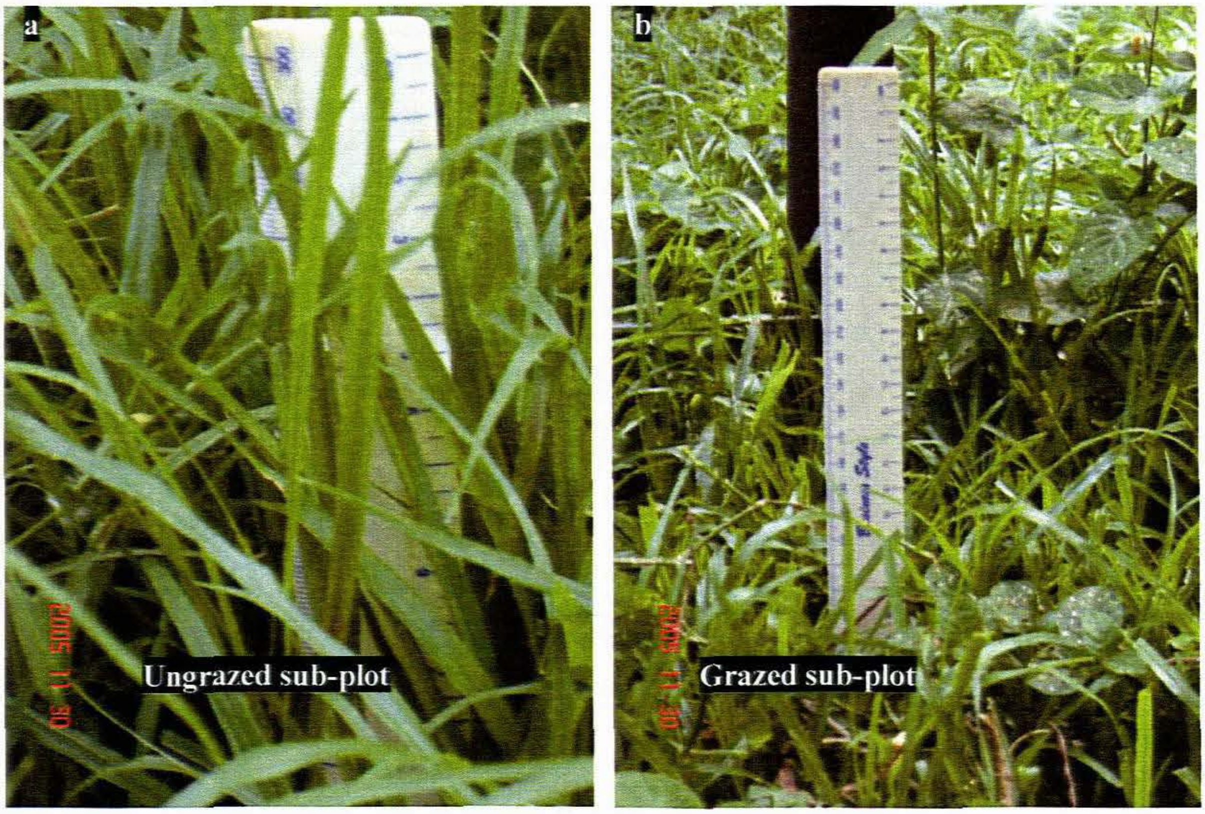

Figure 2.9: The effect of Livestock grazing (a) Herbaceous biomass in fenced off sub-plot and (b) Herbaceous biomass of unfenced sub-plot.

To determine spatial distribution and relative densities of cattle in the rehabilitating dune forests, the road network inside the forests was used for regular cattle counts two days per month. Cattle sightings were fixed with a Global Positioning System (GPS). The older rehabilitating stand was the most often grazed by communal cattle compared with younger stands, as witnessed by the clustering of cattle sightings around the exclosure plot (Figure 9). The older stand is characterised by open canopy with more grass dominated by LM grass while younger stands have closed canopies. Livestock moved from 28^0 41′S, 32^0 12.5′E (younger stand which is the entrance) to 28^0 43′S, 32^0 11.5′E (older rehabilitating stand).

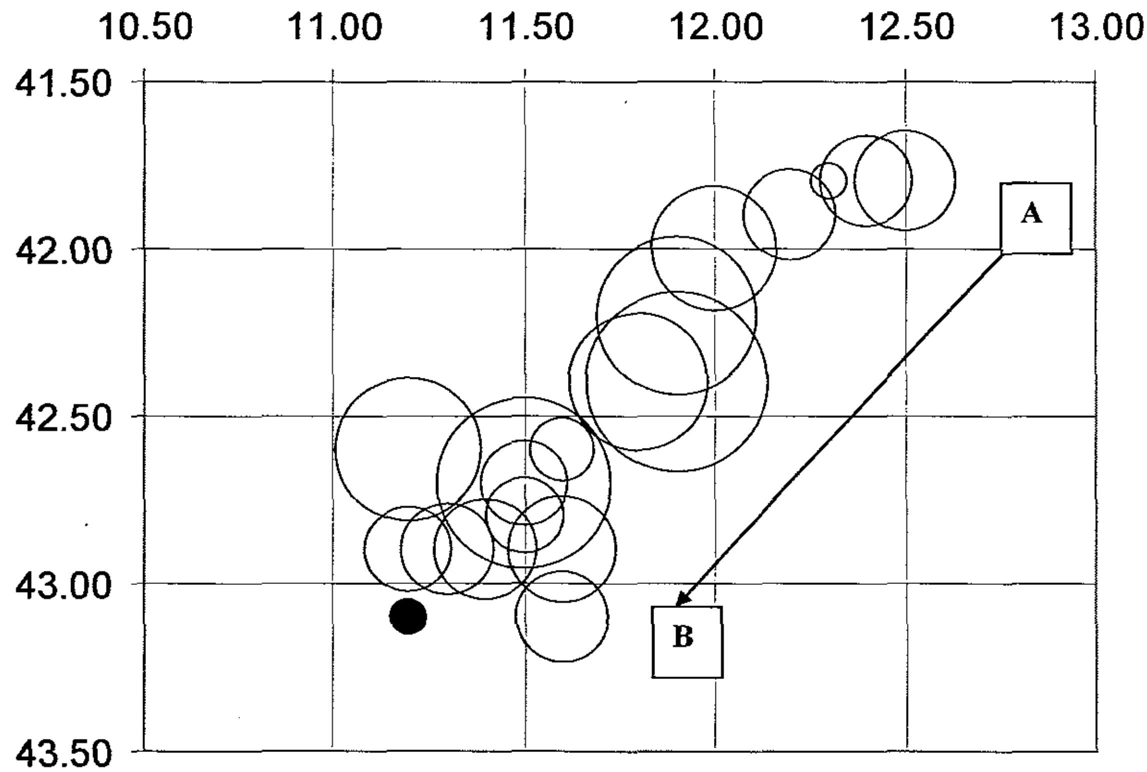

Figure 2.10: Cattle distribution pattern in the rehabilitating forest.

Key: Letters A and B show the direction of cattle movement from younger stands to older rehabilitating stand. The circles represent cattle counted on rehabilitating forests during the experiment. While the circle size indicates the number of cattle were counted per day, the clustering of the circles indicates how often cattle were counted at that particular point. The black solid circle represents the exclosure plot in the rehabilitating forest (see figure 2.4). The x-axis of the graph represent lines of latitude and Y-axis represents lines of longitude, however the graph was drawn using the minutes and seconds south and east of 28^0 and 32^0 respectively.

We found that seeds which were manually removed from dung was guava and therefore communal livestock grazing in the rehabilitating forest dispersed guava seeds from the community (see Figure 2.8b and Table 2.3). Guava seed which had passed through the alimentary canal of cattle was tested for germination, in incubators at different temperatures, as compared with seeds which had not passed through the digestive track of animals (seed from fresh fruit). Seed germination from fresh fruit was higher as compared with seed passed through the alimentary canal of cattle (see Table 2.5).

Table 2.5: Guava seed germination among different origins and temperatures (Forest = seeds removed from forest dung, Village = seeds removed from village dung and control = seeds from fresh fruit)

Average temperature	Total seeds	Forest (%)	Village (%)	Control (%)
20.0^{0}C	300	17.0	11.0	18.0
24.0^{0}C	**300**	**85.0**	**69.0**	**89.0**
30.4^{0}C	300	27.0	11.0	57.0
35.8^{0}C	300	2.0	6.0	20.0

The passage of guava seeds through the alimentary canal (gut) of cattle did not enhance germination in guava, due to the fact that seeds from fruit had higher germination. The highest guava germination was noticed at an average temperature of 24.0^{0}C. Seeds germinating from dung sludge which was spread on a seedling tray half filled with vermiculite was dominated by grass and forbs (data not shown).

2.4 DISCUSSION

2.4.1 Communal livestock survey

Communal farmers have less information with regard to livestock management which results in different problems they come across such as death of livestock. The community livestock survey indicated that more than half (55.1%) of the respondents (farmers) were above 50 years old. In rural areas 66% of the livestock farmers are above 50 years old (Kunene and Fossy 2006). In communal areas livestock farming is considered to be a male activity, where as gardening is a female activity, hence most of the respondents during the survey were male. This is in accordance with Kunene *et al.* (2003) who reported that most of the interviewed communal farmers in northern KwaZulu-Natal for livestock farming were male. It is very rare to find a female head in communal areas if a man is still alive, even if he is not with the family (for some reason). In communal areas illiteracy is the major problem (N Kunene 2003 unpublished data and Bembridge 1984), so it was at Kwa-Mbonambi community. In rural areas livestock farming is regarded as a traditional operation and there is no proper management (Schwalbach *et al.* 2001). Unemployment is another constraint which communal residents are facing which might be due to lack of skills. Poverty is a daily problem; therefore pension is the main source of income.

Livestock production in communal areas is mainly based on cattle farming and in rare cases goats, perhaps because goats are regarded as the poor man's cows (Chesworth 1992). Production functions of livestock ownership in communal areas are comprised of mixed stock types for multipurpose characters (Shackleton *et al.* 2005). Therefore Kwa-

Mbonambi communal farmers keep indigenous cattle for a number of reasons. To keep large herds of livestock in communal areas is common practice (Schwalbach *et al.* 2001), with no proper management tool to be used in terms of animal husbandry. As a result then livestock die due to diseases and starving, and these are regarded as the major constraints for animal production in rural areas (Kunene *et al.* 2003). Livestock mortalities in 2004 due to the shortage of grass and ticks related disease, resulted in a drastic decrease in livestock number in 2005 (Figure 2.6 and 2.7). The primary objective of livestock farming was to increase livestock numbers in the area but they have no planned structure for pasturing. There is a tendency that in rural areas the dignity of man is in number of livestock he owns (Mr Mpangela who was in personal communication with the researcher). Communal farmers of Kwa-Mbonambi perceived their major constraints with farming as the shortage of grass and no grazing land (Table 2.1), as result, rehabilitating forest was invaded by communal livestock (see Figure 2.1) of which the impacts of livestock grazing and its concomitant trampling affect rehabilitating processes negatively.

Local grass species and their estimated levels of consumption are presented in table 2.2. The domination of *Aristida junciformis* in the area indicates that there has been disturbance in the area one way or other (possibly by overgrazing); and this grass species is of poor grazing quality (Van Outdtshoorn 1999). Hence the area is of poor grazing value because *Aristida junciformis* is a less palatable grass species to grazers (Van Outdtshoorn 1999 and Ghebrehiwot *et al.* 2006). Due to shortage of palatable grass species in communal area, animals (cattle) therefore are forced to browse trees and shrubs available in the community (Table 2.3). An estimated level of tree/shrubs preference consumption by communal livestock indicates that guava (*Psidium guajava*) was the most preferred species. Avocado (*Persea americana*) and Orange (*Citrus annum*) were reported as the second preferred tree species in the community by cattle. Cattle are normally characterized as grazers not browsers; but of late, cattle can consume some tree leaves (Chesworth 1992). Communal livestock are active dispersing agents of guava seeds in the rehabilitating forest, but dung which was collected deep in the rehabilitating forests had less seeds as compared with dung collected at the forest edge where cattle enter the forest. However this is from general observation, there were no statistical analysis done, therefore it is open for quantification. Kwa-Mbonambi communal farmers use some of these shrubs and trees for the medicinal purposes to treat livestock (Table 2.4). Communal farmers are knowledgeable about the vast resources available in their localities (Komwihangilo *et al.* 2001), and it is a common practice for the communal farmers to use the local herbs as their livestock remedy (Kunene *et al.* 2003). However there is little scientific research done on these medicinal trees and shrubs.

2.4.2 Cattle impact in the rehabilitating forest

The exclusion of cattle in rehabilitating dune forest led to high production of grass biomass and *Acacia* seedling establishment. Livestock grazing in the rehabilitating dune forest reduces seedling establishment which hinders the restoration programme. The number of *Acacia karroo* seedlings counted in the control plot was less than those counted in the exclosure plot. Therefore the prediction postulated above that grazing reduce seedlings establishment was accepted. Livestock activity (grazing and trampling) can affect seedling establishment and growth (Hayashi 1996). A reduction of grazing activity in woodland sites resulted in recruitment of oak seedling (Mayle 1999). Herbaceous biomass which was clipped during November 2005 showed that animal grazing had a negative effect on soil cover by reducing herbaceous biomass by 51.8% (Figure 2.10). Grazing reduces aboveground biomass by 5 to 35% in grazed sub-plots compared to ungrazed plots (Van Staalduinen *et al.* 2005). The severeness of grazing could be caused by a large number of livestock grazing in a limited place for a short period of time or number of animals grazing in one place for a long period of time. High stocking rates induce severe grazing which reduces grass vigour of forage and that creates and maintains structural and species diversity within the ground flora (Morris *et al.* 1999 and Mayle 1999). NDF and CP were not significantly different between the plots. This might be due to the fact that clipping was done once. Results of this study therefore indicate that grazing practices had much greater negative influence on the under-storey vegetation structure, the ungrazed site (exclosure) had more grass cover to such an extent that it was difficult to see the markers as compared with the grazed sub-plot. *Acacia karroo* seedling establishment was not hindered by grass and shade, as it is reported as a highly invasive and shade tolerant tree species (see O'Connor 1995 and Kraaj 2002). Livestock grazing has been reported to reduce vegetation height (Reed and Clokie 2000), hence the grazed site always had more open under-storey as compared with the ungrazed site (Tasker and Bradstock 2006). Cattle grazing affect plant species richness, cover and abundance of under-storey vegetation (Wassenaar and Van Aarde 2001). Therefore, this could hinder seedling establishment in two ways. Seeds may not have enough moisture to trigger germination or they could germinate but hoof action and grazing could cause stunted growth or death.

The distribution pattern of communal livestock in the rehabilitating dune forest determines the area which is more often grazed by livestock. The old rehabilitating stand in the forest was more often grazed by livestock (Figure 2.1). This stand is represented by senescent *Acacia karroo* which results to open patches and therefore grasses are fully established (Van Aarde *et al.* 1998 and Ferriera and Van Aarde 1997) dominated by *Dactyloctenium austale* (LM grass). Animals choose a place where they can get good forage in terms of quality and quantity (Bailey *et al.* 1996). Forage palatability and availability are the most important parameters which modify grazing behaviour of animals (Roath and Kruger 1982). Younger rehabilitating stands are characterised by dense *Acacia karroo* trees, hence there is no influx of livestock. Trampling effect by grazing livestock may cause soil compactness which influences water runoff, and that favours soil erosion however though in sand it increases water holding capacity (Mayle 1999).

Cattle grazing practices have major effects on forest structure and vegetation composition by dung dropping and urination which increase soil salinity and as stated hoof action and grazing reduce plant vigour. Cattle dung which was collected during surveys indicated that some invasive plant species are dispersed by grazing cattle. Cattle disperse a larger number of seeds with dung during grazing (Tews *et al.* 2000, Grice 1996 and Havstad 1992). Beside the fact that communal farmers reported that their livestock also consume guava fruits and leaves (Table 2.3), guava seeds were found in cattle dung collected from the rehabilitating forest, which means guava was the dispersed species in the rehabilitating forest. Domestic grazers indirectly favour seedling recruitment of woody plants by either dispersing seeds to favourable habitats or creating favourable conditions for germination (Reid and Ellis 1995; Schultka and Conelius 1997). The dispersal density of *Psidium guajava* in the rehabilitating dune forests varies from the forest edge (entrance point) to middle, due to the fact that dung which was collected on the forest edge was observed to have more guava seed, however this is open for further research because there was no statistical analysis done on this. Even though it has been found that guava is the dispersed species in the forest nothing is known about the invasiveness of guava in shady areas.

The passage of guava seed through the alimentary canal (gut) of animals did not increase the germination. Instead fresh seed from a tree had a higher germination percentage in all temperatures as compared to seed passed through the animal's gut (see Table 2.5). There is a general belief that seeds that have passed through the alimentary canal of an animal have higher germination rates compared with fresh seed (Campos and Ojeda 1997), this belief with guava seeds seemed not to be supported. However guava seeds have hard seed coat therefore the passage of seeds in animal's gut did not enhance germination. This was in accordance with Somarriba (1986) who reported that the passage of guava seed through the digestive tract of cattle did not affect germination.

2.5 CONCLUSION

Shortage of grass due to overgrazing and death of livestock due to disease are the major constraints in livestock operations in communal areas. This study has revealed that Kwa-Mbonambi communal farmers had a problem of raising livestock due to over population in the area (see Scogings *et al.* 1999) which resulted in the shortage of grazing land. Most Kwa-Mbonambi farmers want to increase their livestock (Figure 2.9) without considering other parameters like animal husbandry (e.g. pasture, water and health). As a result communal livestock invade the rehabilitating dune forest which then raises a concern for RBM; what impact may grazing cattle have in rehabilitating sand dune forest? Communal farmers still rely on the traditional knowledge in order to keep their livestock in good condition (Table 2.4); scientific research has to be done on these shrubs and trees which are used by communal farmers for their livestock remedies.

The experimental exclusion of livestock from the rehabilitating forest led to the increase in above-ground biomass. It is concluded that the influxes of communal livestock in the rehabilitating dune forest due to lack of grazing resource in the community disturbs the vegetation cover which plays a major role in ecological diversity of the forests. Grazing clearly had a negative effect on above-ground biomass (see Van Staaluinen *et al.* 2005), therefore, grazing practices (grass removal and trampling) by communal livestock hinder the restoration process of vegetation in the rehabilitating forest. This may affect the rehabilitating process. RBM should make provision for the communal livestock grazing.

CHAPTER THREE

EFFECT OF SHADE, WATER, NITROGEN AND DAMAGE ON GROWTH OF *ACACIA KARROO* (SWEET THORN) SEEDLINGS: TUNNEL EXPERIMENT

3.1 INTRODUCTION

Little is known about effects of the interaction of various environmental factors on growth of *Acacia karroo* (Hayne) seedlings. *Acacia karroo* (Sweet thorn) belongs to the family Fabaceae (leguminosae), subfamily Mimosoideae (Mopipi 2005, Wassenaar and Van Aarde 2001). *Acacia karroo* is the pioneer species, which is widely distributed in the southern parts of Africa, particularly South Africa, Zimbabwe, Zambia and Swaziland to name a few (Chirara 2001 and Goheen *et al.* 2004). *Acacia karroo* is the most important woody plant invader of grassland in South Africa, and as such, it reduces grazing capacity for livestock (O'Connor 1995, Stuart-Hill & Tainton 1989 and Kraaij 2002). This phenomenon is commonly referred to as bush encroachment (Walters and Milton 2003). *Acacia karroo* as a pioneer species is able to establish itself in low nutritient soils as long as there is enough water to trigger germination.

African *Acacias* are able to produce large quantities of hard-coated seeds and often accumulate high densities of seeds in soil (Walters and Milton 2003). *Acacia* seeds can stay for about 29 months, becoming viable under unfavourable conditions (Chirara 2001) after which they germinate in conducive conditions. The hardness of *Acacia* seed prevents them from succumbing to fire; in fact, fire enhances germination of the seeds (Mbalo and Witkowiski 1997 and Walters *et al.* 2004). *Acacia* trees are thought to be heliophytic and therefore they require lots of light for optimal growth; however, *Acacia karroo* can also grow in places where low levels of light intensity are found (O'Connor 1995) and therefore it is shade tolerant. Richard's Bay Minerals (RBM) uses a wet mining programme (dredging pond) to extract heavy minerals from sand along the coast, after which rehabilitation is implemented and one third of the mined area is restored by planting *Acacia karroo* trees (Weirmans and Van Aarde 2003). Acacia trees, as leguminosae, nodulate and therefore characteristically fix nitrogen in soil (Johnson 2003 and Mopipi 2005). For this reason *Acacia karroo* has a competitive advantage over other trees in the nitrogen-poor soil (Lubke and Avis 1998).

The area mined by Richard's Bay Minerals (RBM) abuts sites where development is taking place as well as nodes inhabited by a fast growing population of people and their accompanying livestock (cattle). The high influx of people and livestock in the area results in a shortage of grazing land which is a common problem experienced by small-scale farmers in communal areas of KwaZulu-Natal (Kunene and Fossy 2006). The rehabilitating forest in the area is, as a result, increasingly exposed to the influx of communal livestock which takes place (Van Aarde *et al.* 1998), but the impact of livestock grazing in rehabilitating dune forest is not known. The physical structure of under-storey vegetation in the forest plays a major role in the ecosystem as it affects the germination and growth of plant species through prohibiting some plant species while it favours others (Tasker and Bradstock 2006). Moreover, vegetation controls the distribution and abundance of fauna within forest ecosystems. Livestock grazing in the forest disturbs the under-storey cover, which eventually impairs vegetation (Smith *et al.*

1996) and that disturbs the entire ecosystem of the forest by affecting biotic and abiotic components (Tasker and Bradstock 2006). Livestock grazing influences plant diversity (Adler *et al.* 2001) and as a result, grazing is regarded as the major biotic factor which affects vegetation structure and dynamics of pastures (Olff *et al.* 1999). Grazing is regarded as a major disturbance to the grassland ecosystem which increases defoliation dynamics pending the frequency of grazing (Yuxiang *et al.* 2005). Hence, plant growth will be impaired, resulting in disturbance of the entire ecological restoration process (Ruiz-Jaen and Aide 2005). Grazing livestock affect vegetation in many ways either by trampling or by dung deposition, which results in changes of herbaceous cover (Kohler *et al.* 2004). The livestock (cattle in particular) have their favoured place of rest as well as dunging, which result in an increase in soil nutrients (Bokdam and Gleichman 2000). Vegetation in these areas is prone to death, either by trampling, sleepover, dung dropping and urinating, which are all likely to increase nitrogen which becomes detrimental to plants. It is reported that dung may also have harmful effects on plants and on germinating crop and soil life (Hoekstra *et al.* 2002) by increasing soil nutrients which result in the fouling of pastures. The removal of the soil cover due to heavy grazing results in land degradation (Tews *et al.* 2004).

Management of livestock grazing on rangelands could have variable effects on soil fertility and stability, while heavy grazing in rehabilitating places may reduce the rate of soil nutrients and organic matter accumulation (Fuhlendorf *et al.* 2002). Herbivores have negative effects on plant succession by affecting the relative abundance of the plants on which they fed (Davidson 1993). Livestock grazing in rehabilitating areas may hinder the rehab process in two ways, namely by stamping on seedlings (trampling) or by grazing it together with grass, depending on the frequency and stage at which seedlings were when either trampled or grazed. Grazing and its concomitant trampling may accelerate the rate at which plant communities reach thresholds of vulnerability (Rupp *et al.* 2001b). Cattle can damage seedlings by browsing, but major damage is more often caused by trampling (Newman *et al.* 1997). While heavy grazing pressure can cause dramatic changes in plant composition and abundance by reduction of preferred species (Mayle 1999), heavy browsing impairs natural regeneration and stability of the forest ecosystem (Kamler and Homolka 2005).

Seed dispersal by herbivorous animals (cattle, by means of dung dropping) has been reported in savanna grassland (O'Connor 1995). While small animals, such as birds, play a minor role in seed dispersal (Cowling *et al.* 1997), it is the larger herbivores (cattle in particular) that make a major contribution towards seed dispersal because they carry a large number of seeds at a time. Hence, cattle are regarded as a major dispersal agent of seeds (Tews *et al.* 2004 and Barrow and Havstad 1992). Grazing animal ingests fruit of plant and disperses its seeds by means of the dung. The passage of the seeds through the alimentary canal of an animal increases seed germination (Campos and Ojeda 1997). Livestock (cattle in particular) can eat a large number of seeds which are then dispersed in new places by means of dung dropping (Gardener 1993), hence cattle facilitate woody plant invasion in savanna (Milton and Dean 2001). Although seed dispersal from undisturbed forest (unmined areas) to rehabilitating forest (mined areas) by vervet monkeys has been reported with regard to RBM rehabilitating dune forest (see Foord *et* *al.* 1994), but nothing is currently known about the impact of livestock on seed dispersal at RBM rehabilitating dune forest. Short-term grazing of cattle in the rehabilitating dune forest has been reported to affect the richness of plant species, soil cover and abundance of under-storey vegetation (Wassenaar and Van Aarde 2001), which is an important factor in determining species diversity.

This study sets out to determine the possible effects that the introduction of livestock may have on seed germination and the establishment of tree species in rehabilitating dune forest. Since hoof action, grazing and dunging or urinating are all believed to alter the micro environment of soil to the extent that seed germination can be either stimulated or inhibited, a multi-factorial experiment was conducted in order to assess the response of *Acacia karroo* seedlings to these factors and to determine the main factor(s) or interactions that affect these seedlings. Cattle cause damage to seedlings by trampling and clipping (see chapter two, Rupp *et al.* 2001b) but it has been reported that a major damage caused by cattle on plant is by trampling (Newman *et al.* 1997 and Hayishi 1996). In chapter two, cattle grazing has been reported to reduce grass biomass, therefore this creates a lighter environment (less shade) which then reduces soil moisture (Van Staalduinen *et al.* 2005, Tasker and Bradstock 2006). Cattle increase nitrogen cycling in soil due to dung and urine deposition (Hoekstra *et al.* 2002 and Bokdam and Gleichman 2000). Therefore it could be assumed that, among other conditions: 1) Clipping / trampling, watering infrequently, adding fertiliser and having no shading simulates grazed conditions, while 2) daily watering without fertiliser and with shade, but no damage simulates the ungrazed conditions. The main objective of the research was to evaluate which conditions may have possible detrimental effects on *Acacia karroo* seedlings. *Acacia karroo* was chosen due to the fact that it is used for rehabilitation by RBM.

3.2 MATERIALS AND METHODS

3.2.1 Study site

The *Acacia karroo* experiment was conducted during the period of November – December 2005 in a horticultural tunnel at the University of Zululand (28°, 51'S; 31°, 50' E) situated at Kwa-Dlangezwa, in KwaZulu-Natal province of South Africa. The University is situated 56 kilometers west of Richard's Bay at an altitude of about 70 – 80 m above sea level. The area adjoins the Indian Ocean with its warm Mozambique current, therefore rain is received throughout the year, with maximum rainfall experienced during January – March, with mean annual precipitation of 1228mm. The mean maximum temperature is 36^0C, and mean minimum temperature is 20^0C during December and June respectively. The vegetation of the area can be described as Coastal Forest and Thornveld (Acocks 1988).

3.2.2 Experimental design

The experiment was conducted in a 3^4 factorial arranged in a complete randomized design with four replications of three *Acacia karroo* seeds per replicate. Seeds were obtained from RBM. Four factors with three levels each were combined into treatments. Treatments were randomly assigned to pots in a multi-factorial experimental design with three levels of shade, three levels of water, three levels of fertiliser and three levels of damage (Table 3.1). Shade cloth was fixed 25cm above the top surface of pots filled with sandy soil (Holmes & Cowling 1993, O'Connor 1995 and Fulco *et al.* 2001). In order to allow seeds to imbibe enough water for germination, the pots were watered daily for one week. Thereafter watering was controlled and seedling was then subjected to different nitrogen fertiliser treatments which were zero, 0.4 g and 0.6 g of urea as top dressing. After two weeks, the *Acacia* seedlings were damaged by means of clipping just above cotyledonous leaves (to simulate grazing) and momentarily crushed by a 13.5kg steel weight which was dropped from a height of 75cm above the pot surface (in order to simulate hoof trampling) (Clary and Kinney 2000). The 81 possible combinations were randomly allocated to pots with four replicates per treatment. A total of 324 nursery pots, of 4 l each, were filled with sandy soil collected from the rehabilitating stand which was 28 years old (at the time of the study) situated at 28°, 40' S and 32°, 14' E. Each pot was planted with three *Acacia karroo* seedlings. The pots were set out in a configuration of 18 x 18 and each pot was treated as one replicate of three seeds. Therefore a total of 972 *Acacia karroo* seeds were sowed.

Table 3.1: In the experimental setup (according to the mult-factorial experimental design), each pot with three *Acacia karroo* seedlings was randomly subjected to a combination of the following treatments: (n = 3 shade treatments x 3 water treatments x 3 nitrogen treatments x 3 damage treatments x 4 replicates = 324 pots).

Shade Treatment (S)	**Water Treatment (W)**	**Nitrogen Treatment (N)**	**Damage Treatment (D)**
S0 = No shade	W0 = Watered once a week	N0 = 0g Urea	D0 = No damage
S1 = 40% shade	W1 = Watered twice a week	N1 = 0.4g Urea	D1 = Clipping
S2 = 80% shade	W2 = Watered every day	N2 = 0.6g Urea	D2 = Trampling

3.2.3 Data Collection

The germination of *Acacia karroo* was recorded after four days when the germination was noticed. The experiment was terminated on the 23rd of December 2005; three weeks after the *Acacia karroo* germination. The number of surviving tree seedlings was recorded before harvest and seedling heights were measured from the soil surface to the highest living buds. About 85% of the seedlings were recorded at the terminating of the experiment. The *Acacia karroo* seedlings were oven dried for 48 hours at 60°C in brown paper bags. Shoots and roots were separated by cutting shoots at ground level and weighed separately.

3.2.4 Data Analysis

Statistical procedures for growth of *Acacia karroo* seedling were conducted accordingly by means of SYSTAT 10 for Windows (SPSS 2000). Data were first tested for normality and only data for shoots and roots mass were not normally distributed, therefore square root transformation was used to transform data. Transformation is required when data are not normally distributed. Parametric data analysis assumes normal distribution and there is a high probability that incorrect statistical results would be obtained if parametric testing is conducted on non-normal data. An F-test was used to analyse seedling height and dry mass. The Scheffé multiple means comparison test was used to determine the differences among the means. All statistical tests were conducted at 5% levels of significance ($P \leq 0.05$).

3.3 RESULTS

3.3.1 The effect of treatments on seedling height of *Acacia karroo*

Statistical analysis carried out with regard to seedling height of *Acacia karroo* showed that there was a significant effect due to factor interactions (Appendix 2), and the highest order of interaction was all four factors namely shade, water, fertiliser and damage ($F_{16,180} = 10.56$; $P < 0.001$). Shade and damage separately as the main factors had no significant effect on seedling height of three week old *Acacia karroo* ($F_{2,180} = 1.41$; $P = 0.248$; and $F_{2,180} = 0.60$; $P = 0.553$ respectively), but the interaction of these two factors affected seedling height significantly ($F_{4,180} = 7.42$; $P < 0.001$). Results indicated that increased fertiliser to *Acacia karroo* affected seedling height significantly ($F_{2,180} = 6.84$; $P = 0.001$). Water as the main factor also had a significant effect on seedling height (F

$_{2,180} = 4.29$; $P = 0.015$), however when it interacted with shade and damage there was no significant effect ($F_{8,180} = 1.92$; $P = 0.060$). Therefore, due to the significance of these interactions, the effect of fertiliser and water can only be described in consideration of shade and damage in their respective levels.

Therefore, due to the significant results of F-tests for the interaction of factors (shade, water, fertiliser and damage), the Scheffé multiple means comparison test was conducted in order to determine differences among the means of individual treatments and results are presented in Figure 3.1.

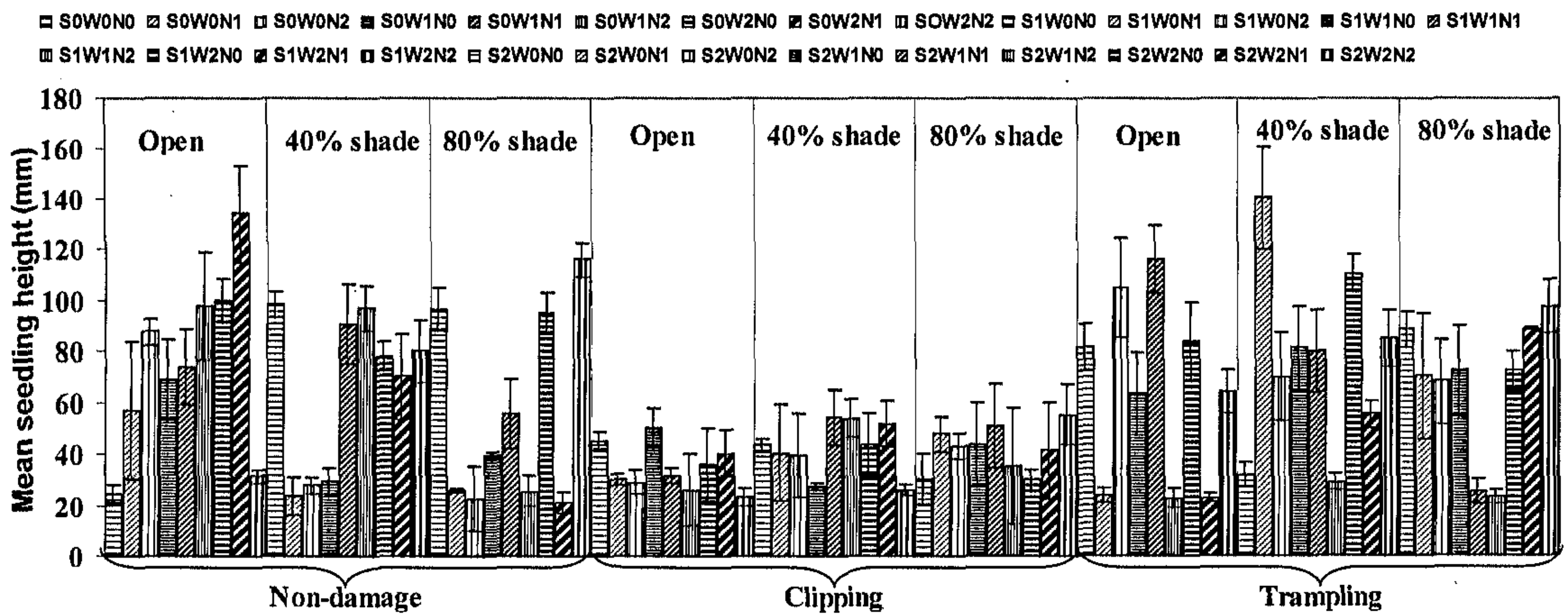

Figure 3.1: Interaction effects of shade, water, fertiliser and damage on mean height of *Acacia karroo* seedlings. Error bars represent ± 1 SE.

Key: **S0**= no shade, **S1**= 40% shade and **S2**= 80% shade. **W0**= watered once a week, **W1**= watered twice a week and **W2**= watered daily. **N0**= no fertiliser, **N1**= 0.4g fertiliser and **N2**= 0.6 fertiliser.

Undamaged and unshaded *Acacia karroo* seedlings watered at various intervals grew taller with fertiliser application (Figure 3.1). Though there was a positive response of seedlings to the interaction of fertiliser and water treatments, 0.6g fertiliser and daily watering reduced seedling height. Unshaded *Acacia karroo* seedlings responded positively to daily watering in the absence of fertilizer. Unshaded *Acacia karroo* seedlings which were treated with 0.4g fertiliser treatment (but watered once a week, twice a week or daily) increased in height (Figure 3.1). Positive effects of water and fertiliser were neutralized by shading or damage.

The interaction of water (watered once a week) and shade (40%) treatments resulted in an increased seedling height, but the application of fertiliser reduced the seedling height (Figure 3.1), however seedlings which were watered twice a week responded positively to fertiliser. Fertiliser levels applied to seedlings which were watered daily and shaded by 40% shade cloth made no significant increase in seedling height. Seedlings which were watered once a week while under 40% shade cloth were taller as compared with other seedlings which were watered twice a week or daily with no fertiliser applied. Shaded seedlings with 80% shade cloth increased height, however the application of fertiliser reduced seedlings heights. The application of 0.4g fertiliser treatment to seedlings which were watered twice a week while shaded by 80% shade cloth resulted in an increase of seedling height in contrast with other fertiliser treatments. Daily watering on 80% shaded seedlings had an increased to seedling height; however 0.4g fertiliser application reduced seedling height.

Clipping reduced height, this then resulted in a negative response of seedlings to fertiliser (Figure 3.1). Application of fertiliser to clipped *Acacia karroo* seedlings, which were watered either once or twice a week reduced height of unshaded seedlings. The application of 0.4g fertiliser to seedlings which were watered daily increased seedling height, as compared with the other two fertiliser treatments applied. Application of 0.6g fertiliser to clipped seedlings but watered once a week, twice a week or daily reduced height of unshaded seedlings. The 40% shade cloth and 0.4g fertiliser with three water treatments increased seedling height, however the application of 0.6g fertiliser reduced height. The application of 0.4g fertiliser to 80% shaded seedlings which were watered either once or twice a week increased seedling height, whereas 0.6g fertiliser application reduced seedling height. Shaded *Acacia karroo* watered daily and clipped responded positively to fertiliser (Figure 3.1).

Unshaded trampled seedlings responded positively to the interaction of fertiliser and water (Figure 3.1). Seedlings which were watered once a week but not shaded responded positively to 0.6g fertiliser, and 0.4g fertiliser and watering twice a week resulted in an increase in seedling height. Daily watered seedlings responded negatively to fertiliser application. Shade (40%) and fertilser (0.4g) resulted in an increase in seedling height of trampled seedlings; however 0.6g fertiliser application reduced seedling height of trampled seedlings when watered twice a week. Daily watering on trampled and 40% shaded seedlings resulted in a reduction of seedling height due to fertiliser application. Seedlings shaded by 80% shade cloth watered either once or twice a week responded negatively to fertiliser treatment, whereas daily watering resulted in an increase in seedling height (Figure 3.1).

3.3.2 The effect of treatments on the dry weight of shoots (above-ground) in *Acacia karroo*

Mean dry shoot mass data were analysed with SYSTAT 10 (SPSS 2000). Analysis of variance (ANOVA) results indicate that the interactions of shade, water, fertiliser and damage had significant effects on *Acacia karroo* seedlings ($F_{16,180} = 11.99$; $P < 0.001$). Shade and damage as main factors had no significant effect on dry shoot weight ($F_{2,180} = 2.73$; $P = 0.068$ and $F_{2,180} = 0.74$; $P = 0.479$ respectively), but their interaction affected seedling shoot dry weight significantly ($F_{4,180} = 9.71$; $P < 0.001$). Fertiliser had a significant effect on seedling shoot dry weight ($F_{2,180} = 7.48$; $P = 0.001$). The interaction of three factors namely shade, water and damage had no significant effect on shoot weight (see Appendix 3).

Due to the significant effect of the four factors (shade, water, feriliser and damage) on mean shoot dry weight of *Acacia karroo* from the F-test table, the Scheffé multiple means comparison test was used to determine the differences between the means of individual treatments, as shown in the results presented in Figure 3.2.

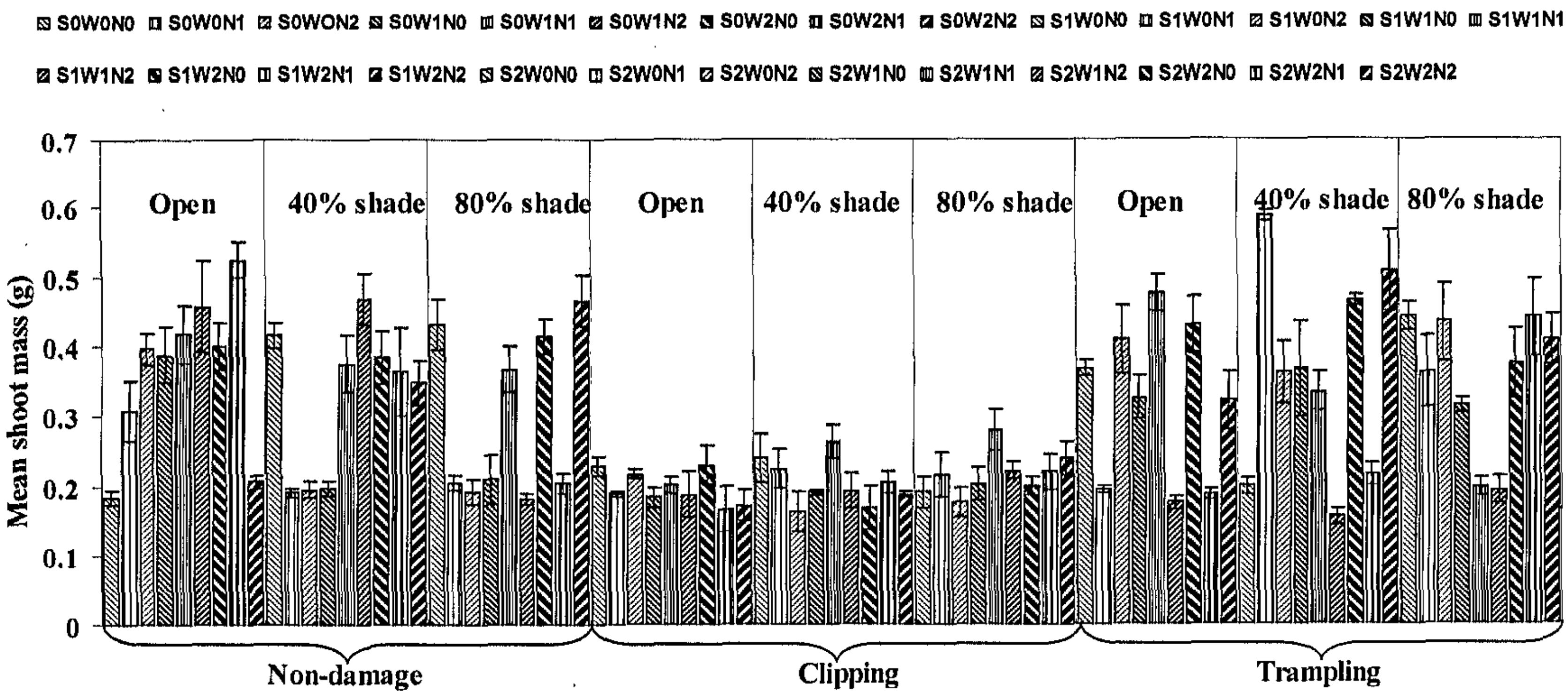

Figure 3.2: Interaction effects of shade, water, fertiliser and damage on the mean shoot weight of *Acacia karroo* seedlings. Error bars represent ± 1 SE.

Key: S0 = no shade, **S1** = 40% shade and **S2** = 80% shade. **W0** = watered once a week, **W1** = watered twice a week and **W2** = watered daily. **N0** = no fertiliser, **N1** = 0.4g fertiliser and **N2** = 0.6g fertiliser.

Undamaged and unshaded seedlings watered once or twice a week responded positively to fertiliser application (Figure 3.2). Application of 0.4g fertiliser to seedlings which were watered daily increased shoot dry weight, however 0.6g fertiliser application reduced shoot dry weight. Undamaged and unshaded seedlings watered either twice a week or daily increased shoot dry weight. Seedlings which were watered daily responded positively to 0.4g fertiliser, while 0.6g fertiliser reduced shoot dry weight. Water treatments (i.e. watering twice a week or daily) caused an increase in shoot dry weight of seedlings which were fertilised by 0.4g fertiliser. Seedlings which were watered either once a week or daily but shaded by 40% shade cloth responded negatively to fertiliser application, but watering twice a week increased shoot dry weight. Fertiliser treatment applied to *Acacia karroo* seedlings which were watered once a week and shaded by 80% shade cloth reduced shoot dry weight. Water treatment applied to seedlings which were fertilised by 0.4g fertiliser resulted in a positive response of seedlings, whereas 0.6g fertiliser treatment only increased shoot dry weight when seedlings were watered daily (Figure 3.2).

Damage inflicted once on seedlings (in the form of clipping) caused a negative response of *Acacia karroo* seedlings to fertiliser application when watered once or twice a week. Watering twice a week and clipping increased shoot dry weight. The application of 0.4g fertiliser to seedlings which were watered daily increased shoot dry weight in contrast with 0.6g fertiliser application. Application of fertiliser treatments to 40% shaded seedling while watered once a week decreased shoot dry weight, however 0.4g fertiliser application to seedlings watered either twice a week or daily resulted in an increase of shoot dry weight. Application of 0.4g fertiliser to seedlings watered either once or twice a week and shaded by 80% shade cloth resulted in a positive response of seedlings by increasing shoot dry weight, compared with 0.6g and unfertilised treatments. *Acacia karroo* seedlings which were watered daily responded positively to fertiliser treatments.

Damaged seedlings (in the form of trampling) that were watered either once a week or daily decreased shoot dry weight when 0.4g fertiliser was applied, but seedlings which were watered twice a week and had 0.4g fertiliser treatment increased shoot dry weight. The 40% shade cloth and watering once a week with the application of 0.4g fertiliser increased shoot dry weight of trampled seedlings, but seedlings which were watered twice a week responded negatively to fertiliser treatments. Seedlings which were watered daily responded positively when there was no fertiliser applied and 0.6g fertiliser. The 80% shade cloth caused a negative response of *Acacia karroo* seedlings from 0.4g fertiliser when watered once a week. Seedlings which were watered twice a week responded negatively to fertiliser application, while daily watering increased seedling shoot dry weight.

3.3.3 The effect of treatment on roots (below-ground) dry weight of *Acacia karroo*

Statistical analysis of variance (ANOVA) indicated that the interaction of all four factors namely shade, water, fertiliser and damage had a significant effect on root dry weight of *Acacia karroo* seedlings ($F_{16,180} = 2.50$; $P = 0.002$), but these factors had no significant effect on root dry weight as individual main factors (Appendix 4). The interaction of water and damage resulted in a significant effect on root dry weight ($F_{4,180} = 5.38$; $P <$

0.001). The interaction of shade, water and damage had no significant effect on root dry weight of *Acacia karroo* ($F_{8,180} = 1.71$; $P = 0.099$). The interaction of three factors namely shade, fertiliser and damage resulted in a significant effect to root dry weight ($F_{8,180} = 2.76$; $P = 0.007$), and also there was a significant effect on root dry weight in the interaction of shade, water and fertiliser (Appendix 4).

Due to a significant interaction of four factors namely shade, water, fertiliser and damage on root dry weight of *Acacia karroo* (as shown on the F-tests table), the Scheffé multiple means comparison test was conducted in order to determine the differences between the means of individual sub-treatments and results are presented in Figure 3.3.

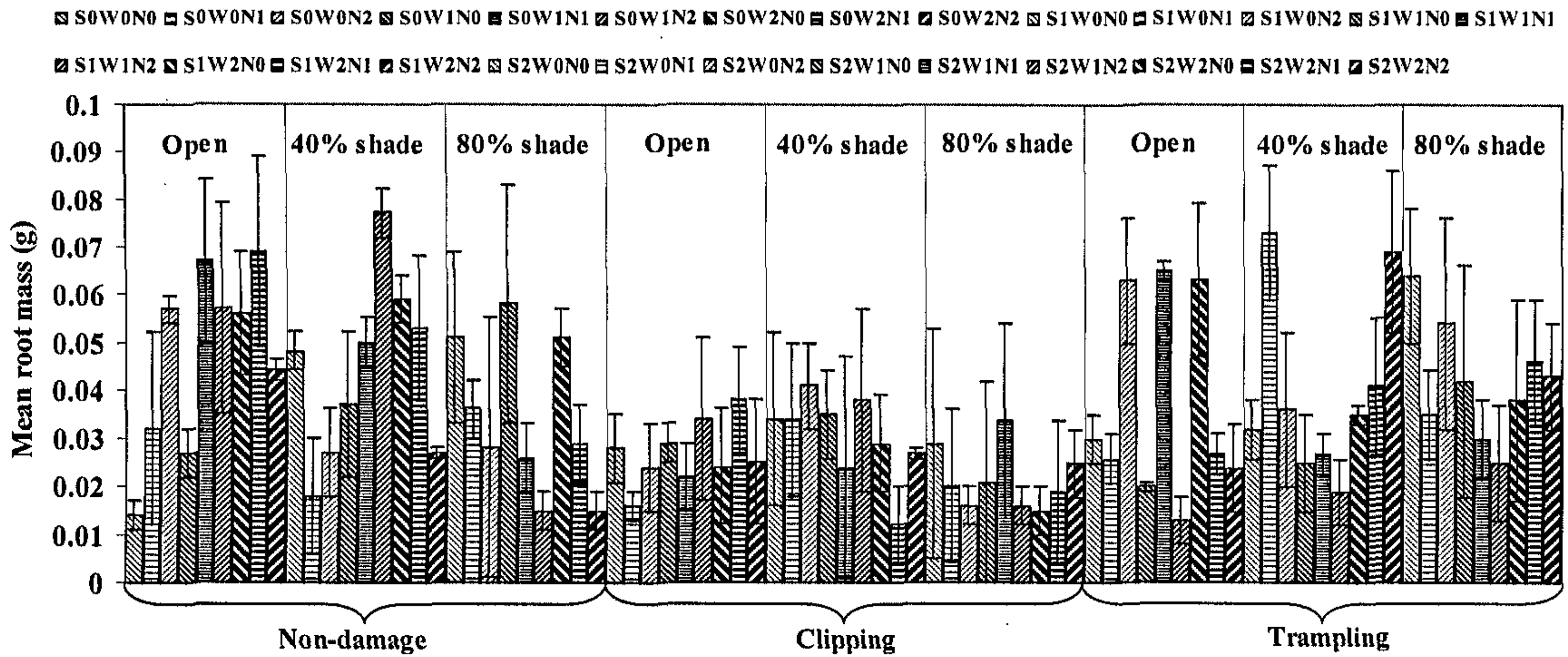

Figure 3.3: Interaction effects of shade, water, fertiliser and damage on mean root weight of *Acacia karroo* seedlings. Error bars represent ± 1 SE.

Key: S0 = No shade, **S1** = 40% shade and **S2** = 80% shade. **W0** = Watered once a week, **W1**= watered twice a week and **W2**= Watered daily. **N0**= No fertiliser, **N1**= 0.4g fertiliser and **N2**= 0.6g fertiliser.

Undamaged *Acacia karroo* seedlings watered once a week responded positively to fertiliser application by increasing root dry weight. The application of fertiliser to seedlings which were watered twice a week reduced root dry weight as compared with non-fertilised seedlings (Figure 3.3). Seedlings which were watered daily and fertilised by 0.6g fertiliser had the lowest root dry weight compared with seedlings which were treated by the other two fertiliser treatments. Seedlings which were watered daily with no fertiliser had an increase in root dry weights as compared with the seedlings which were watered either twice or once a week. The effect of fertiliser application and 40% shade cloth with water twice a week resulted in an increase in root dry weight. Fertiliser treatment (0.6g) reduced root dry weight when seedlings were watered either once a week or daily. Seedlings which were watered either twice a week or daily responded positively to 0.4g fertiliser application. Seedlings shaded by 80% shade cloth responded negatively to all fertiliser treatments.

Clipped and unshaded seedlings responded negatively to fertiliser application. Seedlings which were watered either twice a week or daily increased root dry weight due to 0.4g fertiliser application. The 40% shade cloth and watering once a week with the application of fertiliser reduced root dry weight. The 0.4g fertiliser application to seedlings which were watered either twice a week or daily resulted in an increase in root dry weight. Watering once a week increased root dry weight of clipped seedlings compared to other water treatments. Fertiliser treatments applied with 80% shade cloth and water once a week reduced root dry weight, and where 0.4g fertiliser was applied to seedlings which were watered twice a week and shaded by 80% shade cloth seedlings increased root dry weight. Application of fertiliser increased root dry weight of 80% shaded seedlings which were watered daily. Changing water treatment in seedlings which were fertilised by 0.6g fertiliser resulted in an increase in root dry weight. Daily watering of seedlings increased root dry weight as compared with the other two water treatments.

Unshaded seedlings, trampled and watered once a week responded positively to 0.6g fertiliser treatment by increasing root dry weight. While the application of 0.4g fertiliser to seedlings which were watered twice a week resulted in an increase in root dry weight, fertiliser applied to seedlings which were watered daily reduced root dry weight. Seedlings which were shaded by 40% shade cloth but watered once a week increased root dry weight when they were fertilised by 0.4g fertiliser. Seedlings which were watered twice a week and shaded by 40% shade cloth responded negatively to fertiliser treatment. Fertiliser treatments increased root dry weight of seedlings which were watered daily, however watering either once or twice a week in 80% shaded seedlings reduced root dry weight when fertilised compared with unfertilised seedlings.

3.4 DISCUSSION

Although *Acacia karroo* is known as an important invader tree species in grassland (O'Connor 1995 and Chirara 2001), it is reported that water stress results in stunted growth or complete plant death (Mopipi 2005). The experiment only lasted for three weeks, with emphasis on the effect of simulated livestock grazing and trampling on establishing *Acacia karroo* seedlings. Therefore damage (clipping and trampling) treatments were applied to two weeks old *Acacia karroo* seedlings and the response was measured a week later. Though clipping reduced seedling height, it was not significantly reduced compared with the intact seedling (see appendix 2). This could be caused by the fact that the response was measured in a short period of time, due to the fact that *Acacia karroo* has a tendency of allocating most resources to root growth at an early stage of development (Chirara 2001) for an adequate development of the root system as an invasive plant. Temperature inside the tunnel was very high (45^0C) maybe due to the fact that the tunnel structure would not allow air flow (circulation) and this may have increased water loss through leaves.

3.4.1 Effect of treatments on *Acacia karroo* seedling heights

In general terms water plays a vital role in seed germination. Water availability in soil (as soil moisture) plays a crucial role in seed germination for 10 – 14 days in *Acacia* (Wilson and Witkowski 1998). In *Acacia karroo* water plays a vital role during germination phase, but after germination the subjection of seedlings to water stress does not affect seedling growth. *Acacia karroo* is known as an invader tree species (O'Connor 1995). During the germination period it deposits more nutrients in root growth, so as to access deeper nutrients as an invader species, therefore, water treatment in three week old *Acacia karroo* seedlings had no major effect on seedling height. Watering once a week did not cause seedling death. This is not in accordance with Mopipi (2005) who stated that *Acacia karroo* is sensitive to moisture stress; therefore the subjection of seedlings to water stress may result in seedling death. Therefore the expectation that water stress will reduce seedling growth was rejected. Though there were seedling deaths which were recorded during the experiment, they were not associated with water stress or high fertiliser treatment separately; but instead they were associated with the interaction of the two treatments. Therefore, the application of 0.6g fertiliser to seedlings which were watered once a week resulted in seedling death. Nitrogen is known as the limiting growth factor of plants due to the fact that plants require large amounts, for incorporation into proteins (Krueger-Mangold *et al.* 2004). Nitrogen fertiliser is absorbed as nitrate ions which influences the intake of water by plants.

Shade influenced seedling height due to the fact that shaded seedlings allocate more resources to shoot growth than to root growth for light competition (Holmes and Cowling 1993). Shaded *Acacia karroo* seedlings were taller due to shade but were not thinner. Shaded seedlings normally grow taller and thinner (Holmes and Cowling 1993), but *Acacia karroo* is known as a shade tolerant species (O'Connor 1995). Though shade had an effect on seedling height as a main factor the combination of fertiliser, shade and water reduced seedling height. Though clipping reduced seedling height; shading and the application of 0.4g fertiliser increased seedling height in the presence of water. Trampling did not cause a major effect on seedling height. Trampled seedlings were just pounded once by 13.5kg weight and that resulted in the plants bending (see Figure 4.3b of Chapter 4), from which they recovered. Trampling frequency plays a major role in seedling survival (Yates *et al.* 2000). The recovery of trampled seedlings determines the resistance of seedlings (Roovers *et al.* 2004). Plants can withstand a limited pulse of trampling and then recover (Rogers and Cox 2003). The interaction of fertiliser and shade resulted in an increase in height of intact seedlings, but pulverized seedlings did not respond to the interaction of fertiliser and shade applied together.

3.4.2 Effect of treatments on above and below-ground biomass of *Acacia karroo* seedlings

Water has been reported to decrease the above-ground biomass (Krueger-Mangold *et al.* 2004), however our results disagree with this; water treatment increased the above-ground biomass. Water treatment applied to seedlings which were fertilised by 0.4g increased the above-ground biomass of *Acacia karroo*. Nitrogen dissolved in water becomes more accessible to plants in the form of nitrate ions and that increased soil acidity; therefore 0.6g fertiliser application resulted in decreased seedling above-ground biomass. Shade treatment in this experiment did not represent exactly the same situation of light intensity in forest under-storey, but the response of *Acacia karroo* seedlings in this experiment showed that low level of light intensity reduces shoot dry weight. Shaded seedlings with 40% shade cloth and watered either once a week or daily did not respond to fertiliser application. Shaded seedlings normally grow taller and thinner (Holmes and Cowling 1993), but this study did not confirm this since *Acacia karroo* is known as a shade tolerant species (O'Connor 1995).

Physical injury (damage) which was applied to *Acacia karroo* seedlings did not represent exactly the effect of cattle grazing in the rehabilitating coastal sand dune forest. Clipping treatment applied to seedlings resulted in decreased above-ground biomass, and therefore root dry weight of clipped seedlings was heavier than shoot dry weight. Root growth of plants is dictated by the amount of carbohydrate (Wolfson and Tainton 1999); the greater amount of carbohydrate produced by plants is allocated for root growth. Roots of intact seedlings were heavier in weight as compared with the roots of clipped seedlings. This might be due to the fact that clipped seedlings have used the reserved carbohydrate in roots for the formation of new leaves. Root have been reported as the most important organ of a plant for water and nutrient intake (Chirara 2001), therefore, there is need for adequate development of roots especially by invasive plants. Trampling did not cause a major effect on root dry weight, hence root dry weight of trampled seedlings did not differ to that of intact seedlings. Trampled seedlings were just momentarily squashed once which did not remove the photosynthetic organs (leaves). As a result then there was less utilization of stored nutrients in roots for the seedling recovery. Clipped seedlings did not respond to water application, maybe because plants absorb water in the presence of leaves as it is used during the process of photosynthesis and evapotranspiration. However, added fertiliser would not be utilised by plants.

3.5 CONCLUSION

The multi-factorial experiment conducted at the University of Zululand was intended to mimic the situation in a rehabilitating forest covering a previously mined area, where communal livestock have been introduced. However, tunnel was not conducive for the experiment because there was no air circulation which then resulted in a drastically increased internal temperature. Though some seedling death was recorded, it was not associated with water stress or high fertiliser but was due to their interaction. Therefore, it was concluded that to add more fertiliser to seedlings while reducing watering (irrigation) become detrimental to the plants. Clipping and trampling treatments carried out on the seedlings did not precisely mimic the impact of cattle grazing in the rehabilitating forest. However, livestock grazing in rehabilitating forests affects micro-environments of the forest by grazing; trampling, urinating and dung dropping (Hoekstra *et al.* 2002 and Bokdam and

Gleichman 2000), which may lead to seedling death depending on the frequency of trampling and grazing.

CHAPTER FOUR

EFFECT OF SHADE, WATER, NITROGEN AND DAMAGE ON GROWTH OF *ACACIA KARROO* (SWEET THORN) SEEDLINGS: RAINOUT EXPERIMENT

4.1 INTRODUCTION

Little is known about effects of the interaction of various environmental factors on growth of *Acacia karroo* (Hayne) seedlings. *Acacia karroo* (Sweet thorn) belongs to the family Fabaceae (leguminosae), subfamily Mimosoideae (Mopipi 2005 and Wassenaar and Van Aarde 2001). *Acacia karroo* is the pioneer species, which is widely distributed in the southern parts of Africa, particularly South Africa, Zimbabwe, Zambia and Swaziland to name a few (Chirara 2001 and Goheen *et al.* 2004). *Acacia karroo* is the most important woody plant invader of grassland in South Africa, and as such, it reduces grazing capacity for livestock (O'Connor 1995, Stuart-Hill & Tainton 1989 and Kraaij 2002). This phenomenon is commonly referred to as bush encroachment (Walters and Milton 2003). *Acacia karroo* as a pioneer species is able to establish itself in low nutrient soils as long as there is enough water to trigger germination.

African Acacias are able to produce large quantities of hard-coated seeds and often accumulate high densities of seeds in the soil (Walters and Milton 2003). Acacia seeds can stay for about 29 months, becoming viable under unfavourable conditions (Chirara 2001) after which they germinate in conducive conditions. The hardness of Acacia seed prevents them from succumbing to fire; in fact, fire enhances germination of *Acacia karroo* seeds (Mbalo and Witkowiski 1997 and Walters *et al.* 2004). Acacia trees are thought to be heliophytic and therefore they require lots of light for optimal growth; however, *Acacia karroo* can also grow in places where low levels of light intensity are found (O'Connor 1995) and therefore it is shade tolerant. Richard's Bay Minerals (RBM) uses a wet mining programme (dredging) to extract heavy minerals from sand along the northern coast of KwaZulu-Natal province of South Africa, after which rehabilitation is implemented and one third of the mined area is restored by planting *Acacia karroo* trees (Weirmans and Van Aarde 2003). Acacia trees, as leguminosae, nodulate and therefore characteristically fix nitrogen in soil (Johnson 2003 and Mopipi 2005). For this reason *Acacia karroo* has a competitive advantage over other trees in the nitrogen-poor soil (Lubke and Avis 1998).

The area mined by Richard's Bay Minerals abuts sites where development is taking place as well as nodes inhabited by a fast growing population of people and their accompanying livestock (cattle). The high influx of people and livestock in the area results in a shortage of grazing land which is a common problem experienced by small-scale farmers in communal areas of northern KwaZulu-Natal (Kunene and Fossy 2006). The rehabilitating forest in the area is, as a result, increasingly exposed to the influx of communal livestock which takes place (Van Aarde *et al.* 1998), but the impact of livestock grazing in rehabilitating dune forest is not known. The physical structure of under-storey vegetation in the forest plays a major role in the ecosystem as it affects the germination and growth of plant species through prohibiting some plant species while it favours others (Tasker and Bradstock 2006). Moreover, vegetation controls the distribution and abundance of fauna within forest ecosystems. Livestock grazing in the forest disturbs the under-storey cover, which eventually impairs vegetation (Smith *et al.* 1996) and that disturbs the entire ecosystem of the forest by affecting biotic and abiotic components (Tasker and Bradstock 2006). Livestock grazing influences plant diversity (Adler *et al.* 2001) and as a result, grazing is regarded as the major biotic factor which affects vegetation structure and dynamics of pastures (Olff *et al.* 1999). Grazing is regarded as a major disturbance to the grassland ecosystem which increases defoliation dynamics pending with the frequency of grazing (Yuxiang *et al.* 2005). Hence, plant growth will be impaired, resulting in disturbance of the entire ecological restoration process (Ruiz-Jaen and Aide 2005). Grazing livestock affect vegetation in many ways either by trampling or by dung deposition, which results in changes of herbaceous cover (Kohler *et al.* 2004). The livestock (cattle in particular) have their favoured place of rest as well as dunging areas, which result in an increase in soil nutrients (Bokdam and Gleichman 2000). Vegetation in these areas is prone to death, either by trampling, sleepover, dung dropping and urinating, which are all likely to increase nitrogen which becomes detrimental to plants. It is reported that dung may also have harmful effects on plants and on germinating crop and soil life (Hoekstra *et al.* 2002) by increasing soil nutrients which result in the fouling of pastures. The removal of soil cover due to heavy grazing results to land degradation (Tews *et al.* 2004).

Management of livestock grazing on rangelands could have variable effects on soil fertility and stability, while heavy grazing in rehabilitating places may reduce the rate of soil nutrients and organic matter accumulation (Fuhlendorf *et al.* 2002). Herbivores have negative effects on plants succession by affecting the relative abundance of the plants on which they fed (Davidson 1993). Livestock grazing in rehabilitating areas may hinder the rehab process in two ways, namely by stamping on seedlings (trampling) or by grazing it together with grass, depending on the frequency and stage at which seedlings were when either trampled or grazed. Grazing and its concomitant trampling may accelerate the rate at which plant communities reach thresholds of vulnerability (Rupp *et al.* 2001b). Cattle can damage seedlings by browsing, but major damage is more often caused by trampling (Newman *et al.* 1997). While heavy grazing pressure can cause dramatic changes in plant composition and abundance by reduction of preferred species (Mayle 1999), heavy browsing impairs natural regeneration and stability of the forest ecosystem (Kamler and Homolka 2005).

Seed dispersal by herbivorous animals (cattle in particular, by means of dung dropping) has been reported in savanna grassland (O'Connor 1995). While small animals, such as birds, play a minor role in seed dispersal (Cowling *et al.* 1997), it is the larger herbivores (cattle in particular) that make a major contribution towards seed dispersal because they carry a large number of seeds at a time. Hence, cattle are regarded as a major dispersal agent of seeds (Tews *et al.* 2004 and Barrow and Havstad 1992). A grazing animal ingests some of the fruit of a plant and disperses its seeds by means of the dung. The passage of the seeds through the alimentary canal of on animal increases seed germination (Campos and Ojeda 1997). Livestock (cattle in particular) can eat a large number of seeds which are then dispersed in new places by means of dung dropping (Gardener 1993), hence cattle facilitate woody plant invasion in savanna (Milton and Dean 2001). Although seed dispersal from undisturbed forest (unmined areas) to rehabilitating forest (mined areas) by vervet monkeys has been reported with regard to RBM rehabilitating dune forest (see Foord *et al.* 1994), nothing is currently known about the impact of livestock on seed dispersal at RBM rehabilitating dune forest. Short-term grazing of cattle in the rehabilitating dune forest has been reported to affect the richness of plant species, soil cover and abundance of under-storey vegetation (Wassenaar and Van Aarde 2001), which is an important factor in determining species diversity.

Chapter three results were found to have some difficulties when it came to interpretation. Hence, that led to the repetition of the experiment with alterations made to fertiliser levels (see Table 4.1) and the experiment was conducted in a rain-out shelter (Figure 4.1) in order to allow air flow. The similar experiment was repeated in March – April the following year, which falls in another season (November- December). Fertiliser was changed by halving what was applied in chapter three due to the belief that high fertiliser increases soil salinity which is detrimental to plants, and will affect the growth rate of seedlings which might result in seedling death (Monaco *et al.* 2003). There is a general perception that *Acacia karroo* deposits more nutrients in root growth at an early stage of the establishment (Chirara 2001). However in chapter three, damage that was inflicted on seedlings (in the form of clipping) did not have a significant effect on seedling growth. Hence in chapter four the experiment was prolonged by three weeks. Damage was applied four weeks after germination and responses were measured two weeks later.

This study sets out to determine the possible effects that the introduction of livestock may have on seed germination and the establishment of tree species in rehabilitating dune forest. Since hoof action, grazing and dunging or urinating are all believed to alter the micro environment of seeds to the extent that germination can be either stimulated or inhibited, a multi-factorial experiment was conducted in order to assess the response of *Acacia karroo* seedlings to these factors and to determine the main factor(s) or the order of interactions that affect these seedlings. Cattle cause damage to seedlings by trampling and clipping (see chapter two, Rupp *et al.* 2001b) however, it has been reported that cattle cause a major damage on plant by trampling (Newman *et al.* 1997 and Hayishi 1996). In chapter two, cattle grazing has been reported to reduce grass biomass, therefore this creates a lighter environment (less shade) which then reduces soil moisture (Van Staalduinen *et al.* 2005, Tasker and Bradstock 2006). Cattle increase nitrogen cycling in soil due to dung and urine deposition (Hoekstra *et al.* 2002 and Bokdam and Gleichman 2000). Therefore it could be assumed that, among other conditions: 1) Clipping/ trampling, watering once a week, adding fertiliser and having no shading simulates grazed conditions while 2) daily watering without fertiliser and with shade, but no damage simulates the ungrazed conditions. Hence it can be postulated that: 1) the response to damage is stronger when water or nutrients are added and light is not shaded compared to when no nutrients are added but shade is added (light reduced) and water is reduced and 2) Root mass is reduced relative to shoot mass when nitrogen or water are increased compared to when they are less available. The main objective of the research was to evaluate which conditions may have possible detrimental effects on *Acacia karroo* seedlings. *Acacia karroo* was chosen due to the fact that it is used for rehabilitation by RBM.

4.2 MATERIALS AND METHODS

4.2.1 Study site

The *Acacia karroo* experiment was conducted during the period of March – April 2006 in a rainout shelter (Figure 4.1) at the University of Zululand (28°, 51'S; 31°, 50' E) situated at Kwa-Dlangezwa, in KwaZulu-Natal province of South Africa. The University of Zululand is situated 56 kilometers west of Richard's Bay at an altitude of about 70 – 80 m above sea level. The area adjoins the Indian Ocean with its warm Mozambique current, therefore rain is received throughout the year, with maximum rainfall experienced during January – March, with annual precipitation of 1228mm. The mean maximum temperature is 36^0C, and mean minimum temperature is 20^0C during December and June respectively. The vegetation of the area can be described as Coastal Forest and Thornveld (Acocks 1988)

Figure 4.1: ***Acacia karroo*** **seedlings were raised from seeds in a rainout shelter at the University of Zululand in March 2006**

4.2.2 Experimental design

The experiment was conducted in a 3^4 factorial arranged in a complete randomized design with four replications of three *Acacia karroo* seeds per replicate. *Acacia karroo* seeds were obtained from Richard's Bay Minerals (RBM). Four factors with three levels each were combined into treatments. Treatments were randomly assigned to pots in a multi-factorial experimental design with three levels of shade, three levels of water, three levels of fertiliser and three levels of damage (Table 4.1). Shade cloth was fixed 25cm above the top surface of pots filled with sandy soil (Holmes & Cowling 1993, O'Connor 1995 and Fulco *et al.* 2001).

In order to allow seeds to imbibe enough water for germination, the pots were watered every day for the first two weeks following the sowing of *Acacia karroo* seeds, after which watering was controlled. From the results of chapter three, fertiliser was adjusted. *Acacia karroo* seedlings that emerged after two weeks after being sown were then subjected to different nitrogen fertiliser treatments which were zero, 0.2 g and 0.4 g of urea as top dressing. Due to the belief that roots of *Acacia karroo* grow faster then shoots at an early stage of germination, damage was inflicted to four weeks old seedlings by means of clipping just above cotyledonous leaves (to simulate grazing) and crushed by a 13.5kg steel weight which was dropped from a height of 75cm above the pot surface (in order to simulate hoof trampling) (Clary and Kinney 2000). The 81 possible combinations were randomly allocated to pots with four replicates per treatment. A total of 324 nursery pots, of 4 l each, were filled with sandy soil collected from the rehabilitating stand which was 28 years old (at the time of the study) situated at 28°, 40' S and 32°, 14' E. Each pot was planted with three *Acacia karroo* seedlings. The pots were set out in a configuration of 18 x 18 and each pot was treated as one replicate of three seeds. Therefore a total of 972 *Acacia karroo* seeds were sowed.

Table 4.1: In the experimental setup (according to the mult-factorial experimental design), each pot with three *Acacia karroo* seedlings was randomly subjected to a combination of the following treatments: (n = 3 shade treatments x 3 water treatments x 3 nitrogen treatments x 3 damage treatments x 4 replicates = 324 pots).

Shade Treatment (S)	**Water Treatment (W)**	**Nitrogen Treatment (N)**	**Damage Treatment (D)**
S0 = No shade	W0 = Watered once a week	N0 = 0g Urea	D0 = No damage
S1 = 40% shade	W1 = Watered twice a week	N1 = 0.2g Urea	D1 = Clipping
S2 = 80% shade	W2 = Watered every day	N2 = 0.4g Urea	D2 = Trampling

4.2.3 Data Collection

The germination of *Acacia karroo* was recorded regularly (every 4 – 15 days). The experiment was terminated on the 24th of April 2006; six weeks after the *Acacia karroo* seeds were sown. Seedling heights were measured from the soil surface to the highest living buds (see Figure 4.2) before the experiment was terminated. The *Acacia karroo* seedlings were oven dried for 48 hours at 60°C in brown paper bags. Shoots and roots were separated by cutting shoots at ground level and weighed separately.

Figurer4.2: The researcher measured shoot height of *A. karroo* before harvest

4.2.4 Data Analysis

Statistical procedures for growth of *Acacia karroo* seedling were conducted accordingly by means of SYSTAT 10 for Windows (SPSS 2000). Data were first tested for normality and only data for shoots and root mass were not normally distributed, therefore square root transformation was used to transform data. Transformation is required when data are not normally distributed. Parametric data analysis assumes normal distribution and there is a high probability that incorrect statistical results would be obtained if parametric testing is conducted on non-normal data. An F-test was used to analyse seedling height, shoot and root dry mass and root:shoot ratio. The Scheffé multiple means comparison test was used to determine the differences among the means. All statistical tests were conducted at 5% levels of significance ($P \leq 0.05$).

4.3 RESULTS

4.3.1 Effect of treatments on the height of *Acacia karroo* seedlings

Statistical analysis carried out with regard to seedling height of *Acacia karroo* shows that there were no significant effects due to factor interaction ($F_{16,230} = 1.11$; $P = 0.338$). Damage was the main factor that significantly affected *Acacia karroo* seedling height ($F_{2,230} = 337.65$; $P < 0.001$); in fact, clipping (mean = 27.91 mm; SE = ± 0.622) and trampling (mean = 91.01 mm; SE = ± 2.683) reduced seedling height by 75.87% and 21.32% respectively, as compared to undamaged seedlings (mean = 115.68mm; SE = ± 3.178) (see Figure 4.3a and b), but interaction of damage with other factors had no significant effect on seedling height of *Acacia karroo* (see Appendix 1).

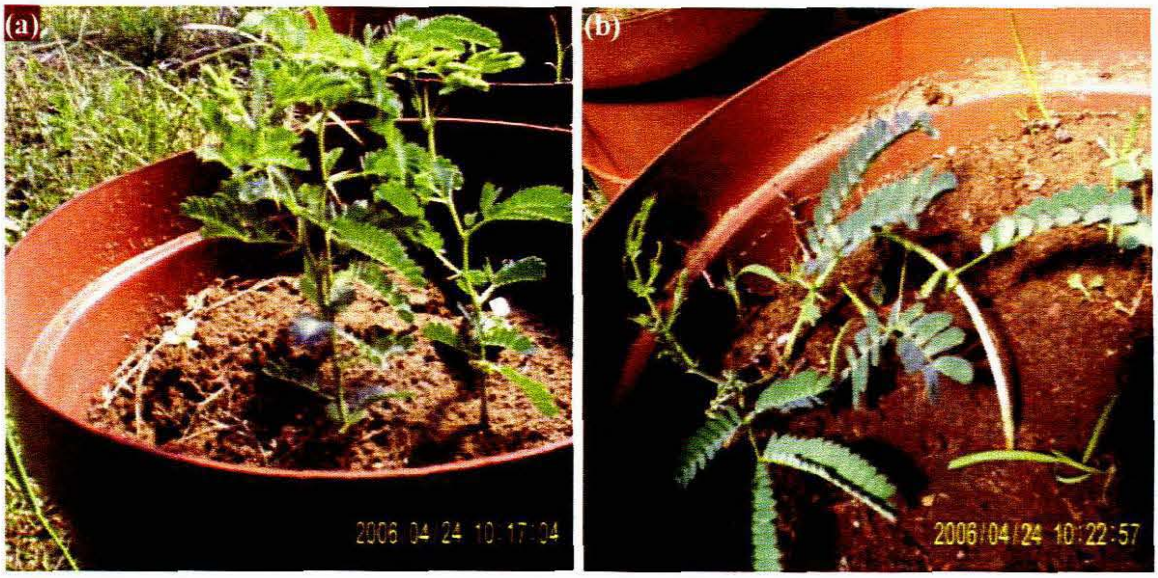

Figure 4.3: Effect of trampling on six weeks old *Acacia karroo* seedlings (A) intact seedlings (b) Trampled seedlings.

4.3.2 The effect of treatments on the dry mass of shoots in *Acacia karroo*

Mean dry shoot mass data were analysed by means of analysis of variance (ANOVA). Results indicate that increased shade applied to *Acacia karroo* seedlings affected shoot mass significantly ($F_{2,230} = 10.34$; $P < 0.001$). In fact, 40% shade (mean 0.21g; SE = ± 0.015) and 80% shade (mean 0.18g; SE = ± 0.012) decreased dry shoot mass by 7.5% and 19.9% respectively as compared to seedlings growing in open ground (mean = 0.23g; SE = ± 0.016), while the interaction of shade with other factors had no significant effect on dry shoots mass (see Appendix 2). Damage in the form of clipping also affect shoot mass significantly ($F_{2,230} = 721.07$; $P < 0.001$) but there was also a significant interaction between water, fertiliser and damage ($F_{8,230} = 2.33$; $P = 0.020$). Therefore, due to the significance of these interactions, the effect of damage can only be described in consideration of water and fertiliser in their respective levels.

Due to the significant results of F- tests for the interaction of factors (water, fertiliser and damage), the Scheffé multiple means comparison test was conducted in order to determine differences between the means of individual treatments and results are presented in Figure 4.4.

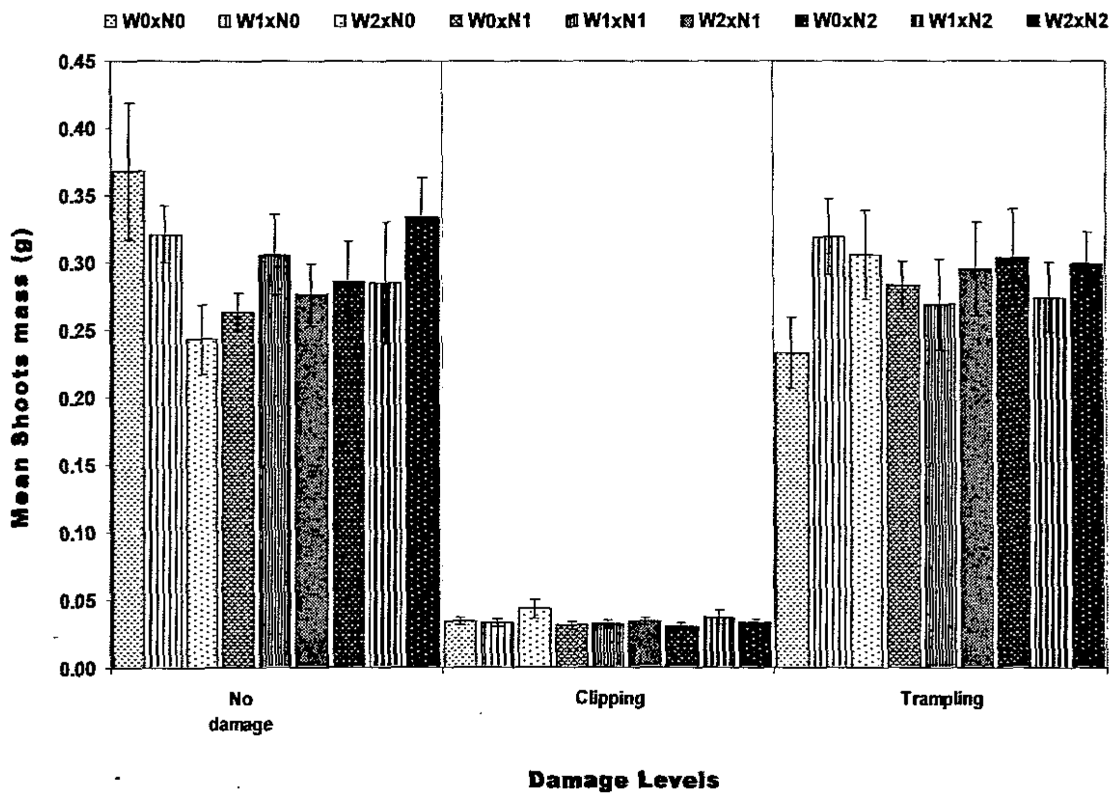

Figure 4.4: Interaction effects of water, fertiliser and damage on the mean shoot mass of *Acacia karroo* seedlings. Error bars represent ± 1 SE.

Key: W0 = watered once a week, **W1** = watered twice a week and **W2** = watered every day. **N0** = no fertiliser, **N1** = 0.2g urea and **N2** = 0.4g urea fertiliser

Undamaged and unfertilised *Acacia karroo* seedlings watered either twice a week or daily were found to have lighter shoot mass as compared with seedlings which were watered once a week (Figure 4.4). Seedlings fertilised with 0.2g urea fertiliser and watered twice a week seemed to increase shoot mass in contrast with the other two treatments. Fertilising seedlings with 0.4g fertiliser, while watered daily resulted in an increase of above-ground biomass (shoot mass). However the application of the same fertiliser on seedlings watered once or twice a week made no difference (seedlings did not respond). Addition of fertiliser (0.2g and 0.4g urea) on seedlings watered twice a week reduced the above-ground biomass (shoots dry mass). Where as the addition of 0.2g and 0.4g urea fertiliser on seedlings watered daily resulted in an increase in the above-ground biomass of intact *Acacia karroo* seedling.

Damage inflicted on seedlings (in the form of clipping) reduced shoot mass, while watering daily increased shoots mass of *Acacia karroo* when there was no fertiliser added. Interactions of fertiliser and water had no impact on clipped seedlings. Trampled seedlings watered twice a week or daily seemed to increase shoot mass in unfertilised *Acacia karroo* seedlings. Seedlings which were watered once a week and fertilised by 0.2g and 0.4g urea fertiliser respectively showed increased shoot mass. Trampled *Acacia karroo* seedlings which were watered twice a week or daily with no fertiliser added, had higher shoot mass as compared with the same trampled seedlings but 0.2g and 0.4g urea fertiliser added respectively (Figure 4.4). Damaged (either by clipping or trampling) seedlings of *Acacia karroo* showed a response that differed to that of undamaged seedlings to water treatment and in the interaction of water with fertiliser treatments (see Figure 4.4).

4.3.3 Effect of treatments on root dry mass of *Acacia karroo*

Analysis of variance (ANOVA) results show that light intensity affected seedling root mass significantly ($F_{2,230} = 22.83$; $P < 0.001$). In fact, the effects of 40% shade cloth (mean = 0.12g; SE = ± 0.006) and 80% shade cloth (mean = 0.10g; SE = ± 0.004) reduced root mass by 18.2% and 33.1% respectively, as compared with non-shaded seedlings (mean = 0.15g; SE = ± 0.008), while shade interaction with other factors had no significant effect on root mass (see Appendix 3). Damage (in the form of clipping) reduced root mass significantly ($F_{2,230} = 129.25$; $P < 0.001$). Interaction between water and fertiliser had a significant effect on root mass ($F_{4,230} = 2.45$; $P = 0.047$) and interaction between water, fertiliser and damage ($F_{8,230} = 2.18$; $P = 0.030$) likewise resulted in a significant effect on root mass. Due to the significant effect of these interactions on root mass, damage or interaction of water and fertiliser cannot be described separately.

Due to a significant interaction of the three factors (water, fertiliser and damage) on the mean root mass of *Acacia karroo* (shown in the F-test table), the Scheffé multiple means comparison test was used to determined the differences between the means of individual treatments, as shown in the results that are presented in Figure 4.5.

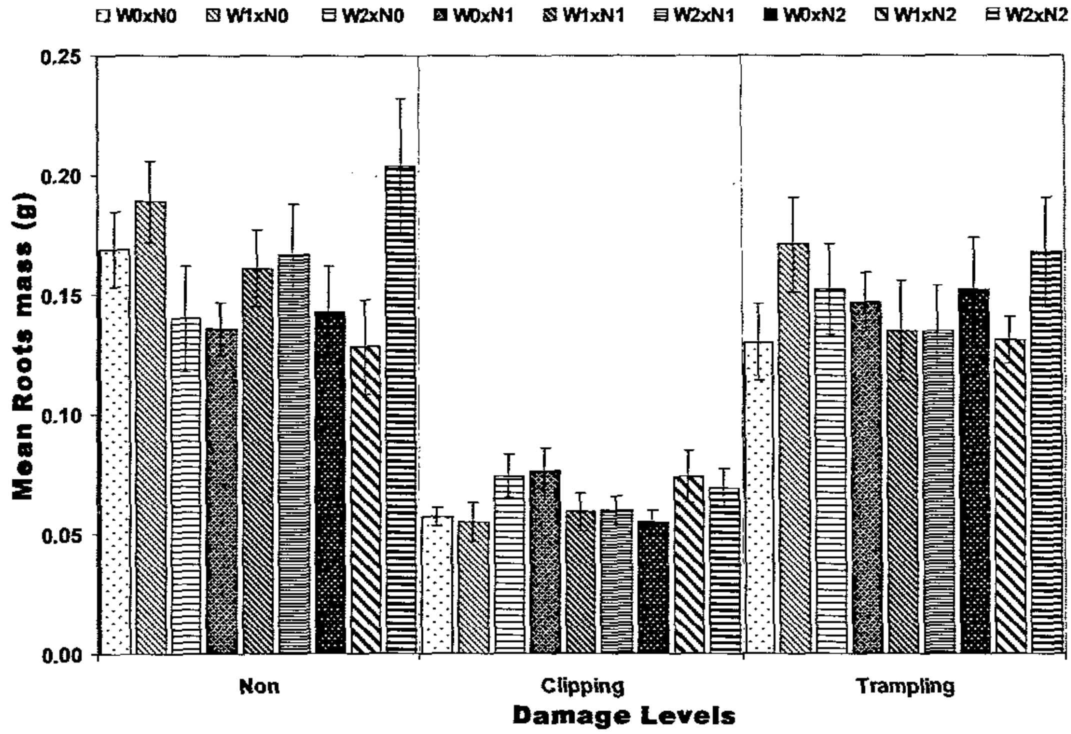

Figure 4.5: Interaction effects of water, fertiliser and damage on mean root mass of *Acacia karroo* seedlings. Error bars represent ± SE.

Key: W0 = watered once a week, **W1** = watered twice a week and **W2** = watered every day. **N0** = no fertiliser, **N1** = 0.2g urea and **N2** = 0.4g urea fertiliser

Watering twice a week increased below-ground biomass (root dry mass) rather more than watering either once a week or daily in intact and unfertilised *Acacia karroo* seedlings. The interactions of watering and fertiliser affected root mass of *Acacia karroo*. Application of fertiliser (0.2g and 0.4g urea) to seedlings watered once a week had a negative effect on dry root mass in that it reduced below-ground biomass in contrast with unfertilised seedlings. In fact, the addition of 0.4 g urea fertiliser made no major difference as compared with 0.2g urea added. Surprisingly, addition of fertiliser (0.2g and 0.4g urea) on seedlings which were watered twice a week reduced below-ground biomass of intact *Acacia karroo*. The *Acacia karroo* seedlings which were watered daily with no fertiliser added had lower below-ground biomass (dry root mass), but the addition of fertiliser (0.2g and 0.4g urea) increased below-ground biomass by 19.5% and 45.7% respectively.

Damage caused to seedlings (in the form of clipping) reduced root mass, but watering every day increased below-ground (root) mass in the absence of fertiliser. Clipped seedlings which were watered once a week and fertilised with 0.2g urea had higher root mass as compared with other seedlings fertilised by the same fertiliser however subjected to a different water treatment. Seedlings which were fertilised with 0.4g urea but watered twice a week and daily had a higher root mass as compared with the ones watered once a week. Damage in the form of trampling had some effect on root mass, but watering twice a week and daily increased the root mass of seedlings in the absence of fertiliser. Seedlings which were watered once a week responded better to 0.2g fertiliser as compared with other seedlings that received the same fertiliser but subjected to other water treatments (watered daily and twice a week). *Acacia karroo* seedlings watered once a week and daily, but subjected to 0.4g urea fertiliser, showed an increase in root mass. The addition of urea fertiliser, in the case of seedlings which were watered once a week showed a positive effect (increasing root mass) but root mass of seedlings showed negative results when watered twice a week.

4.3.4 Effect of treatments on root:shoot ratio of *Acacia karroo*

Analysis of variance (ANOVA) results for root: shoot ratio shows that a reduction in light intensity decreased root: shoot ratio ($F_{2,230} = 6.03$; $P = 0.003$). This might be due to the fact that shaded plants invest more of their nutrients in shoot elongation than on root development, yet there was no significant interaction of shade with other factors with regard to the root: shoot ratio. Damage had a significant effect on the root: shoot ratio in *Acacia karroo* ($F_{2,230} = 533.23$; $P < 0.001$). The interaction of shade and damage factors, however, had no significant effect on the root: shoot ratio of *A. karroo* (see Appendix 4).

4.4 DISCUSSION

Acacia karroo seeds, with their hard seed coats, survive most successfully in a dormant state that inihibits germination (Chirara 2001). In order to enhance water imbibition, the seed coat has to be broken to make it less impenetrable. It is therefore understandable that only 47% of *Acacia karroo* seed germination could be recorded in four days after sowing. In fifteen days, the germination percentage increased to 84%. Chapter four is similar to chapter three except that there were some differences made in chapter four such as that: factor(s) were adjusted (fertiliser in particular), and the experiment was conducted in a rainout shelter. There is a general perception that *Acacia karroo* seedlings deposit more nutrients in root development at an early stage of growth (Chirara 2001), as an invasive plant grows roots faster so as to access deeper nutrients. However, the experiment was extended to six weeks in chapter four as compared with three weeks in chapter three. Due to the similarities between these two chapters, chapter four will be discussed in relation with chapter three.

4.4.1 Effect of treatments on *Acacia karroo* seedling height

Water has a vital role to play in all life processes, not the least as a universal solvent of nutrients. This study shows that water is vitally important to stimulate germination of *Acacia karroo* seed, but once the seedling is fully established, water shortage does not significantly affect its survival, and this was in accordance with Kraaij (2001) who reported that constant availability of water is the most important factor in initiating seed germination. Although hardy, *Acacia karroo* seedlings are sensitive to drought and water stress resulting in stunted growth or death (Mopipi 2005). Test results, however, showed that watering once a week did not affect seedling growth significantly, where as in chapter three results showed that watering once a week and fertilised by 0.4g fertiliser resulted in seedling death.

Damage in the form of trampling and clipping reduced seedling height of *Acacia karroo*, but there was no evidence of seedling death recorded due to these treatments, nor was damage (i.e. trampling) found to have a significant effect on seedling survival (Newman *et al.* 1997). Damage in the form of trampling promotes plant invasion, especially of plants with high reproductive ability (Kohler *et al.* 2004). *Acacia karroo* seedlings that were subjected to trampling recovered after being momentarily crushed by 13.5kg weight, even though this treatment reduced plant growth (see Figure 4.3a and b). Some plants could withstand limited trampling if they were allowed time for recovery (Rodgers and Cox 2003). Reduced growth was seen in seedling subjected to simulated trampling by means of a 13.5kg pressure plate (Figure 4.3b). Trampling frequency plays a major role of reducing growth which results in seedling death (Duncan and Holdaway 1989 and Yates *et al.* 2000). The recovery rate of trampled seedlings depends on the trampling frequency or the compactness of soil. As compacted soil increases in water holding capacity, a decrease in bulk density in sandy soil due to trampling may well prove to be beneficial to the recovery of damaged plants due to the soil's increased water holding capacity (Wood 2001).

Damage in the form of clipping significantly reduced seedling height, which was in accordance with the findings of Mopipi (2005) and Chirara (2001). Whereas no deaths of seedlings were recorded due to clipping, it affected plant growth. The response of seedlings to damage (clipping in particular) depends on intensity, frequency and season; damaged seedlings are more prone to death during the dry season. *Acacia karroo* seedlings kept under 40% shade cloth grew taller, as compared to those covered by 80% shade cloth – yet shade did not have a significant effect (data not shown) in this study. According to literature, seedling height is significantly affected by protection under 80% shade cloth (Holmes and Cowling 1993), yet our results showed no significant effect on *Acacia karroo* seedlings under these conditions. The *Acacia karroo* species is reported as a shade tolerant plant (O'Connor 1995) and therefore shading can be expected to be a major factor in controlling growth in *Acacia karroo* seedlings (Smith and Shackleton 1988). Shade should then have a positive effect on plants during the dry season and a negative effect during wet season when water and nutrients are available (Fulco *et al.* 2001). However, frequent watering and nitrogen addition helped seedlings to recover from simulated trampling.

4.4.2 Effect of treatments on the above and below-ground biomass of *Acacia karroo* seedlings

Even though shade cloth did not represent exactly the same light intensity that could be found in the under-storey of the forest, the response of *Acacia karroo* seedlings in this study indicated that low light intensity reduced the dry weight of plants due to the fact that shoots grew thinner and taller. Shoot etiolation of woody plants in response to shade has been reported before (see Dale and Causton 1992a). In another study, seedlings that were kept under 80% shade cloth were reported to have a diminished dry shoot weight (Holmes and Cowling 1993). Even though it is accepted that shade affects shoot height, however this study could not confirm this. The results of this study illustrate that above-ground biomass of *Acacia karroo* seedlings, specifically, is affected in that the dry mass of the shoots was reduced when the seedlings were grown in shade.

Once *Acacia karroo* was established (fully germinated) it was no longer necessary to water them twice a week (or daily) due to the decrease in above-ground biomass of the seedlings (see Figure 4.4). Additional irrigation tended to decrease total above-ground (shoot) biomass (Krueger-Mangold *et al.* 2004). *Acacia karroo* seedling growth will not be stressed by water shortage during the dry period (i.e. in the winter season). As pioneer (invasive) species they have longer roots that provide access to underground water. Nitrogen is known as the limiting nutrient in plant growth (Van Aarde *et al.* 1998, Krueger-Mangold *et al.* 2004 and Katjiua and Ward 2006) and when limited reportedly gives rise to stunted growth and leaf senescence (Mopipi 2005). However, this study could not support the aforementioned statement in regard to its application to *Acacia karroo*. This is probably due to the fact that

Acacia karroo a nodulated and therefore fixes nitrogen in the soil. It is reported that Nitrogen tends to increase with successional ageing (Tilman 1987). This could cause *Acacia karroo* seedlings to respond negatively to nitrogen fertiliser. In this study the positive response of *Acacia karroo* to nitrogen fertiliser is attributed to daily watering. The response is regarded as favourable, as it resulted in increased above-ground biomass of the seedlings. This result may have been due to the fact that daily watering caused mineral leaching.

The removal of green leaves in plants usually results in an initial re-growth, depending on the reserved carbohydrate (Tainton 1999). Damage to seedlings in the form of clipping resulted in stunted growth of the plant due to the fact that the photosynthetic process is impaired (Anderson and Lee 1995 and Lovelock *et al.* 1999) and the fact that the plant has to use reserved food for the formation of new leaves. In this study, nitrogen and watering treatment proved to have no effect on the plant when damage (clipping) was also applied to the plant. This might be due to the fact that plants absorbed water only if it was going to be used by leaves (evapotranspiration) during the photosynthetic process. Even though the seedlings were severely damaged by trampling, the above-ground biomass was not significantly impaired. As a result, the seedlings responded positively to irrigation carried out more than once a week in combination with fertiliser.

Undamaged *Acacia karroo* roots responded well to a combination of nitrogen fertiliser and watering daily. This might be due to leaching, which made the fertiliser more available to the plant roots. The highest root biomass was obtained at the highest nitrogen fertiliser (0.4g) applied in combination with water (where seedlings were watered daily in the absence of damage treatment). Plants that are subjected to water stress fail to metabolize nitrogen due to a reduction of RNA synthesis through increased protein hydrolysis (Mopipi 2005). Woody plants extend their roots to some distance from the main stem in order to access soil water and minerals. For example, *Acacia karroo* plants extend their roots up to 9m in order to acquire nutrients to be found at the deeper soil levels (Stuart-Hill and Tainton 1989 and Tainton 1999). Removal of above-ground shoots (80% or 90%) encourages inactiveness in root growth for about 12 and 17 days respectively (Tainton 1999). Damaged *Acacia karroo* seedlings (due to clipping) were found to have less root biomass compared to undamaged seedlings. There is a general perception that a normal growing plant invests most of its food in the roots (P. Scogings: personal communication), so that any disturbance of above-ground (shoot) results in root growth impairment, due to the fact that the plant has to use food in the roots for the formation of new leaves (re-sprouting).

4.4.3 The effect of shade and damage on the root: shoot ratio of *Acacia karroo* seedlings

The root mass of the damaged (clipping) *Acacia karroo* seedlings was found to be heavier than the shoot mass of clipped seedling. However, root mass of intact seedlings was heavier than that of clipped seedlings. This indicates that defoliation due to clipping increased the root: shoot ratio, and this is in accordance with Chirara (2001) who found highest root: shoot ratio in clipped seedlings grown in light shade. Root growth of the plants depends on the amount of carbohydrates available. As carbohydrates are manufactured in the leaves, any tampering with the photosynthetic process will reduce the availability of carbohydrates, hence root growth will be influenced as well. For this reason, grazing and shading of plants have a negative effect on root growth. Even though damage had a significant effect on root:

shoot ratio, trampling did not have any effect on this ratio. This might be due to the fact that damage by pulverizing (trampling) did not result in the removal of the above-ground biomass (Figure 4.3b), because the leaves (photosynthetic organs) were not removed and their reserved food was not used for re-growth.

Shading treatment had a significant effect on the root: shoot ratio of *Acacia karroo* seedlings. It has been found that subjection of a plant to low light intensity decreases its root growth. Therefore, shaded plants invest more nutrients in shoot growth than in root and, as a result, the root: shoot ratio decreases. An increase in temperature, decreasing light intensity and increasing nitrogen fertiliser in plants leads to an increased shoot: root ratio (Tainton 1999). Shade reduces water stress in seedlings, which is a positive effect (Fulco *et al.* 2001). Shade also reduces the photosynthetic process and, as a result, plants grow taller in order to access enough light. These results indicate that when *Acacia karroo* seedlings are subjected to shade, they reverse their normal growth by allocating more carbohydrate to shoot growth rather than root growth. As a result, plants tend to have shallow roots, which expose them to competition with other species, such as grass and shrubs, for nutrients. The interaction of shade and damage had no significant effect on the root: shoot ratio. This might be due to the fact that damaged seedlings use stored nutrients from roots to compensate for the lost plant part (leaves) whereas shaded seedlings originally allocated their nutrients to shoots, thereby trying to obtain maximum light intensity.

4.5 CONCLUSION

The multi-factorial experiment conducted at the University of Zululand attempted to mimic the situation in a rehabilitating forest covering a previously mined area, where livestock had been introduced. Results which were obtained in chapter three showed that watering daily had positive impacts on unshaded seedlings, where as chapter four indicated that daily watering had a negative impact on intact seedling. This difference could be due to the fact that these experiments were conducted in different places (structures). The complexity of chapter three results makes it difficult to compare them with that of chapter four. The major differences between the two chapters was that the highest order of interactions in chapter three was in all four factors (see chapter three) for all measured variables, whereas in chapter four it was in three factors (see appendix 7). The positive response of intact *Acacia karroo* seedlings makes it suitable for a restoration processes in an area with low supervision. Problems are posed, however, with regard to interaction between vegetation and livestock when the latter is introduced to such an area. Negative impacts on abundance and richness of vegetation resulted from grazing, which is similar to the damage inflicted when seedlings used in the study were subjected to clipping. Clipping and pounding carried out in the experiment with the seedlings in this study resulted in stunted growth – the same effect caused by livestock in their grazing and trampling of the seedlings in the rehabilitating area. Such damage (trampling), however, may lead to seedling death due to exacerbation or the competition for nutrients, water and light. It is concluded that continuous grazing by communal livestock in rehabilitating sand dune forests is liable to seriously hinder the restoration process, depending upon frequency of grazing.

CHAPTER FIVE

THE EFFECT OF GRASS, DAMAGE AND WATER ON GROWTH RATE OF *PSIDIUM GUAJAVA* (GUAVA) SEEDLINGS

5.1 INTRODUCTION

Little is known about the effect of grass, damage and water on *Psidium guajava* (guava) establishment in forested areas, but a lot is known about guava establishment in disturbed areas (due to grazing) (Palmer *et al.* 2004). *Psidium guajava* (guava) belongs to the family Myrtaceae, and it is known to establish in both tropical and subtropical environments of the world, hence it is regarded as a prominent fruit of the tropical region (Deo and Shastri 2003 and Cavalcante *et al.* 2005). Guava is believed to originate from Mexico (Lin *et al.* 2002). Guava is known as the poor-man's fruit or the apple of the tropics as it is a popular fruit of the tropical and subtropical climates in the world (Yadava 1996). Guava has an advantage of adaptability in various part of the world (tropical and subtropical areas), hence it is cultivated successfully in a wide range of environments as it tolerates moisture stress and soil salinity in comparison with other warm climate fruit plants (Samson 1986), therefore it is cultivated in countries like India, South Africa, Brazil, Venezuela and New Zealand to name few. Hence guava is important for the international trade and domestic economy of several countries in warmer climates (Menzel 1985). Guava consumption by humans has been reported to have positive effects by improving health status, which is to reduce the cholesterol, triglycerides and blood pressure (Singh *et al.* 1992). As mentioned above guava is a good invader in disturbed areas, especial overgrazed places (see Figure 5.1).

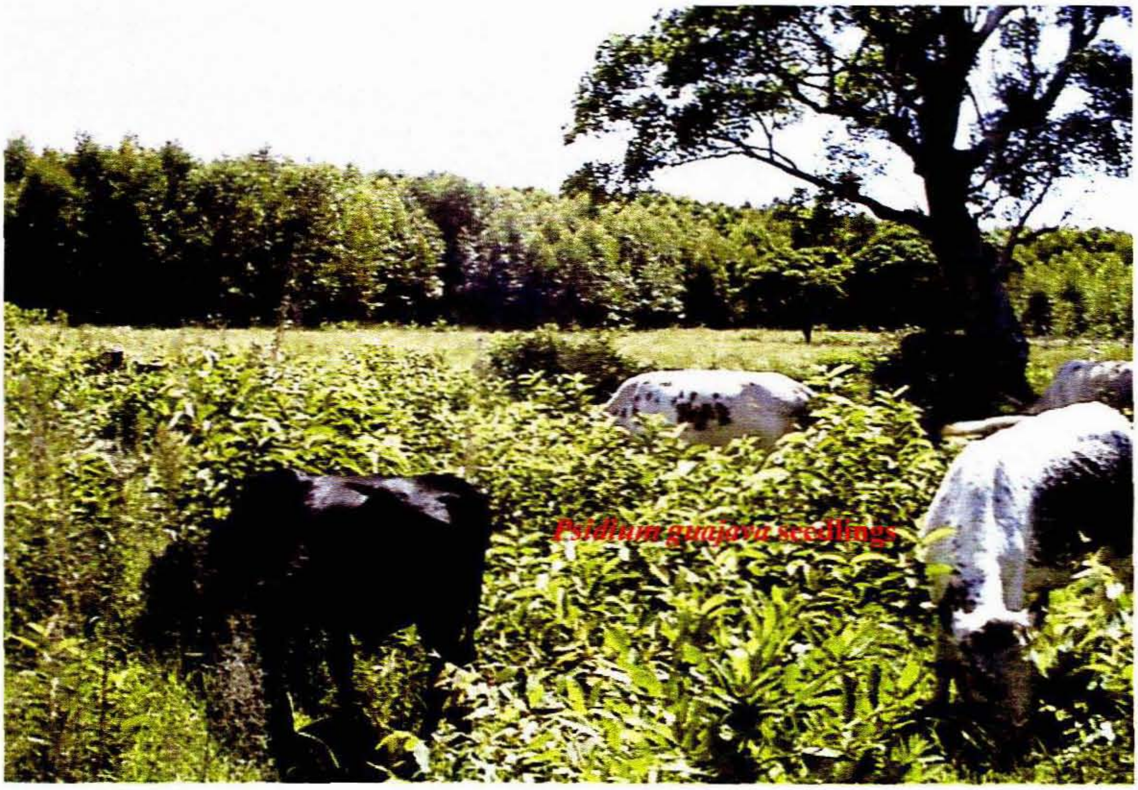

Figure 5.1: Invasion of *Psidium guajava* (guava) in communal grazing area

Seed dispersal by livestock (cattle in particular) through dung dropping has been widely documented (see Malo and Suárez 1995a, Dinerstein 1991, Gardener 1993, Ash and McIvor 1998, Fuhlendorf *et al.* 2002, O'Connor 1995 and Yates *et al.* 2000), however guava has not been reported as one of the tree species dispersed by cattle. Grice (1996) regarded cattle as the major means by which a number of seeds can reach a new site, because cattle consume large quantities of seeds at a time. However little has been reported on guava seeds dispersed by cattle in particular, considering that cattle are regarded as grazers not browsers. The possible dispersers of guava could be birds and monkeys as they are possible consumers of guava. *Psidium guajava* was found to be the most consumed (browsed) tree species by communal livestock (see Chapter two Table 2.3). Study on seed dispersal in rehabilitating coastal forest by vervet monkeys has been reported (Foord *et al.* 1995). Communal cattle which invade rehabilitating forest were found to disperse guava seed from the community to rehabilitating forest (Chapter two). It has been documented that, the passage of seeds from the alimentary canal of an animal results in breakage of seed coats which enhance germination (Malo and Suárez 1995b, Buttenschøn and Buttenshøn 1998 and Campos and Ojeda 1997) due to the partial digestion of the seed coat. However, though passage of guava seeds through the digestive track (alimentary canal) of the cattle did not enhance seed germination (Somarriba 1986). Little has been done regarding the passage of guava seeds from the digestive track of an animal.

Though in chapter two cattle were found to disperse guava seeds in rehabilitating forest, to date nothing is known about the establishment and recruitment process of guava in this rehabilitating forest. Guava is regarded as a good coloniser tree species in disturbed areas due to over grazing and concomitant trampling or any other form of disturbance. Northern coast of Zululand is where Richard's Bay Minerals (RBM) has been disturbing vegetation due to the removal of heavy minerals, however nothing is known about the recruitment process of dispersed seed (guava in particular). This study was then proposed from the result of chapter two in order to check the establishment process of guava after being dispersed by cattle in rehabilitating forest. Though guava invades most of the heavily grazed areas (Figure 5.1), it seems to be not a good competitor tree species. Therefore the main objective of the research conducted here was to answer the following questions: (1) what effect did water have on guava establishment? (2) What effect did simulated grazing have on guava seedling establishment? Therefore a multi-factorial experiment was conducted to find out the external factor(s) which can have detrimental effects on *Psidium guajava* seedlings. Guava is known to adapt in different part of the world (tropical and subtropical areas) (Yadava 1996), hence it can grow in different soil types. From observations guava invade overgrazed pastures (see Figure 5.1). Cattle grazing reduce grass biomass (chapter two) which is in accordance with Turner (1987) who reported that grazing reduced aboveground biomass by 50%. Therefore we assume that: treatment that simulates direct impacts of cattle browsing or trampling seedlings and a treatment that simulates indirect impacts of cattle grazing grass, it was expected that under frequent irrigation the simulated browsing/trampling and grazing would have a positive effect, the seedlings would compensate for browsing/trampling damage and the grazing would suppress any negative competition effect of grass on seedling growth.

5.2 MATERIALS AND METHODS

5.2.1 Study site

The experiment was conducted during the period of December 2006 – March 2007 in a rainout shelter at the University of Zululand (28^0, 51'S; 31^0, 50'E) situated at Kwa-Dlangezwa, in KwaZulu-Natal province of South Africa. Rainout shelter was roofed by clear sheeting to prevent rain. It was 2.5 meters high with an area of 3m x 6m ($18m^2$). A shade cloth of 80% was used to cover pots to simulate forest canopy and it was attached under the rainout roof. The University is situated 56 kilometers west of Richard's Bay at an altitude of about 70 – 80 m above sea level. The area adjoins the Indian Ocean with a maximum rainfall experienced during January – March, and an annual precipitation of 1228 mm. The vegetation is Coastal Forest and Thornveld (Acocks 1988).

5.2.2 Data collection

The experiment was conducted in a 3^3 factorial, arranged in a complete randomized design with eight replications each replicate consisting of one pot. In this experiment the factors were reduced to three namely grass, damage and water with three levels per factor (see Table 5.1). Pots were filled with sandy soil collected from the rehabilitating stand (see Figure 2.2 in chapter two). Each pot was 5 litters. *Dactyloctenium australe* (LM grass) was harvested from the same rehabilitating stand and was planted in two thirds of 216 pots, and pots were watered daily for three weeks for full establishment of grass, after which 5 guava seeds were sown per pot, and seeds were collected from guava tree in Kwa-Mbonambi (village). Grass was cut once a week to the level of a pot to simulate grazing. In order to allow water imbibition pots were watered daily till germination took place which was noticed at in three weeks. After germination, seedlings were given a month for full establishment, after which they were subjected to assigned treatments (Table 5.1). Seedlings were subjected to water stress one week prior the infliction of damage treatment and seedlings height were recorded thereafter. Three of the pots out of eight pots per treatment were harvested the same day on which physical injury (damage) was inflicted to the seedlings and the harvested seedling was oven dried for 48 hours at 60°C. Damage treatment was inflicted by clipping fifty percent (50%) of total leaves together with shoot tip per seedling (to simulate grazing) due to the fact that it was difficult to identify cotyledonous leaves, and to simulate trampling seedlings were momentarily squashed once by a 13.5 kg steel weight which was dropped from a height of 75cm above the soil surface (Clary and Kinney 2000). Each pot received 450 ml of water depending on the level assigned to pot.

Table 5.1: In the experimental setup (according to the multi-factorial experimental design), each pot with *Psidium guajava* seedlings was randomly subjected to a combination of the following treatments: (n = 3 grass treatment x 3 damage treatment x 3 water treatment x 8 replicates = 216 pots).

Grass Treatment (G)	Damage Treatment (D)	Water Treatment (W)
G0 = No grass	D0 = No damage	W0 = Watered once a week
G1 = Cut grass	D1 = Clipping	W1 = Watered twice a week
G2 = Intact grass	D2 = Trampling	W2 = Watered daily

After treatment was initiated height was measured weekly till the termination of the experiment. The seedlings were harvested a month later, and were oven dried for 48 hrs at 60^0C. Shoots and roots were weighed separately. Leaves were also weighed. A total shoot, roots and leaves were weighed together and then were divided by the number of seedlings per pot to estimates the average shoot, root and leaves weight per plant. Weeds was removed manually should they be seen and seedling was checked twice a day in the morning (8h00) and at afternoon (15h00) since no pesticides was used for pest control.

5.2.3 Data Analysis

The effect of grass, water and damage treatments on seedling height, shoot, root and leaf weight was analysed by SYSTAT 10 for windows (SPSS 2000). All data were tested for normality and height data was not transformed, whereas shoot, root and leaf data were log transformed. Transformation is required when data are not normally distributed. Parametric data analysis assumes normal distribution of data; therefore there is high probability that incorrect statistical results would be obtained if parametric testing is conducted on non-normal data. An F-test was used to analyse seedling height and dry weight of shoot, root and leaf separately. The Scheffé multiple means comparison test was used to determine the differences among the means when F-test was significant. All statistical tests were conducted at 5% levels of significance ($P \leq 0.05$).

5.3 RESULTS

5.3.1 Effect of grass, damage and water treatment on height of guava seedling

A statistical analysis of the mean height data showed that grass had a significant effect on seedling height ($F_{2,183} = 26.55$; $P < 0.001$), in fact grass reduced seedling height. Watering once a week increased seedling height as compared with watering twice a week and daily ($F_{2,183} = 8.10$; $P < 0.001$). The interaction of the two factors (grass and water) resulted in a significant effect on seedling height ($F_{4,183} = 4.75$; $P = 0.001$), in fact daily watering reduced seedling height (Figure 5.2) but seedlings that were with grass did not respond to water treatment. Though grass and water independently affected growth significantly, their interactions with damage treatment resulted in no significant effect (see Appendix 9). The interaction of the factors resulted in no significant effect ($F_{8,183} = 0.81$; $P = 0.599$).

Mean seedling height which was recorded weekly was statistical analysis by Systat 10 for windows.

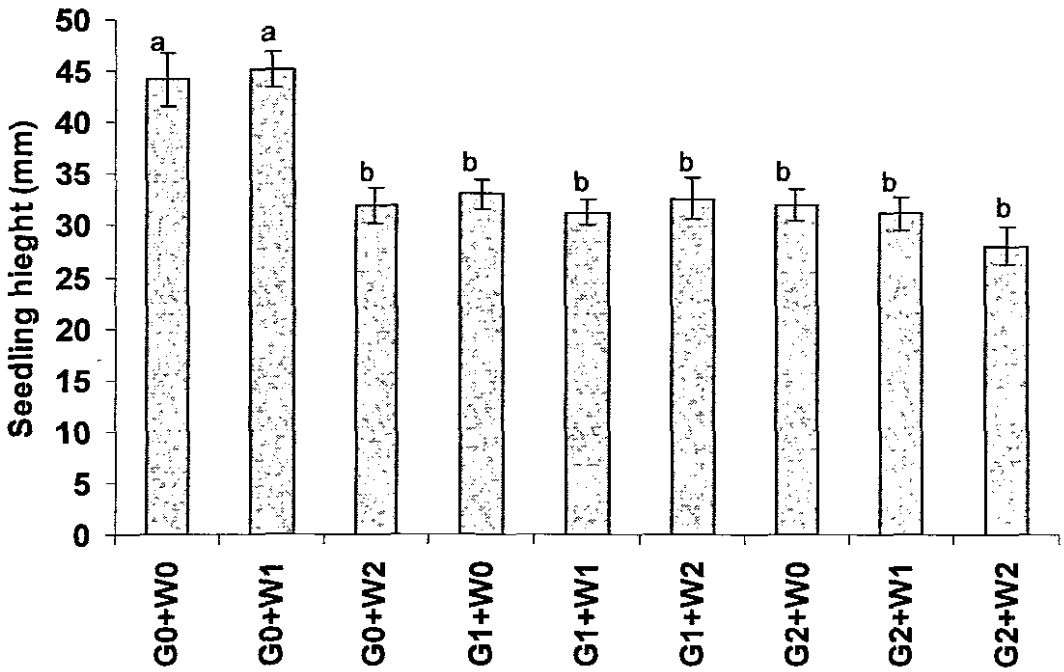

Figure 5.2: Interaction effect of grass and water treatment on seedling height of *Psidium guajava*. Error bars represent ± SE.

Key: G0 = no grass, G1 = cut grass and G2 = uncut grass. W0 = watered once a week, W1 = watered twice a week and W2 = watered daily.

Different letters indicate significance different between the means.

5.3.2 Effect of treatments on shoots dry mass of *Psidium guajava* seedlings

Statistical analysis conducted on shoot mass of guava seedling showed that there was no significant interaction of factors ($F_{8,101} = 1.45$; $P = 0.186$), however grass as the main factor reduced seedling shoot mass significantly ($F_{2,101} = 13.86$; $P < 0.001$) in fact cut grass (mean = 0.05; SE = ± 0.006) and uncut grass (mean = 0.03; SE ± 0.003) reduced shoot mass by 76.2% and 85.7% respectively as compared with seedling grown free of grass (mean = 0.21;

SE ± 0.022) , and there was a significant difference between grass levels. An F test showed that water had a significant effect on seedling shoot mass ($F_{2,101} = 6.67$; $P = 0.002$) such that daily watering (mean = 0.07; SE = ± 0.010) and watering once a week (mean = 0.10; SE = ± 0.020) reduced shoot mass by 41.7% and 16.7% respectively compared to watering twice a week (mean = 0.12; SE = ± 0.022). Daily watering decreased shoot mass as it was significantly different with other two water levels. Damage also had a significant effect on seedling shoot mass ($F_{2,101} = 22.28$; $P < 0.001$). However the interaction of any two of these factors had no significant effect on shoot mass (see Appendix 10) though they have had significant effects as individual factors.

5.3.3 Effect of treatments on root mass of *Psidium guajava* seedlings.

The analysis of variance (ANOVA) which was conducted on root mass of *Psidium guajava* seedlings showed that grass and damage affected root mass significantly ($F_{2,101} = 182.56$; $P < 0.001$ and $F_{2,101} = 15.38$; $P < 0.001$ respectively). The interaction of the two factors had no significant effect on root dry mass ($F_{4,101} = 1.48$; $P< 0.214$). However the interaction of the three factors (grass, water and damage) significantly affected root mass ($F_{8,101} = 2.28$; $P = 0.028$). Due to a significant interaction of the three factors on the mean root mass of guava (Appendix 11), the Scheffé multiple means comparison test was conducted in order to determine the difference between the means.

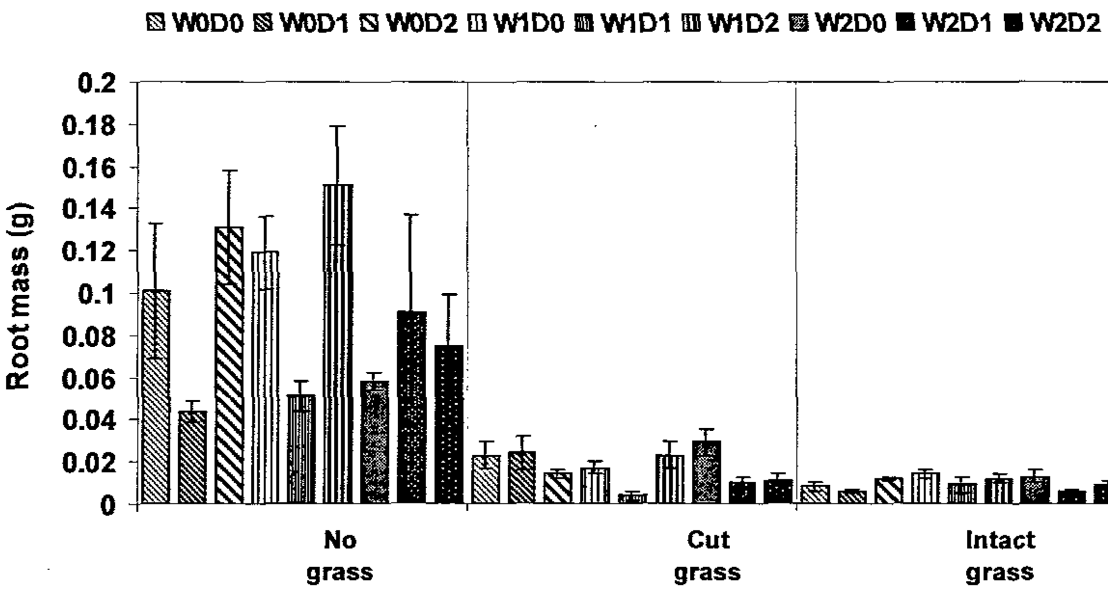

Figure 5.3: Interaction effect of grass, damage and water treatment on mean root mass of *Psidium guajava* seedlings: Error bars represent ± SE.

Key: W0 = watered once a week, W1 = watered twice a week, and W2 = watered daily.

D0 = no damage, D1 = clipping and D2 = trampling.

Root mass of guava seedlings which were grown together with grass were lighter as compared with seedlings grown free of grass (Figure 5.3). However clipping of such seedlings did not have an effect on root mass. Clipping reduced root mass of seedling watered once and twice a week (see Figure 5.3). Water treatments had no significant effect on seedlings which were competing with grass, but daily watering increased root mass of free grown (no grass) seedlings.

5.3.4 Effect of treatments on leaf mass of *Psidium guajava* seedlings

Seedlings which were harvested prior to the infliction of damage, leaves of one pot out of three harvested pots were separated from shoot and weighed separately. At the end of the experiment the remaining seedlings were harvested and dried of to measure shoot, root and leaf dry weight separately. Leaf data was tested for normality and log transformation was used to normalize the data before the statistical analysis was performed. The analysis of variance (ANOVA) which was conducted thereafter (Appendix 12) showed that grass affected leaves significantly ($F_{2,54} = 143.08$; $P < 0.001$). Damage also had a significant effect on leaf dry mass of guava seedlings ($F_{2,54} = 44.32$; $P < 0.001$). Water had no significant effect on mean leaf mass ($F_{2,54} = 0.54$; $P = 0.589$). However, the interactions betweens water and any of the two factors (damage and grass) resulted in a significant effect (see Appendix 12). There was a noticeable significant interactions of all three factors ($F_{8, 54} = 2.25$; $P = 0.038$). Therefore the effect of grass and damage will be described in consideration of water treatment.

Due to the significant effect of the interaction of these factors (grass, water and damage) on the leaf dry mass of *Psidium guajava* as appeared in F-test (table), the Scheffé multiple means comparison test was performed to determine the difference between the means of individual sub-treatments. Results are presented in figure 5.6.

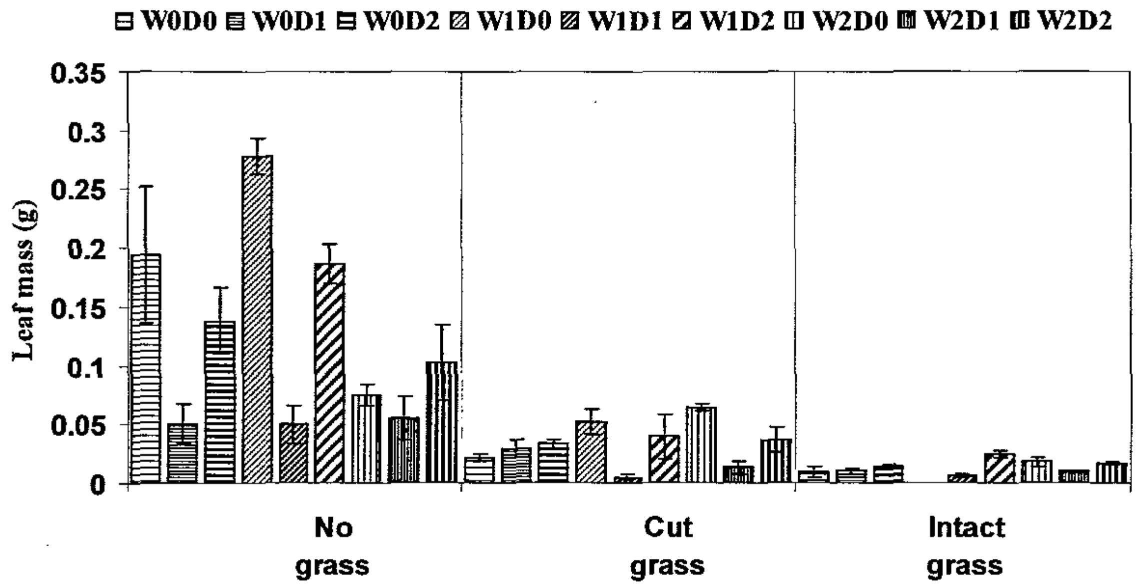

Figure 5.4: interaction effects of grass water and damage on mean leaf mass of *Psidium guajava* seedlings. Error bars represent ± SE.

Key: W0 = watered once a week, **W1** = watered twice a week and **W2** = watered daily.

D0 = intact seedlings, **D1** = clipped seedlings and **D2** = trampled seedlings.

Leaf of seedlings that were planted with grass were smaller, hence they were found to be lighter in contrast with seedlings which were planted with no grass. Therefore, to plant seedling together with grass decreased leaf weight in fact cut grass (mean = 0.023; SE = ± 0.006) and uncut (Mean = 0.008; SE = ± 0.002) as compared with free seedlings (mean = 0.101; SE = ± 0.032) had leaf weight highly affected by grass in such a way that seedlings planted with grass deposited weight on leaf. Seedling planted alone (with no grass) increased leaf weight after clipping, irrespective of water treatment applied in seedling thereafter. Daily watering increased seedling leaf weight. Watering once a week resulted in an increase of leaf weight of the seedling grown with grass, whereas damage (clipping and trampling) work contrary with water as it reduced leaf weight. Clipping increased leaf weight of seedlings which were watered twice a week or daily.

5.4 DISCUSSION

Though guava seeds were found to be dispersed by communal livestock grazing in the rehabilitating forest (chapter 2), their establishment in the forest is not known. Guava is known to establish itself in all types of soil for it is adaptable in various parts of the world (Deo and Shastri 2003 and Yadava 1996). Water stress in seedlings may result in an inhibition of shoot and root growth (Mopipi 2005) which reduces growth rate. However competition for nutrients or water may result in elongation of one part of a plant at the expense of another part, for example, it has been reported that competition for light results in fast growing shoots while roots became dormant (see Holmes and Cowling 1993 and Dale and Causton 1992a). Invasive plants such as *Acacia karroo* as known invasive tree species (O'Connor 1995) develop root systems rapidly so as to access deeper nutrients and water for growth (Chirara 2001). Though *Psidium guajava* is regarded as a highly invasive plant in areas (Palmer *et al.* 2004) disturbed by grazing livestock in particular (see Figure 5.1) grass may hinder the establishment process (Riginos and Young 2007). From the results it was found that guava seedlings which were planted with grass had small leaves, weak shoots and underdeveloped roots systems in contrast with the guava seedling grown free of grass. Guava has been reported to survive the competition of weeds and grass (Samarao and Martins 1999).

As mentioned above seedlings which were grown with uncut-grass had etiolating stem, shallow root and small leaves, where as cutting of grass improved seedling's stem, root and leaves. Therefore grass inhibits the establishment of *Psidium guajava* in rehabilitating forest. However livestock grazing reduce grass vigour which is in favour of guava establishment. Increased grazing pressure may allow trees to escape from competition with grasses (Riginos and Young 2007). As a result over most of the overgrazed area/ pasture, guava established itself easily (see Figure 5.1). All seedlings were subjected to 80% shade cloth, which simulated the forest canopy. Grass reduces seedling growth rates. Therefore this might means that the presence of grass either cut or uncut had the some effect on seedling establishment, however there was no dead seedling reported due to grass competition. Therefore the assumption that grass suppress seedling establishment was accepted.

Damage in the form of clipping reduced seedling height, hence shoot mass was reduced as well, however there was no seedling death reported due to damage. Newman *et al.* (1997) reported that clipping had a significant effect on seedling survival. *Psidium guajava* seedlings which were subjected to trampling recovered thereafter irrespective of the presence of grass which was in accordance with Rodgers and Cox (2003) who reported that plants can recover after limited trampling effect if they can be given enough time do so. Grass free seedlings which were neither clipped nor trampled grew strong as result it had a firm stem developed root system and broader leaves.

Guava seedlings which were grown free of grass responded positively to water treatment, especially watering twice a week, which resulted in higher root and shoot dry mass. Water was more accessible to seedlings free of competition. However seedlings which were subjected to grass competition did not respond positively to water treatment except the seedlings which were grown with cut grass. This could be due to the fact that grass had longer roots (fully developed root system) by the time seedlings were sown because the grass was already fully established and would have better access to water than guava seedlings.

In fact seedlings which were grown with grass either cut or uncut had lighter root mass than the ones grown free of grass (Figure 5.4). Seedlings grown with grass deposit more of nutrients in root growth so as to access deeper soil nutrients freely (P Scogings personal communication). The same trend was also found in leaf mass.

5.5 CONCLUSION

The vegetation in the forest prohibits the establishment of some exotic tree species, which include guava. Result from this experiment indicated that dispersed guava seeds in the rehabilitating forest will not establish it self easily, due to the fact that seedling which was grown with grass had small leaves, etiolating stem/shoot and underdeveloped/ shallow root. This experiment which was set here mimics rehabilitating forest condition and livestock grazing, therefore livestock grazing and trampling may totally control the establishment of dispersed trees in two ways: one by stamp on seedling or graze it together with grass and secondly the removal of grass by grazing might reduce tree-grass competition and that favours guava establishment since grass vigour is impaired. *Psidium guajava* as an invasive tree species mostly in disturbed area normally it benefit from heavy grazing, however guava establishment depends on cattle grazing (see Figure 5.1), therefore it is concluded that though guava is dispersed by communal livestock in rehabilitating forest but its invasion is impaired as long as the forest is not over grazed.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

This chapter summarises the field and laboratory experiments which were conducted in order to provide answers to the problem statement and to achieve the objectives of the study. Livestock ownership in communal areas of northern KwaZulu-Natal is a primary objective of people, because livestock plays major social and cultural roles in people's livelihoods. Social status, cultural rituals, food security and financial security are the major reasons for which communal farmers they keep livestock (Tapson and Rose 1984 and Kunene *et al.* 2003), but the major problem which communal farmers are experiencing with livestock operation is that of poor grazing resources (see Figure 2.8b). It is important for the communal farmers to keep large herds of livestock because it signifies a higher status, especially for men, in the local community. Little knowledge regarding livestock husbandry (including grazing areas/ pastures, health status of animal etc) creates a problem for livestock operations. Livestock operations play a major role in the livelihood of people in the developing node of Richard's Bay at Kwa-Mbonambi communal area, since the rate of unemployment is very high.

A drastic increase of human population and their accompanying livestock in the developing node of Richard's Bay at Kwa-Mbonambi area increases pressures on natural resources (Scogings *et al.* 1999). The resultant overcrowding has left livestock to graze on marginal land (Kassa 2000) causing overgrazing which influences the establishment of the invasive tree species (see Figure 5.1) and the establishment of unpalatable grass species such as *Aristida junciformis*. This decreases the grazing value of pastures which results in a poor grazing resource. The influx of communal livestock in the rehabilitating forest of Richard's

Bay Minerals (RBM) (see Figure 2.1) raises a concern about the impact that the grazing livestock may have on rehabilitating coastal dune forest. This study shows that livestock grazing on rehabilitating coastal dune forest reduces the under-storey vegetation cover, and results in the disturbance of the distribution and abundance of fauna within the forest ecosystem. Under-storey vegetation of the forest has been reported as the key role player in controlling the establishment of plant species in the forest (Tasker and Bradstock 2006). It was concluded that livestock grazing in rehabilitating forest reduces soil cover automatically affecting the biotic factor of the vegetation structure of the forest resulting in delay or disturbance of the rehabilitation programme. The reduction of vegetation cover exposes the ground surface to erosion which could be due to water or wind since soil is sandy, and that might hinder the restoration process because indigenous tree species would fail to establish themselves. The removal of grass cover during grazing by livestock disturbs the establishment of secondary tree species in successions (indigenous plants) because grazing of livestock in the same place for a prolonged period of time results in overgrazing. And that allows dispersed tree species to established itself such as guava.

This study also showed that communal livestock disperse some exotic seed from the community on the rehabilitating coastal dune forest. The dispersed tree species found to be guava (*Psidium guajava*) but the germination rate of this species in shady areas is not known. The main purpose of the rehabilitating programme is to restore the original state of the place as it was before mining commenced and RBM has to use a lot of money for the monitoring of this rehabilitating programme. Any disturbance of the programme means more input of money by RBM. The restoration process of indigenous vegetation only, was reported to cost

RBM R25,000 to R30,000 per hectare (Lubke and Avis 1998). The invasion of foreign species disturbs the restoration process and that means the company has to put more money for the removal of the invasive species. The establishment of the invasive species replaces the indigenous plants and the area will not return to it original state as it was before mining. Livestock grazing in the rehabilitating forest disturbs the restoration process by dispersing some invasive seed and hindering the establishment of indigenous tree species. The mined area will not reach the state of balance (where it is the same as the area not mined) and the rehabilitating programme will not be accomplished.

Chapter three and chapter four report on two *Acacia karroo* experiments but with some adjustment. The first was conducted in a Horticultural tunnel which is closed on each side with one entrance and the experiment ran for three weeks. The second experiment was conducted in a rain out shelter with sides opened and the fertiliser was changed (see table 3.1 and 4.1). The two experiments were conducted in different seasons. The significant interaction in the first experiment was among all four factors, whereas in the second experiment it was among three factors. Though the experiments were conducted in different places germination in both places was noticed in four days after seeds were sowed. There was more seedling death recorded in the tunnel experiment especially those that were irrigated once a week while subject to high fertiliser as compared with the rain out shelter experimental seedlings.

However, *Acacia karroo* in both experiments was found to be suitable for the rehabilitating programme with low supervision. *Acacia karroo* is regarded as an invasive tree species, and since it is a legume it has nitrogen fixing bacteria in the roots hence it enriches the soil with nitrogen and has a strong competitive ability in nitrogen poor soil. The nitrogen fixing character of *Acacia karroo* allows the establishment of the secondary succession, the indigenous tree species, since plants use nitrogen in large quantities. The objective of this study has been achieved in that the results obtained show the negative impact of livestock grazing in the rehabilitating forest which include reducing soil cover, destroying seedling establishment and probably causing vegetation replacement which could delay the whole restoration process of rehabilitating coastal dune forest.

The following recommendations were suggested from the results of this study for the smooth running of the rehabilitating programme for RBM and the local community.

- Since there is a conflict between RBM and the local community for the ownership of the mining area, there is need for consensus between the company and the community to solve the problem of the influx of the communal livestock into the rehabilitating coastal dune forest.
- Livestock operations play a vital role in livelihood of people living in rural area especially for the Kwa-Mbonambi community. RBM should initiate the training programme on how to manage livestock operations particularly cattle.
- Communal farmers seem to have knowledge on using local shrubs and trees as traditional medicine for their livestock but there is little scientific information available on these resources, hence there is need for scientific research to be conducted on these resources.

- RBM should conduct lessons on the importance of rehabilitation and its significance for future use by the next generation because RBM are concerned with the success of the rehabilitating programme in the disturbed areas.
- There is need for future research on the long-term impact of livestock grazing in the rehabilitating areas of RBM which could be conducted at least for 5 years.

The recommendations suggested above may help the local community and RBM to benefit from the coastal sand dune forest and at the same time the place can be accessible for future use by the next generation.

References

Acocks JPH 1988. Veld Types of South Africa, 2nd edition. Pretoria. South Africa.

Adler PM, Raff DA and Laueroth WK 2001. The effect of grazing on the spatial heterogeneity of vegetation. Oecologia 128: 465-479.

AOAC, 1990. Official methods of analysis (15th ed.) Association of Official Analytical Chemists, Arlington, VA.

Anderson C and Lee SY 1995. Defoliation of the mangrove *Avicennia marina* in Hong Kong: cause and consequences, Biotropica 27: 218-226.

Ash AJ and McIvor JG 1998. How season of grazing and herbivore selectivity influence monsoon tall-grass communities of northern Australia. Journal of Vegetation Science 9: 123-132.

Bailey DW, Gross JE, Laca EA, Rittenhouse LR, Coughenour MB, Swift DM and Sims PL 1996. Mechanisms that result in large herbivore grazing distribution patterns. Journal of Range Management 49: 386-400.

Barrow JR and Havstad KM 1992. Recovery and germination of gelatin-encapsulated seeds fed to cattle. Journal of Arid Environment 22: 395-399.

Bembridge TJ 1984. A System Approach Study to Agricultural Development Problems in Transkei. PhD dissertation, University of Stellenbosch, South Africa.

Bokdam J and Gleichman M 2000. Effects of grazing by free-ranging cattle on vegetation dynamics in a continental north-west Europe heathland. Journal of Applied Ecology 37: 415-431.

Buttenschøn RM and Buttenschøn J 1998. Population dynamics of *Malus sylvestris* stands in grazed and ungrazed, semi-natural grasslands and fragmented woodlands in Mols Bejerge, Denmark. Annals. Botanical Fennici 35: 233-246.

Campos CM and Ojeda RA 1997. Dispersal and germination of *Prosopis flexuosa* (fabaceae) seeds by desert mammals in Argentina. Journal of Arid Environments 35: 707-714.

Cavalcante LF, Cavalcante IHL, Pereira KSN, de Oliveira FA, Gondim SC and de Arajo FAR 2005. Germination and initial growth of guava plants irrigated with saline water. Available at www.agriambi.com.br. April 2007.

Chen Y, Lee G, Lee P, Mariko S and Oikawa T 2005. Effect of grazing on net primary production of a Mongolian grassland ecolosystem. Institution of life and Environmental Science, University of Tsukuba. Japan.

Chesworth J 1992. Ruminant Nutrition. CTA Macmillan. London and Basingstoke.

Chirara C 2001. Tree invasion in semi-arid savanna in Zimbabwe- seedlings recruitment of *Acacia karroo*. PhD. Thesis. Profeschrift University of Utrecht.

Clary WP and Kinney JW 2000. Streambank response to stimulated grazing. USDA Forest Service Proceedings RMRS-P-13.

Cowling RM, Kirkwood D, Midgley JJ and Pierce SM 1997. Invasion and persistence of bird-dispersed, subtropical thicket and forest species in fire-prone coastal fynbos. Journal of Vegetation Science 8: 475-488.

Dale MP and Causton DR 1992a. The ecophysiology of *Veronica chamaedrys, V. montana* and *V. afficinakisi*. I. Light quality and light quantity. Journal of Ecology 80: 483-492.

Davidson DW 1993. The effects of herbivory and granivory on terrestrial plant succession. Oikos 68: 23-35.

Davis ALV, Van Aarde RJ, Scholtz CH and Delport JH 2003. Convergence between dung beetles assemblages of a post-mining vegetational chronosequence and un-mined dune forest. Restoration Ecology 11: 29-42.

Deo A and Shastri NV 2003. Purification and characterization of polygacturonase-inhibitory proteins from *Psidium guajava* Linn. (guava) fruit. Plant Science 164: 147-156.

Dinerstein G 1991. Seed dispersal by greater one-horned rhinoceros (*Rhinoceros unicornis*) and the flora of *Rhinoceros* latrines. Mammalia 55: 353-362.

Duncan K and Holdaway R 1989. Footprint pressures and locomotion of moas and ungulates and their effects on the New Zealand indigenous biota through trampling. New Zealand Journal of Ecology 12: (Supplement).

Ferreira SM 1996. Determinants of small mammal community structure on rehabilitating coastal dune forest in northern KwaZulu-Natal, South Africa. PhD Thesis, University of Pretoria, South Africa.

Ferreira SM and Van Aarde RJ 1996. Changes in community characteristics os small mammals in rehabilitating coastal dune forests in northern Kwa-Zulu-Natal. African Journal of Ecology 34: 113-130.

Ferreira SM and Van Aarde RJ 1997. The chronosequence of rehabilitating stands of coastal dune forests: do small mammals confirm it? South African Journal of Science 93: 211-214.

Foord SH, Van Aarde RJ and Ferreira SM 1994. Seeds dispersal by Vervet monkeys in rehabilitating coastal dune forests at Richards Bay. South African Journal of Wildlife Research 24: 56-59.

Forbes JM 1995. Voluntary Food Intake and Diet Selection in Farm Animals. CAB International, London, New York.

Fuhlendorf SD, Zhang H, Tunnell TR, Engle DM and Cross AF 2002. Effects of grazing on restoration of southern mixed prairie soils. Restoration Ecology 10: 401-407.

Fulco L, de Kroon H, Herbert HT and Frank B 2001. Effects of nutrients and shade on tree-grass interaction in an East African savanna. Journal of Vegetation Science 12: 579-588.

Gardener CJ 1993. The colonization of a tropical grassland by *Stylosanthes* from seeds transported in cattle faeces. Australian Journal of Agricultural Research 44: 299-315.

Givens DI, Owen E, Oxford RFE and Omed HM 2000. Forage Evaluation in Ruminant Nutrition. CABI publishing, New York, USA.

Ghebrehiwot HM, Fynn RWS, Morris CD and Kirkman KP 2006. Shoot and root biomass allocation and competition hierarchies of four South African grass species on light, soil resources and cutting gradients. African Journal of Range and Forage Science 23: 113-122.

Goering, H.K. & Van Soest, P.J., 1970. Forage fibre analysis. Agriculture Handbook No. 379. Agriculture Research Station, Washington, DC.

Goheen JR, Kelicia F, Allan BF, Ogada D and Ostfeld RS 2004. Net effects of large mammals on *Acacia* seedling survival in an African savanna. Ecology 85: 1555-1561.

Gorder MM, Manske LL and Stroh TL 2005. Grazing treatment effects on vegetative tillering and soil rhizospheres of western wheatgrass. Dickinson research extension center. Grassland section annual report. Dickinson, ND 58601.

Grice AC 1996. Seed production, dispersal and germination in *Cryptostegia grandiflora* and *Ziziphus mauritiana*, two invasive shrubs in tropical woodlands of northern Australia. Australian Journal of Ecology 21: 324-331.

Hayishi I 1996. Five years experiment on vegetation recovery of drought deciduous woodland in Kutui, Kenya. Journal of Arid Environments 34: 351-361.

Hoekstra NJ, Bosker T and Lantinga EA 2002. Effects of cattle dung from farms with different feeding strategies on germination and initial root growth of cress (*Lepidium sativum L.*). Agriculture Ecosystems and Environment 93: 189-196.

Holmes PM and Cowling RM 1993. Effects of shade on seedling growth, morphology and leaf photosynthesis in six subtropical thicket species from the Eastern Cape, South Africa. Forest Ecology and Management 61: 199-220.

Humphreys LR 1987. Tropical Pastures and Fodder Crops, 2nd edition, Longman Science & Technical, UK.

Humphreys LR. 1991. Tropical Pasture Utilization. 1st edition. Cambridge University Press. New York. USA.

Hutchings A, Scott AH, Gilian L and Cunningham A 1996. Zulu Medicinal Plants, An Inventory. University of Natal Press, Pietermaritzburg, South Africa.

Illius AW and O'Connor TG 2000. Resource heterogeneity and ungulate population dynamics. Oikos 89: 283-294.

Jonson DJ 2003. Wildlife management: Forest and bush restoration. KZN wildlife publisher.

Kamler J and Homolka M 2005. Faecal nitrogen: a potential indicator of red deer diet quality in forest habitats. Folia Zoology 54: 89-98.

Kassa H 2000. Livestock production, household food security and sustainability in smallholder mixed farms. Master's thesis. Swedish University of Agricultural Sciences.

Katjiua ML and Ward D 2006. Resistance and tolerance of *Terminalia sericea* trees to simulated herbivore damage under different soil nutrient and moisture conditions. Journal of Chemical Ecology 32: 1431-1443.

Kauffman JB, Krueger WC and Vavra M 1983. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management 36: 685-691.

Kohler F, Gillet F, Gobat JM and Buttler A 2004. Seasonal vegetation changes in mountain pastures due to simulated effects of cattle grazing. Journal of Vegetation Science 15: 143-150.

Komwihangilo DM, Sendalo DSC, Lekule PF, Mtenga LA and Temu VK 2001. Farmers' knowledge in the utilisation of indigenous browse species of goats in semi arid central Tanzania. Livestock Research for Rural Development 13 (6). Available at: http://www.cipav.org.co/lrrd/lrrd13/6/komw136.htm.

Kumssa DB, Van Aarde RJ and Wassenaar TD 2004. The regeneration of soil micro-arthropod assemblages in a rehabilitating coastal dune forest at Richards Bay, South Africa, African Journal of Ecology 42: 346-354.

Kunene NW 2003. Report on current livestock situation at Kwa-Mthethwa. Department of Agriculture, University of Zululand.

Kunene NW and Fossy A 2006. A survey on livestock production in some traditional areas of northern KwaZulu-Natal in South Africa. Livestock Research for Rural Development 18. available at http://www.cipar.org.co/lrrd18/8/kune18113.htm. October 2006.

Kunene NW, Wilson RAC and Myeni NP 2003. The use of trees, shrubs and herbs in livestock production by communal farmers in Northern KwaZulu-Natal. African Journal of Range & Forage Science 20: 271-274.

Kraaij T 2002. Effects of rain, nitrogen, fire and grazing on bush encroachment in semi-arid savanna, South Africa. Master's Thesis. University of Stellenbosch, South Africa.

Krueger-Mangold J, Sheley R, Engel R, Jacobsen J, Svelcar T and Zabinski C 2004. Identification of the limiting resource within a semi-arid plant association. Journal of Arid Environments 58: 309-320.

Lin J, Puckree T and Mvelase TP 2002. Anti-diarrhoeal evaluation of some medicinal plants used by Zulu traditional healers. Journal of Ethnopharmacology 79: 53-56.

Lovelock CE, Posada J and Winter K 1999. Effect of elevated CO_2 and defoliation on compensatory growth and photosynthesis of seedlings in a tropical tree, *Copaifera aromatica*. Biotropica 31: 279-287.

Lubke RA, Avis AM and Moll JB 1996. Post-mining rehabilitation of coastal sand dunes in Zululand, South Africa. Landscape and Urban Planning 34: 335-345.

Lubke RA and Avis AM 1998. A review of the concepts and application of rehabilitation following heavy mineral dune mining. Marine Pollution Bulletin 37: 546-557.

Malo JE and Suarez F 1995a. Cattle dung and the fate of *Biserrula pelecinus L* (*Leguminosae*) in a Mediterranean pasture: seeds dispersal, germination and recruitment. Botanical Journal of the Linnean Society 118: 139-148.

Malo JE and Suarez F 1995b. Establishment of pasture species on cattle dung: the role of endozoochorous seeds. Journal of Vegetation Science 6: 169-175.

Mayle B 1999. Domestic stock grazing to enhance woodland biodiversity. Forest Commission. Available at http://www.forestry.gov.uk.

Mbalo BA and Witkowiski ETF 1997. Tolerance to soil temperatures experienced during and after the passage of fire in seeds of *Acacia karroo, A. tortilis* and *Chromolaena odorata.* South African Journal of Botany 63: 421-425.

McDonald P, Edwards RA, Greenhalgh JFD and Morgan CA 2002. Animal nutrition. 6th Edition. Prentice hall. London.

Mentis MT and Ellery WN 1994. Post-mining rehabilitation of dunes on the northe-east coast of South Africa. South Africa Journal of Science 90: 69-74.

Mentis MT and Ellery WN 1998. Environmental effects on mining coastal dunes: conjectures and refutations. South African Journal of Science 94: 215-222.

Menzel CM 1985. Guava: An exotic fruit with potential in Queensland. Queensland Agriculture Journal 111: 93-98.

Milton SJ and Dean WRJ 2001. Seeds dispersal in dung of insectivores and herbivores in semi-arid southern Africa. Journal of Arid Environments 47: 465-483.

Monaco TA, Mackown CT, Johnson DA, Jones TA, Norton JM, Norton JB and Redinbaugh MG 2003. Nitrogen effects on seed germination and seedling growth. Journal of Range Management 56: 646-653.

Mopipi K 2005. Effects of moisture, nitrogen, grass competition and simulated browsing on the survival, growth rate, biomass allocation and leaf chemistry of *Acacia karroo* seedlings. Master's Thesis. University of Fort Hare, South Africa.

Morris CD, Hardy MB and Bartholomew PE 1999. Stocking rate. In: Tainton NM (ed). Veld Management in South Africa. University of Natal Press, Pietermaritzburg.

MphinyaneWN and Rethman NFG 2006. Livestock utilization of grass species at different distances from water on both traditional cattle post and ranch management systems in Botswana. African Journal of Range and Forage Science 23: 147-151.

Newman RF, Cameron kJ, Wikeen BM, Youwe PL, Quinton DA, Pitt MD and Powell GW 1997. Response of lodgepole Pine seedlings to simulated cattle damage. Ministry of forests Research Program, British Columbia. available www.for.gov.bc.co/htd/pubs/docs/rr/rr14.pdf. March 2006.

O'Connor T G 1995. *Acacia karroo* invasion of grassland: environmental and biotic effects influencing seedling emergence and establishment. Oecologia 103: 214-223.

Ocumpaugh WR, Archer S and Stuth JW 1996. Switchgrass recruitment from broadcast seed vs. seed fed to cattle. Journal of Range Management 49: 368-371.

Olff H, Vera FWM, Bokdam J, Bakker ES, Gleichman JM, de Maeyer K and Smith R 1999. Shifting mosaics in grazed woodlands driven by the alternation of plant facilitation and competition. Plant Biology 1: 219-234.

Palmer A, Kakembo V, Lloyd W and Ainslie A 2004. Degradation patterns and trends in the Succulent Thicket. Proceedings of the Thicket Forum held at Zuurberg Inn, Addo Elephant National Park. 1-10.

Pooley E 1993. The Complete Guide to Trees of Natal, Zululand and Transkei. Natal Flora Publications Trust, Durban, South Africa.

Raoth LR and Krueger WC 1982. Cattle grazing and behaviour on a forested range. Journal of Range Management 35: 332-338.

Reed MS and Clokie MRJ 2000. Effects of grazing and cultivation on forest plant communities in Mount Elgon National Park, Uganda. African Journal of Ecology 38: 154-162.

Reid RS and Ellis JE 1995. Impacts of pastoralists on woodlands in South Turkana, Kenya: Livestock-mediated tree recruitment. Ecological Applications 5: 978-992.

Riginos C and Young TP 2007. Positive and negative effects of grass, cattle, and wild herbivores on *Acacia* saplings in an East African savanna. Oecologia 153: 985-995.

Roberson E 1996. Impact of livestock grazing on soils and recommendations for management. Available at www. fed.us/im/pubs/rmrs_gtr135_l.pdf. September 2006

Rodgers K and Cox E 2003. Effects of mechanical fracturing and experimental trampling on Hawaiian Corals. Environmental Management 31: 377-384.

Roovers P, Verheyen K, Hermy M and Gulinck H 2004. Experimental trampling and vegetation recovery in some forest and heathland communities. Applied Vegetation Science 7: 111-118.

Ruiz-Jaen MC and Aide TM 2005. Restoration success: how is it being measured? Restoration Ecology 13: 569-577.

Rupp SP, Wallace MC, Waster D, Fetting S and Mitchell R 2001a. Effects of simulated elk grazing and trampling (I): intensity. Alces 37: 129-146.

Rupp SP, Wallace MC, Waster D, Fetting S and Mitchell R 2001b. Effects of simulated elk grazing and trampling (II): frequency. Alces 37: 147-161.

Samarao SS and Martins MA 1999. Influence of arbuscular mycorrhizal fungi, associated with addition of rutin, on the growth of guava (*Psidium guajava* L.). Revista Brasileira de Fruticultura 21: 196-199.

Samson JA 1986. Tropical fruits, 2nd ed. Tropical Agriculture Series, Longman Scientific & Technical, Longman Inc. New York

Schultka W and Cornelius R 1997. Vegetation structure of a heavily grazed range in northern Kenya: Tree and Shrubs canopy. Journal of Arid environments 36: 291-306.

Schwalbach LM, Groenewald IB and Marfo CB 2001. A survey of small-scale cattle farming systems in North West province of South Africa. South African Journal of Animal Scienc 31: 200 – 204.

Schyder H, Schaufele R, Devisser R and Nelson CJ 2000. An integrated view of C and N used in leaf growth zones of defoliated grass. In: Lemaire G, Hodgson J, de Moraes A, de F. Carvalho, P.C and Nabinger, C. (ed) Grassland Ecophysiology and Grazing Ecology. CABI publishing. London, UK.

Scogings PF, De Bruyn TD and Vetter S 1999. Grazing into the future: policy- making for communal rangeland in South Africa. Development Southern Africa 16: 403-414.

Shackleton CM, Shackleton SE, Netshiluvhi TR and Mathabela FR 2005. The contribution and direct-use value of livestock to rural livelihoods in the Sand River catchment, South Africa. African Journal of Range and Forage Science 22: 127-140.

Singh RB, Rastogi SS, Singh R, Ghosh S and Niaz MA 1992. Effects of guava intake on serum total and high-density lipoprotein cholesterol levels and on systemic blood pressure. American Journal Cardiology 70: 1287-1291.

Smith GT, Arnold GW, Sarre S, Abensperg-Traun M and Steven DE 1996. The effects of habitat fragmentation and livestock-grazing on animal communities in remnants of gimlet *Eucalyptus salubris* woodland in the western Australian wheatbelt 11 lizards. Journal of Applied Ecology 33: 1302-1310.

Smith MA, Rodgers JD, Dodd JL and Skinner QD 1992. Habitat selection by cattle along an ephemeral channel. Journal Range Management 45: 385-390.

Smith TM and Shackleton SE 1988. The effect of shading on the establishment and growth of *Acacia tortilis* seedlings. South African Journal of Ecology 75: 603-610.

Somarriba E 1986. Effects of livestock on seed germination of guava (*Psidium guajava* L.). Agroforestry Systems 4: 233-238.

SPSS 2000. SYSTAT 10. SPSS inc. Chicago.

Stuart-hill GC and Tainton NM 1989. The competitive interaction between *Acacia karroo* and the herbaceous layer and how this is influenced by defoliation. Journal of Applied Ecology 26: 285-298.

Tainton NM 1999. Veld management in South Africa, University of Natal press, Pietermaritzburg.

Tainton NM 1999. The forest biome.In: Tainton NM (ed) Veld management in South Africa. University of Natal Press, Pietermaritzburg.

Tapson DR and Rose CJ 1984. An Investigation into the Kwa-Zulu cattle industry. ARDRI, University of Forth Hare, South Africa.

Tasker EM and Bradstock RA 2006. Influence of cattle grazing practices on forest understorey structure in north-eastern New South Wales. Austral Ecology 31: 490-502.

Tews J, Schurr F and Jeltsch F 2004. Seed dispersal by cattle may cause shrub encroachment of *Grewia flava* on southern Kalahari rangelands. Applied Vegetation Science 7: 89-102.

Tilman D 1987. Secondary succession and the pattern of plant dominance along experimental nitrogen gradient. Ecological Monographs 57: 189-852.

Turner MG 1987. Effects of grazing by feral horses, clipping, trampling and burning on a Georgia Salt Marsh. Estuaries 10: 54-60.

Van Aarde RJ, Ferreira SM and Kritzinger JJ 1996a. Successional changes in rehabilitating coastal dune communities in northern Kwa-Zulu-Natal, South Africa. Landscape and Urban Planning 34: 277-286.

Van Aarde RJ, Ferriera SM, Kritzinger JJ, Van Dyke PJ, Vogt M and Wassenaar TD 1996b. An evaluation of habitat rehabilitation on coastal dune forests in northern Kwa-Zulu-Natal, South Africa. Restoration Ecology 4: 334-345.

Van Aarde RJ, Smit AM and Claassens AS 1998. Soil characteristics of rehabilitating and unmined coastal dunes at Richard's Bay, KwaZulu-Natal, South Africa. Restoration Ecology 6: 102-110.

Van Oudstshoorn F 1999. Guide to Grass of Southern Africa. Briza, Pretoria. South Africa.

Van Staalduinen MA, During H and Werger MJA 2005. Impacts of grazing by large and small mammalian herbivores in a Mongolian forest steppe. PhD. Thesis. Proefschrift Utrecht University.

Wade MH, and de F. Carvalho PC 2000. Defoliation Pattern and Herbage Intake on Pastures, CAB International publishers, Grassland Ecophysiology and Grazing Ecology.

Walters M and Milton SJ 2003. The production, storage and viability of seeds of *Acacia karroo* and *A. nilotica* in a grassy savanna in KwaZulu-Natal, South Africa. African Journal of Ecology 41: 211-217.

Walters M, Midgley JJ and Somers MJ 2004. Effects of fire and fire intensity on the germination and establishment of *Acacia karroo, Acacia nilotica, Acacia luederitzii* and *Dichrostachys cinerea* in the field. BioMed Central Ecology 4: 1-13.

Wassenaar TD and van Aarde RJ 2001. Short-term responses of rehabilitating coastal dune forest ground vegetation to livestock grazing. African Journal of Ecology 39: 329- 339.

Wassenaar TD, Van Aarde RJ, Pimm SL and Ferriera SM 2005. Community convergence in disturbed subtropical dune forests. Ecology 86: 655-666.

Weiermans J and van Aarde R J 2003. Roads as ecological edges for rehabilitating coastal dune assemblages in northern KwaZulu-Natal, South Africa. Restoration Ecology 11: 43-49.

Wolfson MM and Tainton NM 1999. The morphology and physiology of the major forage plants In: Tainton NM (ed) Veld management in South Africa. University of Natal Press, Pietermaritzburg.

Wood MK 2001. Grazing management for healthy watersheds. New Mexico watershed management: Restoration, utilization, and protection. New Mexico Water Resources Research Institute.

Yadava UL 1996. Guava production in Georgia under cold-protection structure. Available at www.hort.purdue.edu/newcrop/proceedings1996/v3-451.html. June 2007.

Yates CJ, Norton DA and Hobbs RJ 2000. Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia: implications for restoration. Austral Ecology 25: 36-47.

Yuxiang C, Gilzae L, Pilzae L, Shigeru M and Takehisa O 2005. Effect of grazing on net primary production of a Mongolian grassland ecosystem. Available at htt://raise.suiri.tsukuba.ac.jp/WSTCM2004/37a-chen.pdf. July 2006.

Appendices

Appendix 1: Questionnaires to investigate livestock production management system used by communal farmers around Richard's Bay

1. Name of the ward ....
2. Name of Induna..
3. Year of arrival in the ward............................
4. Family Name..
5. Number in the household...............................
6. Head of the family (Male) .... (Female)...................
7. Approximate age of farmer.......................................
8. Level of education...
9. Source of income: Pension......... Work............Sale......
10. Type of Work..
11. Type of livestock held:

Livestock type	Heifer calves <1yr	Heifer 1-3 yrs	Young cow 3-4yrs	Mature cow 4-9yrs	Old cows >9yrs	Bull Calves >1yr	Young bull 1-3yrs	Mature bull >3yrs	Oxen	Total
Cattle										
	Adult males >1yr	Adult females >1yr	Young male <1yr	Young female <1yr	New born 0-3 months					
Sheep										
Goats										
Other										

12. Are there any preferable type of livestock breeds to be reared in this area:

Livestock type	Available breed	Preferable breed	Reason
Cattle	....	....	....
Goats	....	....	....
Sheep	....	....	....
Pigs	....	....	....
Others	....	....	....

13. Number of livestock owned:

	5yrs ago	10yrs ago	15yrs ago	20yrs ago	30yrs ago
Cattle	....	....	....	....	....
Goats	....	....	....	....	....
Sheep	....	....	....	....	....

14. What are future plans for rearing livestock?

....

....

15. Mortalities

Livestock type	Number in 2004 specify male/ female & whether young, newly born or adult	Number in 2003 specify male/ female & whether young, newly born or adult	Number in 2002 specify male/ female & whether young, newly born or adult
Cattle			
Goats			
Sheep			
Pigs			
Others			

16. Reasoning for mortalities

Livestock type	Number in 2004 specify male/ female & whether young, newly born or adult	Number in 2003 specify male/ female & whether young, newly born or adult	Number in 2002 specify male/ female & whether young, newly born or adult
Cattle			
Goats			
Sheep			
Pigs			
Others			

17. Number of animals sick and survive

Livestock type	Number in 2004 specify male/female & whether young, adult or newly born & ***3 common diseases***		Number in 2003 specify male/female & whether young, adult or newly born & ***3 common diseases***		Number in 2002 specify male/female & whether young, adult or newly born & ***3 common diseases***	
Cattle						
Goats						
Sheep						
Pigs						
Others						

18. Uses of livestock

Livestock type	Number in 2004 slaughtered, other use & **reasons**		Number in 2003 slaughtered, other use & **reasons**		Number in 2002 slaughtered, other use & **reasons**	
Cattle						
Goats						
Sheep						
Pigs						
Others						

19. Number of sold animals

Livestock type	Number in 2004 sold & reason	Number in 2003 sold & reason	Number in 2002 sold & reason
Cattle			
Goats			
Sheep			
Pigs			
Others			

GRAZING LAND AND FARMING METHODS:

1. Communal/ other land tenure system……………………………………
2. Approximate size of communal/ land owned by farmers…………………..
3. Is land divided into camps?...
4. If yes how many camps and how they are divided…………………………
5. Sources of water in the grazing area………………………………………..
6. Types of grass species available for grazing

Types of grass	Livestock consuming	levels of consumption (1=High, 2= medium & 3=Low)
………………	………………………	…………………………………
………………	………………………	…………………………………
………………	………………………	…………………………………
………………	………………………	…………………………………

7. Shrubs or trees available for livestock consumption

Trees/ shrubs name	livestock consuming	levels of consumption (1= high, 2=Medium & 3=low)	part eaten
…………………	……………………	…………………………	…….
…………………	……………………	…………………………	…….
…………………	……………………	…………………………	…….

8. What are problems related to grazing quality and what would be the possible solutions

Problems	Solutions

9. Other problems related to grazing and possible solutions

Problems	Solutions

10. Available shrubs, trees or plant used for livestock medicinal purposes

Name	Part used	Type of sickness	Animals	Preparation
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

11. Shrubs, trees or plants used by farmers for livestock supplement on dry season

Name	Part used	Effect of supplement	Comments (when & how it used)
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

12. Shrubs, Trees/ Fruits or plant used by farmers to increase livestock production

Trees/shrub/other plant	Uses	Livestock	Preparation
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

13. Available poisonous shrubs or trees which hinder livestock production

Trees/shrubs or plant	Livestock	Effect on livestock
....	....	....
....	....	....
....	....	....
....	....	....

14. When was last time the farmer consulted vet. Or used modern veterinary medicines

Name of medicine	Livestock	Use	When was used
....	....	....	....
....	....	....	....
....	....	....	....
....	....	....	....

15. Any other use of available plants, shrubs or trees by farmers

Trees/ shrubs/ plants	Use	Comments
....	....	....
....	....	....
....	....	....

16. Any shrubs/trees/plants for livestock establishment by farmers

Trees/shrubs/plants	Use	Comments
....	....	....
....	....	....
....	....	....
....	....	....

17. Any indigenous trees which the farmers would like to establish

Trees/shrubs/plants	Use	Comments
....	....	....
....	....	....
....	....	....
....	....	....

18. General problems encountered by farmers on livestock rearing and possible solutions

Problems	**Solutions**

Appendix 2: Analysis of variance (ANOVA) table for the mean Heights of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (tunnel experiment)

Source	**Sum-of-Squares**	**DF**	**Mean-Square**	**F-ratio**	**P value**	**Levels of significance**
SHADE	1249.499	2	624.750	1.41	0.248	NS
WATER	3805.057	2	1902.529	4.29	0.015	*
FERTILIZER	6077.968	2	3038.984	6.84	0.001	**
DAMAGE	528.400	2	264.200	0.60	0.553	NS
SHADE*WATER	6727.250	4	1681.813	3.79	0.006	**
SHADE*FERTILIZER	9512.741	4	2378.185	5.36	0.000	**
SHADE*DAMAGE	13179.873	4	3294.968	7.42	0.000	**
WATER*FERTILIZER	9268.227	4	2317.057	5.22	0.001	**
WATER*DAMAGE	14130.614	4	3532.653	7.96	0.000	**
FERTILIZER*DAMAGE	5017.987	4	1254.497	2.83	0.026	*
SHADE*WATER*FERTILIZER	37873.670	8	4734.209	10.66	0.000	**
SHADE*WATER*DAMAGE	6816.487	8	852.061	1.92	0.060	NS
SHADE*FERTILIZER*DAMAGE	34704.989	8	4338.124	9.77	0.000	**
WATER*FERTILIZER*DAMAGE	29231.133	8	3653.892	8.23	0.000	**
SHADE*WATER*FERTILIZER*DAMAGE	**75019.508**	**16**	**4688.719**	**10.56**	**0.000**	**
Error	79922.030	180	444.011			

NB NS= not significant ($P \geq 0.05$); *=$P<0.05$; ** = $P<0.001$

Appendix 3: Analysis of variance (ANOVA) table for mean dry shoots mass of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (tunnel experiment)

Source	**Sum-of-Squares**	**DF**	**Mean-Square**	**F-ratio**	**P value**	**Level of significance**
SHADE	0.027	2	0.014	2.73	0.068	NS
WATER	0.046	2	0.023	4.61	0.011	*
FERTILIZER	0.075	2	0.038	7.48	0.001	**
DAMAGE	0.007	2	0.004	0.74	0.479	NS
SHADE*WATER	0.127	4	0.032	6.30	0.000	**
SHADE*FERTILIZER	0.061	4	0.015	3.02	0.019	*
SHADE*DAMAGE	0.195	4	0.049	9.71	0.000	**
WATER*FERTILIZER	0.108	4	0.027	5.34	0.000	**
WATER*DAMAGE	0.244	4	0.061	12.12	0.000	**
FERTILIZER*DAMAGE	0.073	4	0.018	3.61	0.007	**
SHADE*WATER*FERTILIZER	0.392	8	0.049	9.73	0.000	**
SHADE*WATER*DAMAGE	0.073	8	0.009	1.81	0.078	NS
SHADE*FERTILIZER*DAMAGE	0.288	8	0.036	7.16	0.000	**
WATER*FERTILIZER*DAMAGE	0.423	8	0.053	10.52	0.000	**
SHADE*WATER*FERTILIZER*DAMAGE	**0.965**	**16**	**0.06**	**11.99**	**0.000**	**
Error	0.905	180	0.005			

NB NS= not significant (P≥0.05); *=P<0.05; ** = P<0.001

Appendix 4: Analysis of variance (ANOVA) table for mean dry roots mass of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (tunnel experiment)

Source	**Sum-of-Squares**	**DF**	**Mean-Square**	**F-ratio**	**P value**	**Level of significance**
SHADE	0.002	2	0.001	2.06	0.131	NS
WATER	0.000	2	0.000	0.27	0.764	NS
FERTILIZER	0.002	2	0.001	1.55	0.216	NS
DAMAGE	0.000	2	0.000	0.30	0.742	NS
SHADE*WATER	0.001	4	0.000	0.61	0.653	NS
SHADE*FERTILIZER	0.004	4	0.001	1.84	0.123	NS
SHADE*DAMAGE	0.005	4	0.001	2.40	0.052	*
WATER*FERTILIZER	0.003	4	0.001	1.30	0.272	NS
WATER*DAMAGE	0.011	4	0.003	5.38	0.000	**
FERTILIZER*DAMAGE	0.002	4	0.001	1.02	0.400	NS
SHADE*WATER*FERTILIZER	0.010	8	0.001	2.49	0.014	*
SHADE*WATER*DAMAGE	0.007	8	0.001	1.71	0.099	NS
SHADE*FERTILIZER*DAMAGE	0.012	8	0.001	2.76	0.007	**
WATER*FERTILIZER*DAMAGE	0.008	8	0.001	1.96	0.054	*
SHADE*WATER*FERTILIZER*DAMAGE	**0.021**	**16**	**0.001**	**2.50**	**0.002**	**
Error	0.094	180	0.001			

NB NS= not significant ($P \geq 0.05$); *=$P<0.05$; ** = $P<0.001$

Appendix 5: Analysis of variance (ANOVA) table for the mean Heights of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (rain out experiment)

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P values	Level of significance
SHADE	1750.363	2	875.182	1.42	0.244	NS
WATER	686.664	2	343.332	0.56	0.574	NS
FERTILISER	244.455	2	122.228	0.20	0.820	NS
DAMAGE	**416644.028**	**2**	**208322.014**	**337.65**	**0.000**	**
SHADE*WATER	3991.410	4	997.853	1.62	0.171	NS
SHADE*FERTILISER	2563.681	4	640.92	1.04	0.388	NS
SHADE*DAMAGE	1822.770	4	455.693	0.74	0.567	NS
WATER*FERTILISER	2639.401	4	659.850	1.07	0.372	NS
WATER*DAMAGE	2225.193	4	556.298	0.90	0.464	NS
FERTILISER*DAMAGE	1362.682	4	340.671	0.55	0.698	NS
SHADE*WATER*FERTILISER	5338.847	8	667.356	1.08	0.377	NS
SHADE*WATER*DAMAGE	3921.446	8	490.181	0.79	0.608	NS
SHADE*FERTILISER*DAMAGE	1925.580	8	240.698	0.39	0.925	NS
WATER*FERTILISER*DAMAGE	4339.776	8	542.472	0.88	0.535	NS
SHADE*WATER*FERTILISER*DAMAGE	11048.256	16	690.516	1.12	0.338	NS
Error	141906.325	230	616.984			

NB NS= not significant ($P \geq 0.05$); ** = $P<0.001$

Appendix 6: Analysis of variance (ANOVA) table for mean dry shoots mass of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (rain out experiment)

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P Values	Level of significance
SHADE	**0.121**	**2**	**0.06**	**10.34**	**0.000**	**
WATER	0.004	2	0.002	0.34	0.709	NS
FERTILISER	0.004	2	0.002	0.37	0.689	NS
DAMAGE	8.416	2	4.208	721.07	0.000	**
SHADE*WATER	0.022	4	0.006	0.96	0.429	NS
SHADE*FERTILISER	0.027	4	0.007	1.16	0.329	NS
SHADE*DAMAGE	0.041	4	0.010	1.77	0.135	NS
WATER*FERTILISER	0.028	4	0.007	1.19	0.314	NS
WATER*DAMAGE	0.015	4	0.004	0.63	0.642	NS
FERTILISER*DAMAGE	0.006	4	0.001	0.24	0.917	NS
SHADE*WATER*FERTILISER	0.063	8	0.008	1.35	0.218	NS
SHADE*WATER*DAMAGE	0.040	8	0.005	0.85	0.558	NS
SHADE*FERTILISER*DAMAGE	0.065	8	0.008	1.40	0.199	NS
WATER*FERTILISER*DAMAGE	**0.109**	**8**	**0.014**	**2.33**	**0.020**	*
SHADE*WATER*FERTILISER*DAMAGE	0.141	16	0.009	1.51	0.099	NS
Error	1.342	230	0.006			

NB NS= not significant ($P \geq 0.05$); *=$P<0.05$; ** = $P<0.001$

Appendix 7: Analysis of variance (ANOVA) table for mean dry roots mass of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (rain out experiment)

Source	**Sum-of-Squares**	**DF**	**Mean-Square**	**F-ratio**	**P Values**	**Level of Significance**
SHADE	0.222	2	0.111	22.83	0.000	**
WATER	0.013	2	0.007	1.37	0.256	NS
FERTILISER	0.002	2	0.001	0.20	0.818	NS
DAMAGE	1.258	2	0.629	129.25	0.000	**
SHADE*WATER	0.007	4	0.002	0.38	0.823	NS
SHADE*FERTILISER	0.008	4	0.002	0.41	0.803	NS
SHADE*DAMAGE	0.036	4	0.009	1.87	0.117	NS
WATER*FERTILISER	0.048	4	0.012	2.45	0.047	*
WATER*DAMAGE	0.003	4	0.001	0.13	0.970	NS
FERTILISER*DAMAGE	0.009	4	0.002	0.46	0.765	NS
SHADE*WATER*FERTILISER	0.012	8	0.001	0.31	0.963	NS
SHADE*WATER*DAMAGE	0.034	8	0.004	0.88	0.536	NS
SHADE*FERTILISER*DAMAGE	0.046	8	0.006	1.18	0.313	NS
WATER*FERTILISER*DAMAGE	**0.085**	**8**	**0.011**	**2.18**	**0.030**	*
SHADE*WATER*FERTILISER*DAMAGE	0.054	16	0.003	0.69	0.800	NS
Error	1.119	230	0.005			

NB NS= not significant ($P \geq 0.05$); *=$P<0.05$; ** = $P<0.001$

Appendix 8: Analysis of variance (ANOVA) table for root: shoot ratio of *Acacia karroo* seedlings in a trial conducted at the University of Zululand (rain out experiment)

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P Values	Level of Significance
SHADE	**0.318**	**2**	**0.159**	**6.03**	**0.003**	**
WATER	0.042	2	0.021	0.79	0.455	NS
FERTILISER	0.009	2	0.004	0.17	0.843	NS
DAMAGE	**28.085**	**2**	**14.043**	**533.23**	**0.000**	**
SHADE*WATER	0.147	4	0.037	1.40	0.237	NS
SHADE*FERTILISER	0.078	4	0.020	0.74	0.564	NS
SHADE*DAMAGE	0.177	4	0.044	1.68	0.156	NS
WATER*FERTILISER	0.144	4	0.036	1.37	0.245	NS
WATER*DAMAGE	0.136	4	0.034	1.29	0.276	NS
FERTILISER*DAMAGE	0.177	4	0.044	1.68	0.155	NS
SHADE*WATER*FERTILISER	0.086	8	0.011	0.41	0.914	NS
SHADE*WATER*DAMAGE	0.194	8	0.024	0.92	0.498	NS
SHADE*FERTILISER*DAMAGE	0.102	8	0.013	0.49	0.866	NS
WATER*FERTILISER*DAMAGE	0.148	8	0.018	0.70	0.690	NS
SHADE*WATER*FERTILISER*DAMAGE	0.609	16	0.038	1.45	0.122	NS
Error	6.057	230	0.026			

NB NS= not significant ($P \geq 0.05$); ** = $P<0.001$

Appendix 9: Analysis of variance (ANOVA) table for the mean height of *Psidium guajava* seedling in a trial conducted at the University of Zululand.

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P values	Levels of significance
GRASS	4126.286	2	2063.143	26.55	0.000	**
WATER	1259.214	2	629.607	8.10	0.000	**
DAMAGE	283.658	2	141.829	1.83	0.164	NS
GRASS*WATER	**1477.484**	**4**	**369.371**	**4.75**	**0.001**	*
GRASS*DAMAGE	238.897	4	59.724	0.77	0.547	NS
WATER*DAMAGE	410.625	4	102.656	1.32	0.264	NS
GRASS*WATER*DAMAGE	500.408	8	62.551	0.81	0.599	NS
Error	14221.264	183	77.712			

NB NS= not significant (P≥0.05); *=P<0.05; ** = P<0.001

Appendix 10: Analysis of variance (ANOVA) table for mean shoot mass of *Psidium guajava* seedling in a trial conducted in the University of Zululand.

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P values	Levels of significance
GRASS	**90.27**	**2**	**45.135**	**128.86**	**0.000**	**
WATER	**4.672**	**2**	**2.336**	**6.67**	**0.002**	*
DAMAGE	**15.607**	**2**	**7.803**	**22.28**	**0.000**	**
GRASS*WATER	1.756	4	0.439	1.25	0.294	NS
GRASS*DAMAGE	1.067	4	0.267	0.76	0.553	NS
WATER*DAMAGE	2.691	4	0.673	1.92	0.113	NS
GRASS*WATER*DAMAGE	4.055	8	0.507	1.45	0.186	NS
Error	35.378	101	0.35			

NB NS= not significant (P≥0.05); *=P<0.05; ** = P<0.001

Appendix 11: Analysis of variance (ANOVA) table for mean root mass of *Psidium guajava* seedling in a trial conducted in the University of Zululand.

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P values	Levels of significance
GRASS	113.778	2	56.889	182.56	0.000	**
WATER	0.724	2	0.362	1.16	0.317	NS
DAMAGE	9.582	2	4.791	15.38	0.000	**
GRASS*WATER	2.994	4	0.748	2.40	0.055	NS
GRASS*DAMAGE	1.843	4	0.461	1.48	0.214	NS
WATER*DAMAGE	4.773	4	1.193	3.83	0.006	*
GRASS*WATER*DAMAGE	**5.684**	**8**	**0.711**	**2.28**	**0.028**	*
Error	31.474	101	0.312			

NB NS= not significant (P≥0.05); *=P<0.05; ** = P<0.001

Appendix 12: Analysis of variance (ANOVA) table for mean leaf mass of *Psidium guajava* seedling in a trial conducted in the University of Zululand.

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P values	Levels of significance
GRASS	57.44	2	28.72	143.08	0.000	**
WATER	0.215	2	0.107	0.54	0.589	NS
DAMAGE	17.794	2	8.897	44.32	0.000	**
GRASS*WATER	3.396	4	0.849	4.23	0.005	*
GRASS*DAMAGE	1.275	4	0.319	1.59	0.191	NS
WATER*DAMAGE	5.985	4	1.496	7.45	0.000	**
GRASS*WATER*DAMAGE	**3.605**	**8**	**0.451**	**2.25**	**0.038**	*
Error	10.84	54	0.201			

NB NS= not significant (P≥0.05); *=P<0.05; ** = P<0.001