Grazing Management in the Communal Rangelands of the Upper Thukela, Kwazulu-Natal

By

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ABSTRACT

The grazing management project in the Okhombe ward of the Amazizi Tribal Authority formed part of the National Department of Agriculture's LandCare program to address communal natural resource management issues. Okhombe land is communal whereby every member of the community is the legal owner of the rangeland with individual ownership of stock with the chieftaincy playing a major role in land allocation. In order to avoid critics of the past and address the top-down approach of the past interventions, a participatory approach was conducted in the planning and implementation of the grazing system. The service providers held a series of visioning workshops with the community in an effort to better understand community resource use patterns, needs, constraints and opportunities as part of the participatory approach. Issues identified by the community were the need for fencing grazing camps, animal health improvement, subdivision of rangeland and crop fields and the development of a rotational grazing system.

The main aims of this study were to develop a participatory grazing plan with the community, develop and support institutional structures governing range management, and build capacity of the community in range management. The effect of the current grazing system on species composition was determined. In addition to these, the project investigated the potential different fodder trees has on alleviating feed and nutritional deficit, particularly during the dry winter months of the Upper Thukela.

Among the main achievements of this study was the development and strengthening of local institutional structures and effective liaison by all structures with the *Inkosi* and the tribal council. The community developed a rotational grazing plan, marked the camp boundaries, produced digital maps and successfully built fence boundaries (approximately 20 kms of fencing) to divide their land. The fence boundaries separated the crop fields and rangeland, closed ward boundaries in the upland to prevent access by cattle from neighbouring wards, and divided the land into three camps. Six crush pens were constructed in each subward of the Okhombe ward. A communal herders fund

opened and fence construction improved crop yields due to a decrease in crop damage by cattle.

Okhombe ward, located in the Highland Sourveld region of KwaZulu-Natal, experiences feed and nutrition deficits to ruminants during winter. The prevailing species composition in Okhombe was investigated as part of the grazing plan. The veld condition of the sites ranged from poor (40.7%) in the bottomland to an averaged of 47.0% in upland sites. The most distinctive feature of the rangeland in this area was the loss of highly palatable Decreaser grass species ($P < 0.05$), such as *Themeda triandra* in the bottom slopes (< 1300 m) when compared to the upland (> 1800 m). The proportional abundance of Decreaser species accounted for an averaged of 1.02% of the bottomland and an averaged of 11.5% of the upland compared to the values of 49% in the benchmark (grassland in optimal condition). The composition of the less palatable Increaser II species was very high at all elevations (1200 m -80.7%, 1400 m – 75.8% and 1700 m – 55.7%) when compared to the low benchmark composition of 19%. The dominant grasses of the bottom slopes were Increaser II species, such as *Eragrostis curvula*, *Eragrostis plana* and *Sporobolus africanus* and unpalatable Increaser III species such as *Aristida junciformis*. A significant difference ($P < 0.05$) in the composition of Decreaser, Increaser I and Increaser II species was found between the bottom and slopes compared to the upland region. However, the grass cover formed by these tufted species was generally high, making it more resistant to physical degradation. The bottom slope ranged from reasonable to excellent cover (16.9%), the middle slope ranged from reasonable (15.9%) to a good cover of 18.1%, averaging 16.7% and a range of 16.1% to 17.9% for the upland plateau.

In the agroforestry trial the potential of different fodder species for supplementing fodder was examined. *Leucaena leucocephala* had the potential of being a suitable fodder tree species for use in alley cropping ($P < 0.05$) compared to *Morus alba* and *Acacia karroo*. Results from the partially intercropped treatments showed that *L. leucocephala* yield (665 kg ha^{-1}) varied significantly ($P < 0.05$) from the *A. karroo* (378 kg ha^{-1}) and *M. alba* yield (345 kg ha^{-1}). Treatments that were fully intercropped varied, but no significant difference ($P > 0.05$) were recorded. *Morus alba* produced the least yield of 345 kg ha^{-1}, *A. karroo* yielded 378 kg ha^{-1} and *L. leucocephala* recorded the high of 664 kg ha^{-1}. Results from the second season showed similar trend in that *L. leucocephala* yielded a significant ($P < 0.05$) fodder production of 1715 kg ha^{-1} in comparison to *M. alba* (1101 kg ha^{-1}) and *A karroo* (1140 kg ha^{-1}).

M. alba yielded the least dry matter production ($P < 0.05$) but had high potential ($P < 0.05$) for addressing lack of firewood in rural areas. *Morus alba* yielded high fuel wood production from both two seasons. There were no significant differences in fuel wood yield ($P > 0.05$) from the partially intercropped *M. alba* (507.9 kg ha^{-1}) and *L. leucocephala* (455.0 kg ha^{-1}) but the yield from both species varied significantly from the *A. karroo* yield (103.kg ha^{-1}). With regard to fully intercropped plots, fuel wood yield from all tree species varied significantly, *A karroo* resulting in low yield (63 kg ha^{-1}), *L. leucocephala* recorded 243 kg ha^{-1} and *M. alba* the highest yield of 444 kg ha^{-1}. In the second season, *M. alba* yielded an averaged fuel wood production of 728 kg ha^{-1} and a low of 439 kg ha^{-1} from *L. leucocephala*.

Acacia karroo, a slow growing indigenous tree, might be preferred by farmers due to its less branches resulting in minimal light competition with crops. *Leucaena leucocephala* tend to grow slowly in its initial establishment stage, but once roots become well established, it grows fast and produces high quantity of fodder. The effect all fodder trees had on crop yield was not negative during the trial period and further research on long term effects of alley cropping is recommended. The conclusions drawn here were based on tree growth and their likely impact in alley cropping.

Leucaena leucocephala was also recommended as a preferred species for rural ruminants based on the forage quality study. The results showed high content of crude protein (19.27%), low NDF content (50.38%) and very low tannin content (1.19%) from *L. leucocephala* compared to *A. karroo* with a high tannin content of 5.69%. *Acacia karroo* had a crude protein content of 13.60%, NDF percentages of 44.16 and 34.64% of ADF content. *Morus alba* also had a recommended chemical composition of 11.71% of CP,

42.86% of NDF, 36.96% of ADF and a low tannin content of 0.65%. *L. leucocephala* foliage proven is readily degradable under different diet ranging within 24 hrs of intake ($P < 0.001$) compared to other feeds. *L. leucocephala* had high dry matter loss degraded from the rumen under *Eragrostis* hay diet with poor nutrients to high protein concentrates diet. Under the *Eragrostis* hay diet for instance, *L. leucocephala* tend to degrade rapidly with values of dry matter loss ranging from 32.2% to 39% at 4 hrs to 16 hrs, when compared to low dry mater loss of 26% at 4 hrs to 31.33% at 16 hrs. Feeds such as *M. alba* tend to degrade slowly within 24 hrs of intake and rapidly degrades after the stated period.

The CP content of maize stover was very low ranging from 1.60% in maize stalks to 2.63% in maize leaves. The fibre content in maize stover was very high when compared to lower values in fodder samples. The NDF content ranged from 77.92% in maize leaves to 81.60% in maize stalks. Maize leaves when compared to a combination of maize leaves and maize stalks sole tend to degrade better within 24 hrs of intake. This was due to low ($P < 0.05$) degradability rate of maize stalks compared to a combination of maize stalks and leave and leaves sole and least NDF content in maize leaves might have attributed to these results. Due to poor chemical compositions of these roughage samples, the study recommended the establishment of fodder banks and agroforestry systems to curb the nutrients deficit during winter.

In conclusion therefore, this study highlight that the sustainability of rural systems to manage communal grazing land should be further explored. Most of the challenging issues in communal range management are social in nature rather than technical concepts. These include ways of improving social contributions from cattle to the community while maintaining cultural values of the use of cattle. The interventions in communal range management by service providers should understand the institutional arrangements within a community and an attempt to strengthen such existing structures is recommended.

Further interventions by service providers in Okhombe ward should bring in the planning discussions, experts from social sciences, to deal with understanding of community

dynamics. Complexities in communal range management involve dealing with non-stock owners within project boundaries. Communities from neighbouring wards should not be ignored and ways of improving communications and updating project details to them should be formulated. Shortage of land and closing of ward boundaries to prevent access to land by neighbouring wards is among community complexities to be explored. Communities in rural lands do share land and in most cases boundaries are known but invisible by an outsider to identify. It is important to strengthen and maintain every success in communal lands as that may form core of the project. Successes on grazing management by locals is far from being the improvement in veld but there are rather various factors to the successes of grazing projects in rural areas. Examples of successes based on Okhombe project are reduction in stock theft, improved in relationship between community and locals institutions, a reduction in stock mortalities during winter and improved animal health. Veld improvement is among successes but there are accomplishments phases to fulfil before focusing on improvement of species composition.

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This thesis is dedicated to my late father

Matsobane Tau

DECLARATION

The experimental work described in this thesis was conducted in the Department of Grassland Science, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Dr. TM Everson (Senior Lecturer in the Department).

I hereby certify that this research is the result of my own investigation, except as acknowledged herein, and that it has not been submitted in any form for any degree or diploma to any University.

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.... Date 28/03/2006

Dr. TM Everson (Supervisor)

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List of Abbreviations

A.s.l	Above sea level
ADF	Acid Detergent Fiber
AIDS	Acquired Immune Deficiency Syndrome
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
AU	Animal Unit
CA	Correspondence analysis
CC	Carrying capacity
CP	Crude Protein
CSIR	Council for Scientific and Industrial Research
CT	Condensed Tannin
DM	Dry Matter
DoA	Department of Agriculture
FSG	Farmer Support Group
GA	Grazing Association
GPS	Global Positioning Systems
HSD	Honest Significant Different
IVOMD	In vitro organic matter digestion
Kg ha^{-1}	Kilogram per hacter
KZN	KwaZulu-Natal
LSD	Least significant difference
N	Nitrogen
NDF	Neutral Detergent Fiber
NGO	Non-Governmental Organisation
OM	Organic Matter
Ph	Potential of hydrogen
PRA	Participatory Rural Appraisal

RMA	Range Management Area
SADC	Southern African Development Committee
T ha^{-1}	tons per hacter
TTGA	Thaba Tseka Grazing Association
UKZN	University of KwaZulu-Natal

1. CHAPTER ONE: Introduction

1. 1. Background

Communal rangelands are those areas where agriculture is largely subsistence-based and where rangelands are generally communally owned and managed as opposed to private or individual ownership (Everson & Hatch 1999). These lands in southern Africa support the majority of the rural population, many of whom live below the poverty line.

Improving management of communal resources of any type is not a simple proposition. The introduction of effective management on communal natural resources was stated by Weaver (1990) as a difficult and time consuming process. Numerous constraints must be recognised and overcome and management objectives must be directed on the multiple needs of the community or communities involved. For many years, the donor community and host African countries have met with little success in their effort to institute successful range management. The traditional practices of resource management were systematically ignored and even condoned as irrational and destructive (Squires, Mann & Andrew 1992). Much of the literature reflects a belief that whenever property is owned communally, no one takes full responsibility (Thobela, Lax & Oettle 1998). Rural people were for many years considered by policy makers, academics, and development workers to be incapable of managing common property resources in a sustainable manner (Hesse & Trench 2000). Customary tenure systems with their communal farms of ownership and management were considered to be archaic, locking people into a 'tragedy of the commons' scenario. The community was considered unable to stop individual users from over-exploiting the resources (Hesse & Trench 2000).

By holding land in commons, it was thought that individual users had no incentive to limit the number of animals they grazed on that land. Without such limits, the conditions were set for land degradation and desertification, as most of the Sahel deserts were reported to be the result of overgrazing. It was thought the way to avert an environmental disaster was for the state to take charge and impose an external solution (Hesse & Trench 2000; Allsopp, Ainslie, Laurent & Debeaudoin 2003).

1.2. Social approach to communal grazing management

1.2.1. South Africa's Betterment planning programme

Over the years, deliberate efforts have been made by donors and the state to bring about agriculture development in communal areas without much progress. In South Africa, poor range productivity in many communal lands led to the 'Betterment' planning of the 1950's. The programme sought to address land degradation in South African rural areas by initiating a natural resource management scheme that divided the communes into three main resource areas, namely, the crop fields, rangeland and residential areas; each of these had unique resource tenure arrangements and rules (Allsopp *et al.* 2003; von Maltitz 1998).

The scheme replaced the traditional practices of natural resource management and imposed new regulations on managing cattle movement without any form of information sharing with the community. The top-down approach by the 'Betterment' programmes to implement management strategies excluded the local people from decision-making. Although the 'Betterment' scheme was based on sound ecological principles and was well designed, it failed to solve the problems of environmental degradation as there had been a lack of consultation and involvement of the rural population (Everson & Hatch 1999). Inappropriate institutional frameworks, poorly implemented rural development assistance and the absence of equitable, local governance regimes are among the reasons that led to a total collapse of the state programmes (Hesse & Trench 2000; von Maltitz & Evans 1998). One of the areas that were subjected to 'Betterment' was the Okhombe municipal ward located in the Upper Thukela district. People from Okhombe were relocated from the high lying areas into six residential subwards (villages), namely, Enhlanokhombe, Oqolweni, Sgodiphola, Ngubhela, Mpameni and Mahlabathini.

Little achievement by the 'Betterment' programme indicates that no attempt at improving veld will succeed without community support and that all members of the community should be included. The community should know and understand that any development is for their benefit; not only for a few farmers. The result will be an improved natural resource scheme drawn up and managed by the community themselves (Du Preez, Rossouw & Robinson 1993; Hesse & Trench 2000; Squires *et al.* 1992).

1.3. Ecological approach to communal grazing management.

In KwaZulu-Natal, cattle are kept for social reasons (family security, wealth, bridal dowry) as well as the provision of diverse flow of outputs such as milk, meat, and draught power (Arntzen 1998; Thobela *et al.* 1998; Schwalbach, Groenewald & Marfo 2001). Schwalbach *et al.* (2001) pointed out that the productivity of this form of farming system is generally low and the poor economic return of these small-scale cattle farming activities and the potential environmental degradation associated with overstocking poses a serious risk to the long-term sustainability of such farming systems.

1.3.1. Carrying capacity in communal rangeland

Carrying capacity (CC) is a term often talked about in relation to livestock in the communal areas. It is the source of much confusion especially when planning with communal farmers. Much debate in the literature has been whether to consider planning communal range management on ecological carrying capacity or economic carrying capacity basis (Abel 1993). Smith & Hardy (1999) stated that the development of a successful grazing management system is largely dependent on the number of animals that a certain area of veld is able to support. It has been argued that economic carrying capacity defined as the stocking rate that offers maximum economic returns and is determined by the economic objectives of the producers, will never be sustained under communal tenure. Economic carrying capacity is guided by the output of the marketable meat and milk and applies mostly to commercial farmers (Grossman, Holden & Collinson 1999; Abel 1993). In communal areas the value of cattle is determined by a range of outputs including use for draught power, transport, manure, and milk production. Cattle in communal areas are valued as a relatively stable investment for time of death or for food security purposes. This highlights the high value of cattle in rural areas which, in contrast to commercial farming systems, is based on high stocking rates (Morris, Hardy & Bartholomew 1999). The perception that high stocking rates are the result of irrational behaviour, poor management or backward attitudes is therefore unfounded. Rather, higher stocking rates are economically desirable by rural people. Cattle are therefore stocked and maintained at ecological carrying capacity controlled by external factors such as climatic fluctuations (Grossman *et al.* 1999; Abel 1993). This is the grazing capacity concept occurring in communal range. Rural people tend to focus on the maintenance and survival of animals, therefore exacerbating ecological destruction of the range. They control animal numbers by available grazing, which fluctuates with variable rainfall (Everson & Hatch 1999). A challenge to range planners is the view that with an improvement in pastures, economic carrying capacity will always change towards poor veld condition as individuals try to maximise stock.

1.3.2. Sour grassveld region of South Africa

Poor grass resource in communal land, the seasonal nature of forage supply, together with low intake and digestibility of forage are factors contributing to low productivity of ruminants in Africa (Ngwa, Nsahlai & Bonsi 2000). In South Africa these constraints are more dominant in the sour grassland regions, which predominate in the high rainfall areas (> 800 mm) at high altitude in eastern and southern parts of the country, and occur mostly as fire climax grasslands (Tainton 1999). Due to the leaching of vital nutrients by heavy rainfall, the veld type generally occurs in acid soil that is poor in nutrients. The sour grassveld is palatable for only six to nine months of the year from early spring (October/November) to winter (May/June) after which the grass palatability and quality declines rapidly. As a result its forage value is poor in winter (Edwards 1988; Hardy, Barnes, Moore & Kirkman 1999). Fodder shortage, especially during dry winter season, is one of the main problems facing rural livestock owners in sour grassveld areas Low nutritional fodder affects ruminants' productivity and reproductive performance (Everson, du Toit & Everson 1998; Trytsman & Mappledoram 2003).

Unfortunately improvement of growth rates and milk yields of livestock in these areas using commercial supplements is difficult because the supplements are expensive and are not easily available in the remote villages with poor infrastructure. Purchasing more feed would probably prove to be expensive unlike a cost effective method of feeding entirely on maize stovers (Trytsman & Mappledoram 2003; Bennett, Harris & Lent 2003). According to Everson *et al.* (1998), one option to increase agricultural production is to provide alternative sources of fodder through agroforestry implementation. This would be a relatively low cost option of increasing feed production by supplementing the diet with high protein fodder from trees. Alternatively, improving summer production through rest programmes would be possible. This project examines the potential of two options of increasing communal rangeland productivity.

1.3.3. Potential of agroforestry to increase fodder production.

Agroforestry is defined as a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence (Esterhuyse 1989).

Growing trees together with crops can greatly enhance productivity of rural farming systems, since tree roots can exploit water and nutrients below the shallow roots of crops. Trees can also increase productivity through soil nitrogen fixation and the production of green manure (Everson & Underwood 2003). Agroforestry has the potential to provide dry season forage and at the same time diversify the range of products from the cropland. Fodder tree species have the capacity to produce fodder when other species have become dormant in order to avoid harsh climatic conditions and can tolerate a wide range of management practices (Everson & Underwood 2003; Roothaert 2000). Everson *et al.* (1998) stated that agroforestry has the potential to increase the farmer's profit margin and saves costs. The project investigated the potential different fodder trees have on alleviating feed, particularly during the dry winter months of the Upper Thukela.

In rural South Africa ruminants are fed entirely on natural grassland in summer and on crop residues in winter. The amount of high quality grassland is usually sufficient during the rainy season, but decreases towards the dry season when the grasses are matured (Ngwa *et al.* 2000). These largely determine the performance of ruminants to seasonal fluctuations in digestibility of fodder and nutrient availability. Seasonal fluctuations affect its productivity condition such as milk production, become susceptible to diseases, energy fluctuations with variability in season. Cattle are vulnerable to diseases during winter as their energy level weakens; such diseases include bone impairment and dysfunctional rumen (Ngwa *et al.* 2000; Gerber, Nsahlai, Bonsi & Gous 2000). In order to alleviate nutritional deficiencies in the rumen and enhance roughage utilization, dairy farmers usually supplement low quality roughage diets with additional nutrients. This study also aimed at assessing the potential of fodder trees to alleviate nutritional deficiencies and roughage utilization by investigating their chemical composition and the rate of dry matter loss after intake.

1.4. Background of the study area

1.4.1. Okhombe grazing management project

Okhombe land is communal whereby every member of the Okhombe community is the legal owner of the rangeland with individual ownership of stock. The community relies heavily on their natural resources for their daily living. They subsist from the crop fields allocated to them by the *Inkosi* for planting maize (von Maltitz 1998; Farmer Support Group 2000). They extract soil from the fields for building their huts, livestock graze on communal grassland in summer and crop fields during winter. People depend on the streams for water. They also depend on the remaining remnants of indigenous forests for firewood and also need to purchase extra firewood to meet their daily requirements. The people of Okhombe are generally extremely poor and depend on limited employment income, pensions, welfare payments and income from migrant labour who work on the mines in Gauteng. There are a wide variety of informal economic activities to enhance food security and generate income. This includes selling milk, thatch grass and the occasional sale of livestock and chickens. The income generated from these is low but vital for household survival (von Maltitz 1998; Farmer Support Group 1999).

The study area is located in sourveld region in the northern Drakensberg, KwaZulu-Natal, where the rural farming systems still operate under communal tenure. The area is experiencing critical shortage of fodder, low quality fodder during the dry season, inadequate grazing land and shortage of firewood. The veld type of the area is classified Highland Sourveld (Acock 1988). The grassland under this region is palatable for only six to nine months of the year from early spring to autumn after which the grass palatability and quality declines rapidly (Edwards 1981). With the cost of supplements being high at the market, rural farmers feed their cattle entirely on maize-stover (roughage), low protein feed for the entire dry months.

Okhombe project was initiated as part of the first LandCare project in South Africa. The overall goal of LandCare South Africa is 'to optimise productivity and sustainability of resources resulting in greater food security, job creation and a better quality of life for all (National Department of Agriculture 2000). LandCare is a community-based programme supported by both the public and private sector through a series of partnerships. In accordance to the national goal of the programme the Okhombe LandCare project was initiated on the basis of recognition that land degradation is a community problem, not a farmer's problem or a Government problem. This specific project was aimed at identifying sustainable, integrated grazing management options that will improve the veld condition of Okhombe communal rangelands.

The emphasis was on developing grazing strategies in a much-needed coordinated and participatory manner with the communal farmers. Involvement of land users in LandCare embraces problem definition; developing visions, planning and implementing better land use and management. It was developed to support the community to have a sense of ownership of their land and enhance capacity building for managing grazing. Some of the key objectives of the National LandCare program include developing the capacity and skills of land users to manage their resources with minimal outside assistance, support institutional buildings at all levels of governance, empower all people through knowledge and understanding to take the responsibility for the care of the environment and maintain and enhance the ecological integrity of natural systems (Department of Agriculture 2000). The Okhombe project is covered by three chapters in this thesis and each chapter outlines the relevance of the project in accordance to the national objectives of the LandCare project.

1.5. Natural resource management in Okhombe

The current project is part of the LandCare initiative and addresses the issue of grazing management and fodder shortage. The development and implementation of a grazing management plan with the community is an extremely complex process which has taken approximately 4-5 years. This project has built on earlier initiatives which are outlined below. The main area identified by the community for further development were income generation, environmental management and other activities explained in this section. The service providers and the community then formed a partnership to address these issues. The partnership was formerly constituted when funding was obtained from the National Department of Agriculture to initiate a LandCare project in 1999.

Before the initial engagements of participatory exercises with the community, service providers attended a series of participatory rural appraisal (PRA) training conducted by a specialist from India. India is known for its successful accomplishments of involving communities in their natural resource management. The aim of the training was for the Okhombe community and the service providers of the area to develop an integrated development plan for the Upper Thukela project. Members who participated were from the University of KwaZulu-Natal, CSIR-Environmentek, Farmer Support Group (FSG), KwaZulu-Natal Department of Agriculture, World Vision, and KwaZulu-Natal Wildlife. Issues raised from the workshop included the need for an increase in local income generating opportunities, improvement of household food security, water access and energy access and also to increase capacity to manage their natural resources.

The Council for Scientific and Industrial Research (CSIR) is primarily a research rather than implementing organization. However it has a state mandate that its research must enhance the livelihoods of previously disadvantaged communities and be relevant to South Africa. The Forestek division identified resource management in communal areas as an important component within its division. The division has been involved in Okhombe since 1992 particularly in the Ngubhela subward interacting with the community on natural resource management

The University of **KwaZulu-Natal (Grassland Science)** has been involved in Okhombe through a number of community projects stated above to set up different natural resource management projects in Okhombe. With funding from the University Research and Community Development Fund an environmental development programme in the degraded catchment in the subward of Ngubhela was initiated in 1996.

Farmer Support Group (FSG) has been involved in the area since 1997 with the University of KZN in collaborative catchment rehabilitation project in Ngubhela subward. FSG is a Non-Governmental Organisation established from the UKZN's Center for Rural Development Systems to facilitate rural development projects, provide training, advice and technical support in sustainable agriculture, natural resource management, entrepreneurship, and institutional development.

KwaZulu-Natal Department of Agriculture and Environmental Affairs is a state department committed to the support of all rural agriculture-based community programmes. Within the districts are networks of agricultural extension staff that are tasked to promote appropriate agricultural techniques and to facilitate associated activities with the ultimate goal of achieving sustainable agriculture. The department was involved in the area prior to the 1994 PRA training exercise with the community.

PRA workshops were held in 1994 with the Okhombe community particularly in Ngubhela subward in an effort to better understand the community's natural resource utilization management and the needs for overcoming critical problems threatening their livelihoods.

The project initiated a community garden and rehabilitation project to address income generation and shortage of fodder. It was agreed among the service providers that there must be long term commitment for the development process.

The CSIR focused their exercises mainly on natural resource management. In order to address income generation and food security, the CSIR set up a community garden, initiated a tree project (nursery) and introduced a tree educational project in Ngubhela. Allocations of the site for the community garden and tree project were chosen in consultation with the Inkosi for approval. Collaboration was also formed at the time between the local school and the CSIR to raise awareness of tree planting to promote re-vegetation of degraded areas.

It was revealed during transect walks that a major concern of the community was that water flow has begun to be a problem. Some of the perennial streams in the catchment no longer flow throughout the year. This led to an integrated catchment management project co-ordinated by the University of KwaZulu-Natal, the CSIR and Farmer Support Group in 1997.

The Okhombe community decided that the pilot natural resource management project should commence in one of the subwards called Ngubhela. Ngubhela was selected as it was the most poorly resourced subward in terms of infrastructure such as roads and water access. People from neighbouring subwards also participated in the project activities. These volunteers from the community developed and initiated a rehabilitation programme in the degraded Ngubhela catchment. The success of the pilot project in Ngubhela and the request by the community to broaden the project to include the whole Okhombe community resulted in a process of joint proposal development for LandCare in Okhombe by close co-operation of all stakeholders (the community and service providers). A broader approach was seen necessary to address the underlying causes of the degradation. This was essential for raising environmental awareness, and protecting the land.

The process consisted of an initial workshop in June 1998 in which the principles and vision for the pilot project in LandCare were discussed, followed by another more in-depth workshop in July 1998. These were integrated workshops in which a number of organisations participated in the proposal draft. Participants included the following organisations: the Farmer Support Group (FSG), University of KwaZulu-Natal, the CSIR, the Agricultural Research Council (ARC), WorldVision Institute, the Umgeni Water, KwaZulu-Natal Agricultural Department (DoA) and KwaZulu-Natal Wildlife. A number of PRA workshops were held in 1998 (See Chapter 3) prior to the launch of the LandCare project in 1999.

During PRA workshops conducted prior to 1999, the community identified cattle movement during the state's dipping programme as a major contributing factor to erosion due to opening of cattle routes susceptible to erosion. The gullies created posed a danger to cattle, as they often fell inside. There was a single dip tank at the base of the valley and all cattle had to move to this dip tank twice a month during summer. This had a number of negative consequences: Cattle had to move through the fields as they were taken to the dipping tank from the grazing land. Due to lack of proper paths for the cattle, cattle had to cross the fields resulting in crop damage. This led to strained community relations between cattle owners and crop owners. The movement also required labour, which was limited due to attendance of school by small boys who traditionally used to be herders. This management problem primarily resulted in resource degradation and participation of the whole community in management planning was essential. Grazing was not only the problem. Gully formation, soil erosion and water run-off from the bare hill slopes; sub-optimum crop production; and unemployment, poverty and food insecurity were other problems identified in the workshops. Project partners envisaged that the development plan would include a range of focus areas such as grazing systems, cropping, water management, tree planting, gardening, erosion control and income generation. The plans for these actions were to be developed with the community.

The National LandCare project was launched in 1999, as part of the State's plan to help people to manage their natural resources and provide advice and financial support for community projects. The project's main target was to enhance capacity building of the Okhombe community in land rehabilitation and generate job creation. About 50% of the total funds allocated were budgeted for job creation. The job creation budget was shared by approximately 500 community members for a period of three years. The money was distributed to all the six subwards to employ community members for rehabilitation work. The project employed teams comprised of 12 members from each sub-ward. Each team worked for 3-4 month after which a new team was employed. The people employed were identified during the PRA exercise. Criteria used were based mainly on poverty and absence of breadwinners in a family. This ensured that as many people as possible benefited from the job creation component of the LandCare project. The project therefore gained huge popular support and commitment from the people. Project activities planned for generating income included community gardens and nurseries. It was the gully rehabilitation project that the grazing management project emanated from.

The project started with a gully rehabilitation programme, and the community was paid for reclaiming gullies through a number of methods described below. The most preferred rehabilitation method was the establishment of stone packs and stone lines. Small walls, called stone packs, were built inside the gullies and other erosion excavations in order to retain silt and thus to make terraces. Similar stone structures were built on some large and steep slopes more sensitive to erosion. To retain silt and sediments, plants were planted to protect the soil from wind and water erosion. Planting vegetation was the only effective method in retaining the deposited silt. Brush packs were used to establish grass cover on eroded areas. These are made by cutting seeded grass, laying it down to a thickness of approximately 5 cm, and covering it with small branches. The branches protect the grass from livestock and wind damage, and create a moist microclimate within which the grass seeds germinate and establish.

Indigenous trees (*Acacia karroo*) and lines of vetiver grass (*Viteviria zizanoides*) were planted and swales constructed. Vetiver grasses are strongly rooted plants, growing in tufts, which can reach almost 2m length. Vetiver lines were established in sensitive places such as the top of stone structures, or at the head of gullies, where there was a high erosion risk. Kikuyu (*Pennisetum clandestinum*) is a stoloniferous tropical grass effective in covering bare land (Van Oudtshoorn 1992). It spreads quickly and provides quality fodder. This grass was opted after lower rate of survival of indigenous *Hyparrhenia* and *Melinus* grass species (Everson 2000). *Acacia karroo*, an indigenous water efficient tree was protected from grazing by livestock with barbed wire or dead wood (Barnes, Filer & Milton 1996). Although the use of indigenous plants should encouraged where possible, their disadvantage over alien plants are that, they are slow growing and yield tangible benefits after a long time (Maliehe 1991).

Concern over shortage of grazing, and the destruction of erosion control structures by cattle obliged the community to request service providers to assist in developing a grazing management plan (See details on Chapter 4). The grazing project and the gully rehabilitation program were facilitated by the University of KwaZulu-Natal (UKZN), the CSIR, the

Agriculture Department, the KwaZulu-Natal Wildlife and the FSG. An environmental education program in schools was developed after realising the need for involving learners in environmental awareness and was facilitated by the CSIR, UKZN and FSG.

BergWatch, a non profit organisation joined later in 2002 to facilitate the current community-based tourism initiative project. The community garden and the nurseries were co-ordinated by the FSG and the Agriculture Department. An HIV/AIDS and food security initiative was co-ordinated by the Bergville Child Survival program in partnership with the FSG to address food security through the establishment of home gardens to families affected by AIDS. All these activities were facilitated in co-operation with relevant local institutional structures developed by the community. Representatives from the above-mentioned organisations in partnership with representatives from each local institutional structure together formed a team called Okhombe Partners that met once every month for progress reports from each section to co-ordinate activities, assess progress and plan interventions.

1.6. Research techniques

Explained below are the approaches used to address constraints faced by farmers under communal range management in Okhombe. Main techniques used were participatory rural appraisal (PRA) approach and the establishment of an agroforestry trial.

1.6.1. Participatory Rural Appraisal (PRA)

A participatory approach is defined by Van Vlaenderen & Nkwinti (1993) as a process involving the gathering of data with the active participation of all involved in the process and an educational process for development. It is believed that combining data gathering with education and capacity building, and involving the affected people as participants in the process, will lead to the collection of valid and reliable data and will enhance the sustainability of processes and programmes. Ineffective efforts by the 'Betterment' planning necessitated the grazing management project to be community driven, with decisions being taken primarily by the community. The approach used to ensure effective participation by the community is called Participatory Rural Appraisal (PRA). The approach tends to empower people and give them a sense of ownership of the project (Everson & Hatch 1999).

In Okhombe, the project partners held a series of PRA activities with the community from 1994 to 2000, in an effort to better understand community resource use patterns, needs, past and present land use, and constraints and opportunities for development. Community understanding of the LandCare objectives and the expected outcomes of the project were also examined. The PRA techniques conducted with the community and outcomes of the exercises are summarised under chapter 4.

1.6.2. Background to agroforestry establishment

The vegetation of the area is fire climax grassland with scattered indigenous trees such as *Acacia karroo*. Due to low presence of these trees, there is pressure on the available forests (*Acacia mearnsii*) for firewood. Some wattle trees were in the past planted to provide fire wood to the community. The Working for Water national scheme was launched in 2000 to eradicate water-wasting alien species (e.g. wattle) in catchment areas such as Okhombe (Farmer Support Group 1998). In the valley, all exotic tree plantations were cleared, in order to improve water-provision from the catchment. The programme offered temporary job opportunities to the community and cleared all wattle without participatory planning on controlling the invasion of wattle trees in their area and establishes alternative sources of fuel wood. At present there is a critical shortage of fodder and wood for fuel in Okhombe. Fire wood is either purchased or accessed in remote areas far from homesteads. There is only one private wattle woodlot, a small plot of gum trees (*Eucalyptus*) belonging to the traditional authority and wood can only be accessed thorough payments (Farmer Support Group 2000). As mentioned above, the area is located in the highland sourveld (Acocks 1988) and the length of the dry period (April to October) is a limiting factor for grazing.

An on-station agroforestry trial was therefore implemented at the UKZN research farm (Ukulinga farm), to address the problem of shortage of fodder and fuel wood by investigating the role of exotic species (*Morus alba* and *Leucaena leucocephala*) and an indigenous species (*Acacia karroo*) in overcoming these major constraints to rural farmers. A seasonal fluctuation in sour grassveld quality has a direct impact on animal performance via nutrient absorption, intake and digestibility (Kirkman 1989). The aim of implementing the trial was to investigate and evaluate the potential of tree species to increase production of fodder and fuel wood in Okhombe. The digestibility and chemical composition of three potential fodder tree species, *Acacia karroo, Morus alba* and *Leucaena leucocephala* were also investigated. In addition to addressing fodder shortages, the study investigated the potential of alley cropping to maximise crop yield. Land in Okhombe area is allocated into residential, grazing and arable land. These were designated by the past Government. Each homestead subsists from 1 ha of land for planting mainly maize crops. Hence described the study area is situated in the sourveld region; the soil types are generally acidic and poor in nutrients. Encouraging the community to practise an alley farming system may maximise yield from the fields.

CHAPTER 2: Literature Review

2.1. Subsistence farming: Introduction

Everson and Hatch (1999) defined communal rangelands as those areas where agriculture is largely subsistence-based and where rangelands are generally communally owned and managed as opposed to private or individual ownership. These lands in Southern Africa support the majority of the rural population, many of whom live below the poverty line. It is reliably estimated that up to 80% of agricultural land in Southern Africa is suited to extensive livestock production (Du Preez *et al.* 1993; Hundleby 1991). In South Africa, these areas comprise the previous homelands and constitute approximately 12% of the country, supporting a quarter of South Africa's human population and half of the livestock population (Everson and Hatch 1999). Shackleton, Shackleton & Cousins (2001) stated that communal land plays a significant role in the livelihoods and household economies of rural dwellers.

2.2. Historical background to communal rangeland management.

Livestock plays a central role in the economic and social welfare of rural inhabitants throughout the Southern African region. A great proportion of rural people would not be able to survive without livestock (Portillo, Weaver & Motsamai 1990). Livestock provide meat, milk, hides and skins for subsistence needs; they also provide draught power and transport in remote areas; they are used for ceremonial and traditional purposes; and the sale of livestock and livestock products generate income. To maintain these multiple uses of livestock, rural people always strive to manage land and fodder on which their stock depends. Historically, many subsistence farmers were nomadic and used very large areas for grazing. Fodder shortages were solved through livestock mobility to new reserved sites. Cattle were kraaled at night and released in the morning following milking.

Traditionally, among the responsibilities of the chieftainship in Southern Africa is the management of rangeland (Erskine 1993; Motsamai 1991). These areas are designated for summer cattle grazing, but are also used for other resources such as water, fuel wood, timber, and medicinal plants. All members have access to this area, and patterns of use are controlled by local rules and regulation. However, in many rural areas there are no rules limiting the number of cattle that an individual may keep. An extensive nomadic type of grazing systems would not require limiting numbers of cattle. However as the life style changes to sedentary, rules and regulations would have changed and land allocations becomes a key practice to ensure that all members of a tribe have access to grazing land. It would seem that controlling the size of a herd would become an issue of concern. This might not have translated in a set of regulations. This implies that the community enjoys open access with no control; only the chief has the power to allocate land and revoke allocations particularly with regard to cropping fields (von Maltitz & Evans 1998; de Bruyn, Goqwana & van Averbeke 1998). In winter the fields in almost all community rangeland are used for communal winter grazing resource (von Maltitz 1998; Everson & Hatch 1999).

Matters of great concern that aroused from these traditional practices to rangeland were overgrazing, soil erosion, veld fires, lack of veld management schemes, random and unplanned settlements leading to shrinking of arable land and rangelands (Soko 1990). Hurt (1998) pointed out that communal grazing systems in particular have been singled out as some of the worst examples of rangeland degradation in South Africa. These allegations have however, been complemented by state funding projects to address rangeland degradation. The past Government viewed the traditional system ineffective in managing rangeland. The authority of the chief or headmen to oversee communal grazing practices (for instance, resting certain areas or regulating the movement of cattle between residences and cattle posts) has been diminished (Ainslie, Palmer, Hurt and Swart 1998; Erskine 1993; Motsamai 1991). Village settlements were fenced in and formed smaller units (especially post-Betterment planning) that often required management as discrete areas and seriously undermined mobility of livestock (Ainslie *et al.* 1998). This process was viewed by the State as a major contributor to erosion, and was halted by establishing camps for overnighting cattle. The State programmes initiated the destocking campaign to address the issue of fodder shortages (Ainslie *et al.* 1998).

In South Africa, the 'Betterment planning' was initiated to achieve rangeland sustainability through the control of excessive livestock numbers. The destocking programmes of the past states of the Southern African Development Cooperation (SADC) region floundered, as so many similar attempts in Africa have (Everson and Hatch 1999). Communal grazing lands were divided up into bounded areas and a rotational grazing plan developed without community consultation. The demarcation of communal rangelands into villages has the potential for disruption of customary pastoral land-use patterns (Sithole 2003). Village boundaries not only divide communal rangeland areas into discrete administrative units, they also provide the potential for exclusion from access to resources (Allsop, Ainsle, Laurent & Debeaudoin 2003; Lane & Moorehead 1995; Sithole 2003). This is because village land areas are unlikely to cover the whole area that makes up an ecological land-use unit, particularly in those times when migration is extended to include distant forage and water resources in times of drought (Lane & Moorehead 1995). These facts were not considered during the planning process and communities remained outside the formal planning process. Technical specialists determined carrying capacity and the community were given a limited number of stock that each could own (Perrier 1994).

In most literature it was argued that State plans of improving rangelands clashed with reasons for keeping stock in communal areas (Allsop *et al.* 2003; Letty, Alcock, Masondo, Trench, Gumede, & Dladla 2003; Turner 2003. Due to the top-down approach, state authorities were not aware of the consequences of implementing their designed range plans without formal consultation with the chief and his people (Everson & Hatch 1999). The most important reasons that should have been considered when dealing with rural farmers is that stock are kept for non-commercialisation purposes tabulated below:

Table 2.1. Reasons for keeping stock in communal areas.

AREA	VALUE
Botswana	Home slaughter and sales, draught power, manure, milk, social functions (Arntzen 1998)
Zambia	Manure, draught power, milk, prestige (Kaoma, Kawimbe & Maseka 1998)

Swaziland	Milk, meat, draft, social exchange (lobola), manure (Critchley 1995)
Malawi	Dowry payments, social functions (ceremonies), prestige, draft power (Msiska and Nkhonjera 1990)
Tanzania	Meat, milk, social functions (Mwenye 1990)
Lesotho	Draft power, milk, meat, fuel, sale, social exchange (Mokitimi, Mokuku, Prasad, Quinlan & Letsela 1996; Artz 1993)
KwaZulu-Natal	Milk, social exchange, draught, insurance against disaster, live sale, prestige (Tapson 1991)

2.2.1. Elements of failures of past State programmes

In Lubisi village of the Eastern Cape (South Africa), the community organised themselves into an active campaign to destroy the old fence systems (von Maltitz & Evans 1998). They viewed the implementation of the system as a Government strategy to take powers from chiefs. The fence was therefore destroyed for political reasons. In Gazankulu (South Africa) a top-down approach was used in implementing range management solutions without consulting cattle farmers (Nghatsane 1991). The approach failed to accomplish its objective of range management. The State blamed cattle farmers who were thought to be short sighted and irrational by destroying State's grazing management schemes (Nghatsane 1991).

Dube and Kalua (1998) reported many grazing schemes established in communal areas of Zimbabwe, have not yielded desired results. Farmers in most grazing schemes, whilst prepared to use rotational grazing, are not prepared to follow the recommended low stocking rates and therefore most farmers rotated at heavy stocking resulting in no improvement of the range.

The Agro-Pastoral Development Project of Algeria called in an Australian team of experts to work with Algerian farmers in harnessing range deterioration (Squires *et al.* 1992). The project failed in its initial phase because of: a) lack of involvement of nomads and settled farmers in determining their own destiny, b) little attempt was made to utilize the knowledge and capabilities of local people and c) the Australians failed to establish a working relationship with their counterparts. They tended to work on their own perceptions, which they gained from literature rather than from a developed understanding of local ways of living and managing the environment (Squires *et al.* 1992).

In Malawi, the Northern Region Grazing Project was implemented to improve the quality and carrying capacity of the range through the introduction of suitable and appropriate legume species (Msiska & Nkhonjera 1990). The project involved a few farmers selected from the community. Non-members caused social problems by starting fires and moving their cattle to the improved areas without authorisation by private owners (Msiska & Nkhonjera 1990).

Lesotho experienced the same problem with its Thaba Tseka Grazing Association (TTGA) from the start (1979) to the end (1980). This was a joint project between the Lesotho government and the Canadian Government, which was enthused by the idea of establishing grazing associations on an area of 1.500 ha (Motsamai 1990). The first problem of the TTGA was that membership was limited to wool and mohair growers association members. These were the most progressive farmers with the most advanced breeding programmes. The majority of other livestock farmers saw the association as an elite group to which the government granted special privileges, such as the exclusive use of grazing land (Motsamai 1990; Motsamai 1991; Turner 2003).

As time passed, the land set aside for the association improved its production considerably and it was at this point where non-members thought that the area had been opened to all, brought their cattle in for grazing the high herbage yield in the fenced land. Fences were destroyed and this brought an abrupt end of the project. It was reported that attempts have been made to revive the project but all in vain (Motsamai 1998). The lesson learnt from the TTGA project in relation to the Okhombe project is that no attempt at improving range resources or allocating land would be successful without community decisions to the programme. Even including working on small boundaries, the land has to be allocated with an agreement from the tribal authority and the community (Motsamai 1990; Motsamai 1998).

2.2.2. Elements of success

According to Everson & Hatch (1999), participation empowers people and gives them a sense of ownership of the project. Participatory Rural Appraisal (PRA) is an approach that is being used internationally in rural areas to investigate work, planning, implementing, monitoring and evaluating the work done with communities. A United Nations Development Programme (UNDP) project carried out in Eastern Senegal provides an example of participatory management (Mache 1990). In an attempt to overcome problems resulting from communal use of grazing, permanent rights were allocated to units of 100 families. Between 1977 and 1983 the grazing condition in the project area improved resulting in increased calving rates, decline in mortality and a change in herd composition. Between 1980 and 1982, the average income from livestock per family increased by 48% owing to a higher off take with the better price. This project belongs to the community not to the service providers (Mache 1990).

Lesotho's lesson

Lesotho is among the developing countries that has accomplished an improved community range condition with its Range Management Area project (Mache 1990). In 1982, the Government initiated the Lesotho Range Management Area (RMA) Programme. The RMA approach is based upon the allocation of exclusive grazing rights to a specific group of users in a defined area (Weaver & Sekoto 1991; Ivy & Turner 1994; Erskine 1993; Motsamai 1990). Management of the RMA is undertaken through a community-based grazing association composed of livestock owners. In 1990, four RMA's were established covering approximately 130 000ha (more than 6% of Lesotho rangeland) incorporating 18 000 residents in 81 villages.

This is a community-driven project and gained popular support since its inception because the ownership and management control of the project was vested into the hands of the community. Fines were set for those who violate the grazing plan regulations. Range riders were employed and paid by the community and work closely with the police. Stock was impounded for grazing where the herd of a member were not entitled to be at the date in question. Members were advised of culling and castration of bulls and were encouraged in the selling of stock. The Government provided injections and dips (Weaver & Sekoto 1991; Ivy & Turner 1994; Erskine 1993; Motsamai 1990).

Hunter & Weaver (1991) on the basis of various monitoring programmes cited an impressive list of technical achievements that were addressed from the RMA program. Total ground cover in the RMA increased from an average of 65.3% to 69.1%. Range condition scores improved from 88.4 points (fair) in 1983 to 134.8 points (good) in 1991. Plant species diversity on sample areas increased by 42% during the same period. Herd demographics showed an increase from 57.2% females in the 1983 cattle herd to 64.9% in 1991. Cattle weight and cattle value improved. These are the results of involving local people and giving them a full ownership of their project.

Recent reports by Turner (2003) indicated that RMA has been shadowed by misfortunes to accomplish its ultimate successes in sustainable range management. The approach and operational range management used in RMA projects undermined the role of chiefs in land allocation and the management of natural resources such as pastures. The use of grazing lands by few, members of the Grazing Association only became difficult to implement. The project had difficulties in enforcing their exclusive rights to mountain grazing areas that had previously been used by much broader groups of stock owners. Members had to police their pastures vigorously, impounding the stock of non-members from further afield. The concept of locally exclusive tights was enormously contentious and required sustained commitment from GA's and Government. Some RMA have therefore floundered on this issue, notably when party politicians sought to intervene.

Turner (2003) reported after the management plan for the RMA pastures were developed, a more rigorous rotational plan was enforced to members than had previously prevailed. The technical and environmental perceptions of local stock owners and external advisers did not always coincide, and violations of RMA management plans have been common.

The RMA achieved a marked initial reduction in livestock numbers within the GA, as non-local users and their animals were excluded. To some extent these management plans shifted the problem of grazing pressure to other grazing areas, while privileging the relatively limited pastures that fell within RMAs (Turner 2003).

2.3. Debates on rangeland ecological dynamics and their management implications.

The traditional approach to range management is based on the assumption that a dynamic equilibrium exists between grazing animals and their forage resource, and that there is constant feedback between the two. Any notion of carrying capacity is predicated on the notion that herbivore numbers are controlled through the availability of forage and that the availability of forage is controlled by animal numbers, a pattern of negative feedback which eventually produces a stable equilibrium between animal and plant populations (Behnke & Scoones 1993). A fundamental assumption of the equilibrium view is that pastoral systems are inherently stable, but are destabilised by overgrazing, a term used for the continuous utilization of rangelands at high stocking rates without periodic resting. The disequilibrium theory argues that overgrazing is not the factor in arid areas but rather rainfall fluctuations is the main factor determining veld condition (Tainton, Morris & Hardy 1996; Cousin 2003).

The theory argues that the equilibrium assumptions underpinning conventional range management are inappropriate in areas that experience low and highly variable rainfall. Animal numbers tend to decrease in bad seasons and recover after dry winter seasons and stabilise in good years. But in most communal areas, grazing in equilibrium rangeland can have a considerable impact on the vegetation, both in terms of its composition and density, leading to a non-equilibrium situation- a change from an ecological equilibrium system to a non-equilibrium livestock production system (Behnke & Scoones 1993; Cousin 2003; Scoones 1994).

This statement was the basis of the debate on rangeland dynamics particularly when interventions of stabilising rangeland were inappropriately applied. Interventions at stabilising the highly variable rainfall regions such as destocking programmes were viewed inappropriate and damaging to pastoralist livelihoods (Cousin 2003; Ellis & Galvin 1994). This is largely due to the fact that fodder production follows rainfall distribution and amount, and animal production tracks fodder production patterns (Tainton *et al.* 1999; Behnke & Scoones 1993). Ecologists have therefore argued that in such areas, the grazing systems are at disequilibrium, since environmental variability seldom allows the system state to equilibrate. The systems are found in areas where rainfall is persistently erratic, both in timing and spatial distribution, mainly in arid and semi arid tropical environment. In areas subject to extremely variable rainfall; fluctuation of rainfall may have a much stronger effect on the vegetation than animal number (Behnke & Kerven 1994; Fitters, Kruger, Fuller, Hlangula & Seely 1996).

This debate frequently contrasts the conventional model of continuous and reversible vegetation dynamics (Briske, Fuhlendorf & Smeins 2000). It was stated the debate received much attention since it first surfaced in the 1980s but remains largely unresolved and agreement on appropriate and sustainable management strategies in rangelands not reached as a result. Rangeland ecology has emphasized vegetation dynamics as the primary variable to assess ecosystem behaviour. Much emphasise of the debate was therefore on equilibrium rangeland and non-equilibrium rangelands (Briske *et al.* 2000). The range model is based on the equilibrium paradigm and it emphasizes the importance of plant competition and plant herbivore interactions on ecosystem behaviour (Briske *et al.* 2000; Tainton *et al.* 1996).

The equilibrium view holds that rangelands vegetation follows a predictable succession which can be predictably influenced by adjusting stocking rates (Behnke & Kerven 1994; Behnke & Scoones 1993). Every environment has a carrying capacity determined by biophysical factors, and exceeding the carrying capacity in the long term leads to degradation, especially in communal rangelands. Livestock populations in the system are limited by available forage in a density-dependent manner, so that excessive animal numbers above a carrying capacity level result in negative effects on the vegetation (Behnke & Kerven 1994; Tainton 1999).

There has been concern about the state and sustainability of communally grazed rangelands in Africa and other parts of the world (Allsop *et al.* 2003). Communal rangelands are commonly viewed as overstocked, overgrazed, degraded and unproductive and this has resulted in interventions to reduce stock numbers in an attempt to halt degradation (Cousin 2003). This implies that to stabilise the system, conventional range management makes sense in this kind of grazing system. Conventional range management applies ecological carrying capacity whereby the number of stock is manipulated by human beings to balance with the available feeds. Herds are rotated from one camp to another to maintain species diversity and keep the ecosystem at equilibrium level. This view has been widely challenged regarding its underlying ecological and economic assumptions. In communal rangelands, stock owners derive a multitude of benefits from multi-species herds, many of which are non-consumptives (Cousin 2003; Behnke & Scoones 1993).

It is argued that multiple benefits in communal areas are maximised at higher stocking rates than commercial farming objectives such as beef production. This implies factors like species composition and forage availability cannot be applied when planning grazing management in rural areas (Cousin 2003) because interventions based on the equilibrium paradigm focus on reducing stocking rates and increasing stability. The community themselves rely on external factors to adjust their stock numbers rather than equilibrium between grazing animals and forage resources. From an ecological point of view, high climatic variability in semi-arid rangelands means that no single carrying capacity applies at all times. Repeated mortalities during droughts followed by slow herd recovery keep livestock below densities where they are able to overgraze the vegetation, and rainfall rather than stocking rate is the primary driver of plant productivity (Galvin & Ellis 1996). According to Tainton *et al.* (1996) the theory therefore appears to be useful in understanding the dynamics of grazing systems in humid perennial rangelands and where environmental variability is low. Low environmental variability refers to areas like Highland sourveld whereby environmental conditions tend to be homogenous, unlike arid areas which are heterogeneous in nature and manipulated by external factors.

Given the study area as an example, the main determinant factor of animal populations tends to be internal factors such as grass quality. Thus variation in forage variability is a key factor in improving grazing in Okhombe. The grass quality of the area has been identified as the main factor affecting the animal populations. The actual carrying capacity at any time is determined by range condition, which is a function of grass composition, biomass and basal cover. Heavy grazing in communal areas pushes back the climax stage to a pioneer stage dominated by generally low-quality grass species (Cousin 2003; Morris, Hardy & Bartholomew 1999).

In conclusion, in non-equilibrium grazing systems, because the grazier has little influence on system dynamics, the appropriate management strategy is to exploit the variation in forage availability (Tainton *et al.* 1996). Destocking programmes favoured by the past state is not recommended in these systems hence as rainfall is the main factor determining veld conditions. Prevention of free migration of herbivores by paddocking may lead to local soil and vegetation degradation (Tainton *et al.* 1999). In equilibrium systems, considerable attention is paid to grazing systems which either reduces the extent to which animals selectively graze (short duration grazing) or reduce the impact of selective grazing on the forage resource, high performance grazing, and deferred-rotation systems. Such systems usually involve paddocking in order to reduce the variability of the forage resource available to the animals at any one time. (Tainton *et al.* 1996).

2.4. Carrying capacity in communal rangeland

The past Government viewed management problems of communal rangelands as the control of rangeland degradation through the control of excessive livestock numbers. The scientific basis for this concern has been the concept of rangeland carrying capacity, defined and measured according to assumptions about the impact of herbivores on plant succession (Behnke & Scoones 1993). The scientific standards led to conclusions that communal rangelands are overstocked, overgrazed and exacerbate land degradation. Abel (1993) stated range degradation was defined in terms of an irreversible decline in secondary productivity.

Scientific range management differs from the traditional cattle management system in terms of targeted objectives. The argument was clearly covered by Hardy (1994) in that the objectives of maintaining livestock in communal management systems are not aimed at financial benefits to the farmer but rather to provide households with, amongst other products, milk, draught power, dung, equity and bride price. Maximising animal numbers rather than livestock production is one of the main objectives. The veld in communal areas therefore tends to be heavily stocked and according to disequilibrium theory animal performance tracks rainfall and that during good rainfall seasons, animal performance and numbers improve (Hardy 1996; Behnke & Scoones 1993). Animal numbers and performance therefore decline dramatically during times of drought. The consequences impact severely on the livelihoods of communal graziers.

The validity of carrying capacity as a management concept is based on the premise that range productivity is dependent upon stocking rate. It implies heavy grazing promotes degradation and reducing the stocking rate leads to range improvements. According to Bartel, Perrier & Norton (1993), the great variability in rainfall, can overshadow the influence of herbivory on the range resource. Thus range productivity becomes more a function of climate than of stocking rate. Another point is that communal farmers apply their own carrying capacity in a sense that as forage resources decline under increasing grazing pressure, they tend to move their herd to more favourable areas. This is the basis of rational drought-survival strategy (Bartel *et al.* 1993). The points above involve two notions of carrying capacity; ecological and economic carrying capacity.

The two notions brought to light an understanding of the definitions of carrying capacity in communal areas. It is known for a fact that as the animal populations increases, the edible plant biomass declines. In an undisturbed grazing system, the increase in animal numbers will eventually be checked by the declining availability of natural forage. This occurs when the rate of forage production equals the rate of its consumption by animals, and the livestock numbers ceases to grow (Behnke & Scoones 1993; Grossman *et al.* 1999). This point of equilibrium is termed ecological carrying capacity. It is widely stated that communal rangeland are maintained at ecological carrying capacity. The reason is that livestock in rural areas are kept at a maximum, but are not in good condition, neither is the veld in good condition. Tainton *et al.* (1999) stated that communal farmers revolve around maintaining livestock numbers rather than around the marketing of livestock and hence maximizing animal mass. The off take therefore is the form of products such as milk, draught power and dung rather than the physical off take of animals. Livestock numbers are therefore regulated mainly by the fecundity rates and the availability of forage. The system of cattle management in communal rangeland is termed the maintenance level (Tainton *et al.* 1999; Hardy 1996).

In the past, policy makers and range scientists believed the main problem to livestock development in communal areas was over-accumulation of stock (Abel 1993). It was assumed by lowering livestock density, the productivity of individual animals would increase (as such is the case for commercial farmers). The idea was that individual productivity will compensate for the reduced number of animals, and that the reduction in density will conserve rangeland (Abel 1993). This point of maximum sustained yield with an increase in productivity lies below the ecological carrying capacity whereby only few cattle are kept with maximal off-take and financial gains. This was termed economic carrying capacity. The notion goes against the rural farming due to reasons indicated above. Rural farmers harvest animal output in the form of live-animal products and off-take of these producers does not require animal slaughter (Behnke & Scoones 1993).

2.5. The potential of agroforestry in communal grazing management

A major constraint to successful livestock rearing in the summer rainfall areas of southern Africa is the shortage of fodder available to livestock during winter. During summer months grass is plentiful, nutritious and palatable (Ngwa *et al.* 2000; Trytsman & Mappledoram 2003). When the very same grasses reach maturity, their nutrient value declines, and become unpalatable to cattle. Tropical grasses in particular are different from grasses in temperate regions as their growth pattern is influenced by high temperature, high solar radiation and periodical drought stress (Roothaert 2000; Bisschop 1994). A physiological implication is a higher cell wall related fibre content and less plasma related cell content. The grass in these regions matures rapidly accompanied by a higher content of structural elements such as fibre. The grass dies back and becomes fibrous and unpalatable. Its nutrient value, especially protein content becomes very low (Roothaert 2000; Hardy *et al.*1999).

To overcome this unproductive season, commercial farmers alleviate winter fodder shortage through rotational resting systems. Additionally some of the grass is cut and used as hay feed, supplemented by crops such as Lucerne and protein rich licks containing urea and molasses are purchased for additional nutrient supplementation. Such practices in rural areas are very rare, mostly because the purchasing of additional supplements is beyond the means of the rural poor. Rural farmers therefore depend on maize stover as winter feed. (Trytsman & Mappledoram 2003; Bennet *et al.* 2003).

A wide variety of options is available to range managers to overcome feed deficits during winter. Kirkman (2003) indicated some options include ameliorating soil fertility, modifying species composition by including more productive grasses or legumes, establishing forage trees, incorporating crop residues where available, replacing rangeland with cultivated pastures or low input strategies such as humid grassland and to improve quality. Everson *et al.* (1998) and Bisschop (1994) emphasised that the cost effective option available to rural farmers is planting of fodder trees in agroforestry systems. Cattle which depend mostly on grass can switch their pattern to leaves and twigs of woody plants. Trees and shrubs stay green longer than grass in times of drought, probably due to their deeper root system which can tap water and nutrients beyond the reach of the grassroots (Roothaert 2000; Everson *et al.* 1998). Many trees and shrubs provide high nutritive value with crude protein content ranging from 10-30% of dry matter (Roothaert 2000).

The use of supplements during dry season was questioned by Kirkman (2003) particularly their timing of use to range management. The emphasis of his debate was on the impact feed supplement has on exacerbating rangeland degradation. The argument is mostly on stocking rate in that the amount of forage produced from alternative sources for use during the dry season has a profound effect on the number of animals that can be carried on rangeland (Kirkman 2003). During a defined growth season of eight months for example, the forage produced has to support animals for 12 months in the absence of any alternative sources of feed, or has to carry animals for a short period if there is a source of alternative feed. Consequently where alternative dry season feed is available, stocking rates on the rangeland tend to be heavier during the growing season. Kirkman (2003) argues that graziers do not use much of the improved quality during the wet season when livestock generally have the greatest demand for quality feed (lactating females, young growing animals) but conserve it for dry use. Lactating cows require bulk of forage and the provision of quality feed during winter to maintain animal condition led to a destruction of early growth. Kirkman (2003) concluded by stating that most management interventions aimed at overcoming these deficits are developed by those interested in sustaining animals and not by those interested in conservation of rangelands. Provision of alternate sources of feed usually only benefit the animals and not the vegetation. A detailed review of the debate and its implications on the promotion of the use of agroforestry in rural areas will be explored in this thesis.

2.5.1. Indigenous and exotic fodder species.

Most research in South Africa for intensive use of fodder has been carried out on exotic species, neglecting indigenous ones. Maliehe (1991) stated that the use of indigenous species should be encouraged, particularly if suitable to the preferred site for implementation. Some of the advantages of the indigenous species over exotic species are that they are well adapted to the local environment, farmers know them, they are locally available and planting materials are abundant. Roothaert (2000) raised the point of involving farmers in the process of species selection. This is essential as they are the potential end-users of new technology and their knowledge and skills are critical. An example of an indigenous South African tree species is *Acacia tortilis*, a drought resistance species that can be established under extremely arid condition. In comparison with exotic species most are water loving species that dies easily under stress conditions (Roothaert 2000).

The establishment of fodder trees to address forage shortages led scientists to draw up characteristics of trees suitable for planting. Among the important characteristics for selecting suitable species for the fodder supplement production are the ability to yield more in a short period of time, drought resistance, establish over a range of different site types, resistance to common soil and plant pests, easy propagation methods and the ability to produce large quantities of palatable material of sufficient nutritional value, especially protein content (Bisschop 1994; Maliehe 1991; Roothaert 2000).

Looking at these characteristics one can draw the conclusion that most cannot be met by the growing pattern of indigenous trees. For example, there are wide varieties of *Acacia* species in South Africa which are leguminous and highly palatable (Bisschop 1994). For instance, *A. karroo* occurs naturally over a wide range of climate with rainfall distribution ranging from summer maximum, through evenly distributed to winter maximum (Barnes *et al.* 1996). The main disadvantages are that they grow slowly and discourage cattle from browsing due to thorns. Another indigenous shrub, *Atriplex* species, produces fodder high in protein; it requires little water and is well adapted to highly salty soil conditions (Bisschop 1994). However yields from this plant can only be realised after a long period of time.

Some disadvantages of exotic trees are their susceptibility to pest attacks. For instance, *L. leucocephala* becomes unproductive due to infestation with the psyllid *Heteropsylla Cubana* (Roothaert 2000). Roothaert (2000) mentioned most cannot withstand frequent pruning, for instance *Sesbania sesban* and *Gliricidia sepium* has a low acceptability to livestock. Though they may have shown disadvantages, exotic trees such as *L. leucocephala, Sesbania* species, and *Calliandra* species have been widely used due to their high nutritional yield over a short period of time (Roothaert 2000; Maclaurin 1982).

Leucaena leucocephala is an exotic fast growing species that yield extraordinary quantities of wood and forage within remarkably short time spans. This species has been widely adopted all over the world, providing the bulk of feed in some farming systems (Morris 2002). A 100% diet can produce poor results, with animals not gaining weight. Poor planned diet can result in an enlarged thyroid gland, reduction in fertility, loss of hair and even abortion. However mixed diets with grass can be beneficial to ruminants (Morris 2002; Ngwa, Nsahlai & Bonsi 2000).

Local species are well adapted to the climate and have evolved surviving strategies during periodic adverse climatic conditions. For instance *A. karroo*, thrives from a minimal rainfall of 200 mm to over 1500 mm, and can withstand low temperatures of 12° C and up to maximum daily temperatures of 40° C (Teague 1989; Barnes *et al.* 1996). If they are affected by pests at all, there should be natural predators of these pests as well, as is the case of *L. leucocephala* in

South America. Natural predators do not control the pest but reduce damage to significant levels (Roothaert 2000).

South African legislation encourages the planting of indigenous trees for multi purpose uses. The legislation prohibits the planting of many exotic species many of which are advantageous for use in agroforestry. A multi-departmental initiative led by the Departments of Water Affairs and Forestry (DWAF), Environmental Affairs and Tourism (DEAT), and Agriculture (NDA) developed the National Working for Water Project aimed at restoring productive potential of land and enhancing water security by eradicating exotic trees (Working for Water Project 2000). The Government has declared 198 exotic plants in three restricted categories. In addition to eradicating weeds, the project is also aimed at alleviating poverty through a job creation programme.

Mulberry (*Morua alba*) has been declared as Category 3 invader: Invader plants that may no longer be planted due to its nature of growing wildly particularly if unmanaged. The planting of *M. alba* is only allowed with special permission from the Department of Water Affairs and Forestry. *Leucaena leucocephala* has been categorised as Category 1 in the Western Cape only: Invader plants must be removed and destroyed immediately and Category 2 for the rest of South Africa except Western Cape: Invader plants may be grown under controlled conditions only. (Working for Water Project 2000). This implies careful consideration of promoting these species for use in rural land is very essential. Everson & Underwood (2003) stated the legislation poses a problem in the temperate regions of the Drakensberg, where there are no suitable, fast growing indigenous species for fodder and fuel wood. The CSIR has been interacting with DWAF during the planting of these trees and controlled measures were guaranteed to ensure they are not becoming uncontrollable invaders. The DWAF officials were often invited to trials to observe progress and positive effects of these invader plants.

In conclusion, indigenous multi purpose trees need to be evaluated not only those that are common locally but those that are less well known. The most important factor in all cases is to make the best choice for the farmer and for the site. Involvement of the farmer in selecting suitable trees is therefore strongly recommended. Findings from this project justified the need of promoting selected alien plants for inclusion in aroforestry. This trial was labour intensive to ensure that plants on the invader list are well controlled as recommended by DWAF.

2.5.2. Alley cropping

Alley cropping is an agroforestry practice in which trees or shrubs are grown simultaneously with an arable crop (Palm 1995). The trees, managed as hedgerows are grown in wide rows and the crop is planted in the interspaces between the tree rows. Some of the advantages of alley cropping include: improved total yield in comparison with sole crop yields; more efficient utilization of resources (light, water, nutrients); less rapid spread of diseases and insect pests; insurance against crop failure; supply of a range of products without much investment in storage and reduction in soil erosion and exposure of the soil to solar radiation (Palm 1995; Everson *et al.* 1998; Nair 1993).

Disadvantages of alley cropping include attraction of birds and crop pests which can damage crops; competition with crops for water and nutrients is almost inevitable even if well planned. It is important to plant trees with deeper roots than those of the crops grown alongside. Alley cropping requires considerable labour and management and results will be poor if planting and pruning schedules are not carried out properly (Everson & Underwood 2002).

Kang (1988) has demonstrated the long-term yield sustainability of alley cropping in trials conducted over 10 years in southern Nigeria. The maize yields in the *L. leucocephala* alley cropping trial were maintained at an average of 3210 kg ha^{-1} while in unfertilised control plots yield fell to 1632 kg ha^{-1}. Everson *et al.* (2003) recorded high yield of maize from alley cropping when compared to control plots with no trees at their agroforestry trial. It was recorded *A. karroo* had the highest maize yield of 6500kg ha^{-1} and *L. leucocephala* had 6000kg ha^{-1}. They concluded that this may be attributed to the nitrogen fixing properties of these two species. Tree spacing did not have a significant effect on maize yield.

Table 2.2. Maize production from legume and non-legume trees in alley cropping (Kang 1988).

Woody hedgerows	N yield from pruning	N uptake by maize (kg ha^{-1})	Maize grain yield (kg ha^{-1})
No trees		26.2	1632
Non-legumes			
Acioa batenii	24.5	12.6	2588
Alchorrea cordifolia	62.0	18.7	2557
Legumes			
Gliricidia sepium	127.8	42.4	3349
Leucaena leucocephala	231.1	41.9	3210

Legume plots resulted in more maize grain yield than plots of non-legume trees. The N contribution from pruning of these two species is estimated at about 40 kg ha^{-1} to the associated maize crop (Kang 1988). The most limiting factor to alley cropping is competition between crops and trees for light, nutrients and moisture. Competition for resources could be eliminated with proper design of cropping and intervening management options such as frequent pruning. Judicious pruning of the tree species during the cropping phase can largely eliminate competition for light.

It was noted in times of water stress alley cropping may yield disappointing results. Everson *et al.* (2001) recorded a decreased maize yield from all treatments when compared to previous years and was due to dry period occurred in the area. For example, maize yield of the control in 2000 decreased from 3099 kg ha-1 to 3000 kg ha-1 in 2001.

2.5.2.1. Feed degradability

Voluntary intake of roughages in ruminants is affected by the rate at which digestion occurs. In subsistence farming, crop residues assume great importance in ameliorating the feed deficit. Most stovers are fed to animals *in situ* but some farmers harvest and store these residues to feed to their animals later in the year (Nsahlai *et al.* 2000). The most limiting factor to animal performance fed on crop residues is dietary protein.

Table 2.3: Chemical composition of maize stover and *Leucaena* hay (Kabatange & Shayo 1991)

Feed %	DM	Ash	N	NDF	OM	CP	ph	IVOMD
Maize stover	91.9	7.9	0.38	73.3	89.7	10.6	3.71	67.4
Leucaena hay	90.7	16.8	2.22	33.5				

The lower nutritive values of maize stover justify the need for alternative protein fodder supply to ruminants during the dry season when they are in the crop fields. Kabatange and Shayo (1991) reported a positive effect on the degradation of maize stover in all diets supplemented with *L. leucocephala* foliage. The rate of digestion in ruminants during the dry season implies more energy consumption resulting in better animal performance during winter season. The use of quality fodder trees is therefore encouraged.

CHAPTER 3: Study Area

3.1. Okhombe Ward

3.1.1. Location

The Okhombe ward is located in the KwaZulu-Natal province of South Africa in the Bergville district (28° 30′ 27″ S and 29° 00′ 23″ E).

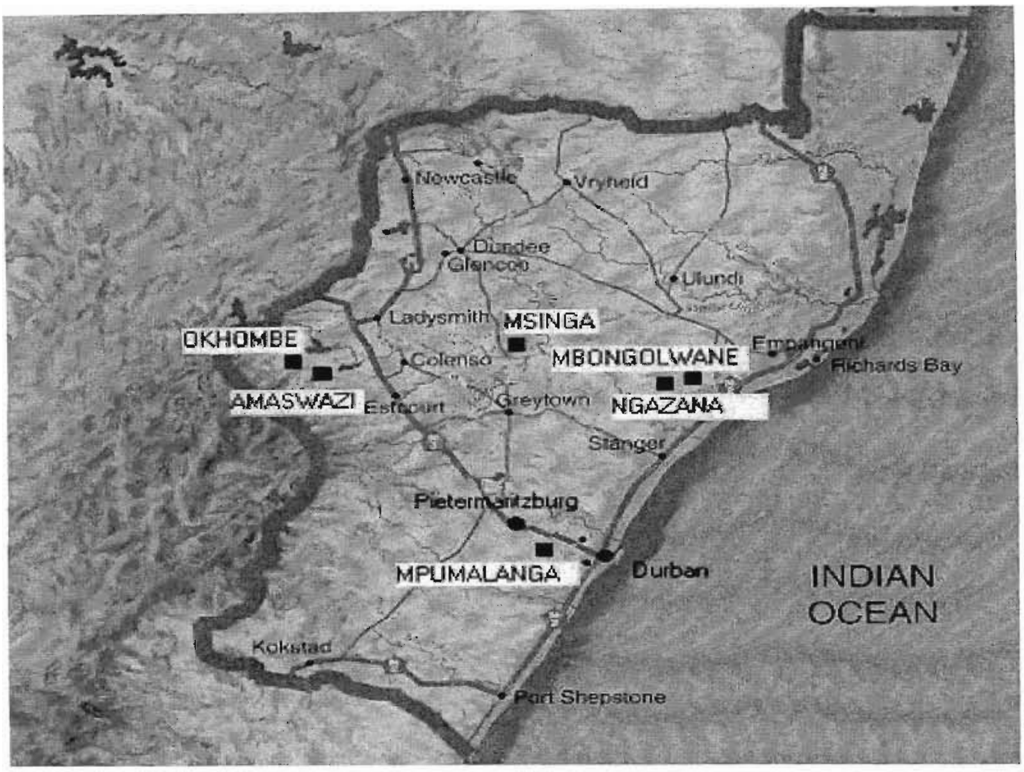


Figure 3.1. Locality of Okhombe ward shown from KwaZulu-Natal map (Farmer Support Group 2000).

The ward is under the Amazizi Tribal Authority of the Upper Thukela, and comprises six subwards, namely, Mpameni, Mahlabathini, Ngubhela, Oqolweni, Sgodiphola and Enhlanokhombe. Okhombe is situated in the foothills of the KwaZulu-Natal Drakensberg mountains between the Royal Natal and the Cathedral Peak National Parks. The Drakensberg mountains in KwaZulu-Natal form a continuous crescent-shaped escarpment situated between 160 and 240 km inland of the east coast of South Africa varying in altitude between 1380 m and 3350 m a.m.s.l (Everson 1996). The mountains create a natural boundary between the province of KwaZulu-Natal (South Africa) and Lesotho (between latitudes 28° 30' S and 30° 30' S, and longitudes 28° 30' E and 29° 30' E).

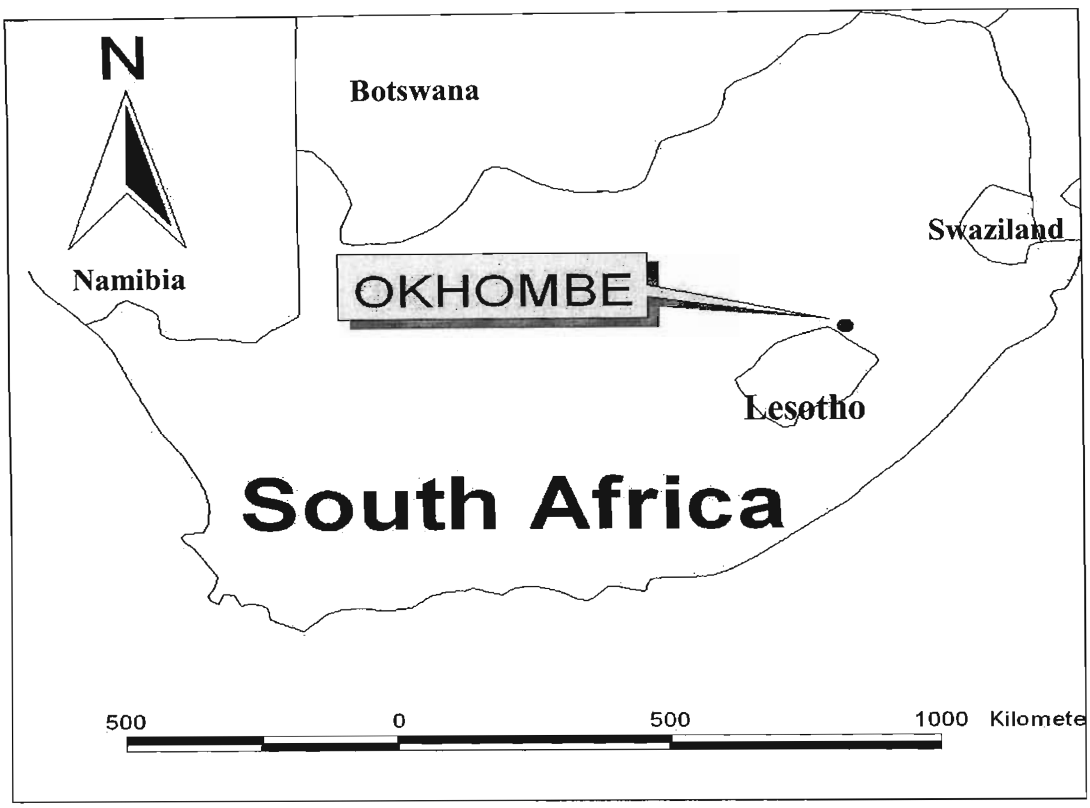


Figure 3.2. Locality of Okhombe ward situated near Lesotho.

3.1.2. Topography

The mountain range of the Drakensberg is part of the Eastern escarpment of Southern Africa, reaching heights of 4000 m (Montusi 2002; Dollar & Goudy (1999). The Drakensberg mountains were formed during the continental uplifting that took place during the late Pliocene. During the Pliocene period, the KwaZulu-Natal province used to be covered with up to 1000 m thick layers of lava from lava flows some 160 million years ago, which provides a protective capping for the underlying soft sandstone layers (Montusi 2002). When this mass solidified, the heavy granite stone pressed onto the layers of sandstone beneath. Due to the high relief and associated steep gradients down to the Indian Ocean, significant erosion occurred. Alluvial streams and rivers deposited rubble at the base of the escarpments and carried away finer materials. Through millions of years of constant erosion by wind and water the valleys and gorges have worked their way through the basalt and then the more erodible layers (Montusi 2002; Dollar & Goudy (1999).

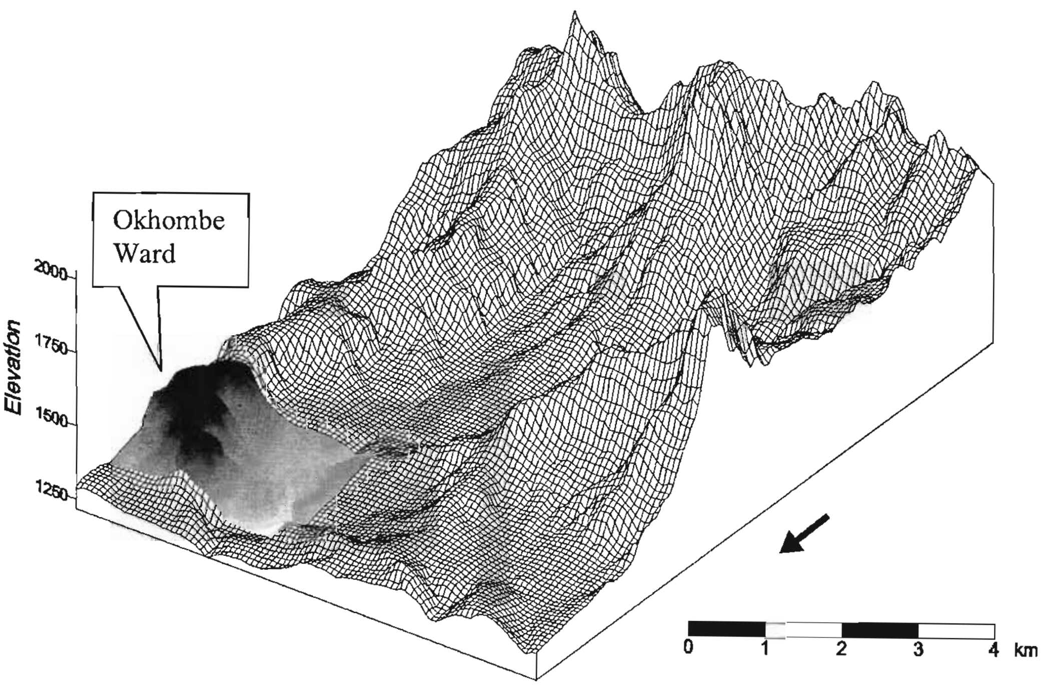


Figure 3.3. Location of Okhombe Ward along the escarpment (Sonneveld 2002)

Erosion of major eastward-flowing drainage channels resulted in the formation of the basaltic lava cliffs of the main range (1800 m and 2500 m a.s.l) and a broken plateau lying below. This plateau is known as the Little Berg and the study site is situated at the foothills of this Little Berg (Everson 1996). The Little Berg is characterised by deep ravines and swift flowing streams and ends abruptly in conspicuous Clarens sandstone cliffs. The spurs are capped with basalt and at the heads of these spurs lies the catchments that feed the main rivers. Most of the Okhombe area is steep and mountainous with the flat land characterising the upper plateau. The ward extends from an altitude of about 1200 m in the valley to over 1800 m in the hills (von Maltitz 1998). A number of streams and the Okhombe river cut through the area and flow into the Thukela River.

3.1.3. Geology

The main geology of the study site consists of rock types belonging to the Karoo Supergroup of Permian, Triassic and even Jurassic age. This Karoo system occupies about half the area of South Africa and almost 9/10th of the Thukela Basin. Table 2.1 below shows the subdivision of the Karoo into subgroups according to the specific lithology.

Table 3.1: Generalised Stratigraphy for Okhombe (Beckendahl 1996; Verster 1998)

Super group	Group	Formation	Lithology	Period	Appr. Yrs (mil)
Karroo	Drakensberg		Basalt	Jurassic	180
	Stormberg	Clarens	Yellow to pale-red, fine grained sandstone	Upper Triassic	200
		Elliot	Red and purple mudstone; interbedded yellow to grey siltstone; fine to medium-grained sandstone	Upper Triassic	215
		Molteno	Medium to coarse-grained glittering sandstone; gritstone; subordinate green and red mudstone; carbonaceous shale	Middle Triassic	235
	Beaufort	Tarkastad	Fine to medium-grained sandstone; red, green and blue mudstone	Lower Triassic	250
		Adelaide	Grey mudstone; dark grey shale (carbonaceous in places); siltstone' sandstone	Permian	
	Ecca	Volksrust	Blue-grey to dark grey shale	Permian	280
		Vryheid	Medium to coarse grained sandstone; micaceous shale, coal	Permian	

Sonneveld (2004) observed that moving into Okhombe from the north, there are formations of Adelaide, Tarkastad, Molteno, Ecca and Clarens. The plateau consists of sandstone of the Tarkastad formation whereas the lower area consists of shales and sandstones of the Adelaide formation. In the lowest part, dolerite of Jurassic age is present. The Karoo Supergroup basically represents a depositional sequence during a time of progressive aridification (Beckendahl 1996).

3.1.4. Soil

The predominant parent materials in the study area are basalt in the low areas, and shales, sandstone and mudstone prevail on slopes and plateaux (Natal Parks Board 1997). The base is formed by fine sandstone and shale and above this lies the coarse blue/grey sandstone found in the ledges and terraces at the foot of the Little Berg. Fine red or purple shales form the steep slopes below the sandstone cliffs, which are soft, fine and a cream colour where the San lived (Natal Parks Board 1997). Soils on the Little Berg were classified as Lateritic Red and Yellow Earths (Jones 2001). They are of residual and colluvial origin and derived from basalt. Characteristically they are acidic, highly leached and structure-less. Jones (2001) stated that commonly found soils are Griffin and Hutton (Oxisol), Clovelly (Alfisol), Mispah and Glenrosa (Ebtisol/Inceptisol) on slopes and plateaux.

Table 3.2. Soils in the Okhombe catchment adapted from Jones (2001)

South African Classification	Closest USDA classification	Description of features	Location in the Okhombe catchment
Mispah	Entisol/Enceptisol	Brown orthic topsoil over hard rock	Trampled and denudated north facing slope at 1390 m
Glenrosa	Entisol/Enceptisol	More weathered Mispah –B horizon containing more than 80% rock fragments	Trampled and denudated north facing slopes at 1390 and 1500 m
Clovelly	Alfisol	Orthic A over yellow brown apedal B	Plateaux at 1480 m, dense grass vegetation
Griffin	Oxisol	Brown, orthic A horizon over a yellow brown apedal B1 horizon over a red apedal B2 horizon	Plateaux at 1480 m and north facing slope at 1430 m. Soils near cattle paths
Hutton	Alfisol/Oxisol	Brown A horizon over red apedal B	North facing slopes at 1500 and 1570 m

The Glenrosa and Mispah soils are weakly developed mineral soils on bedrock with no B horizon and low productivity (Jones (2001). These soils are exposed to soil erosion as a result of trampling, denudation and relatively steep slopes. The Clovelly soils are alfisol types, which form in cool to hot humid areas. Their location on plateaux with low slope gradients and dense vegetation indicates higher production capacity and lower susceptibility to soil erosion. The Griffin and Hutton soils are oxisol or alfisol. They are generally highly weathered deep mineral soils, several meters deep, with a genetic A horizon formed *in situ.* The red apedal B horizon is characterised by a generally uniform red colour and the lack of well formed aggregates. The apedal B horizon is highly erodible because of the weak structure and the predominance of the weak kaolinit (Soil Classification Working Group 1991).

3.1.5. Climate

The KwaZulu-Natal Drakensberg lies in the summer rainfall area of South Africa. Okhombe ward is located between 1200 m to 1800 m altitude and this higher altitude and the proximity to the Drakensberg results in cool dry winters and warm wet summers. Mean annual rainfall ranges from a minimum of 800 mm to 1265 mm per year with the higher altitude receiving more rainfall and below 800 mm during dry years (Camp 1999). Okhombe has a sub-humid climate.

The summer rains from October until March make up to 82% of the total rainfall per year (Dollar & Goudy (1999). Although it receives high rainfall, Okhombe does suffer from drought periods that affect mostly domestic animals. The area also experiences hail and thunderstorms. The high amount of precipitation that occurs in the summer period has led to significant leaching of the major soils in the area and heavy erosion along the slopes. Approximate rainfall distributions are shown in Figure 3.5.

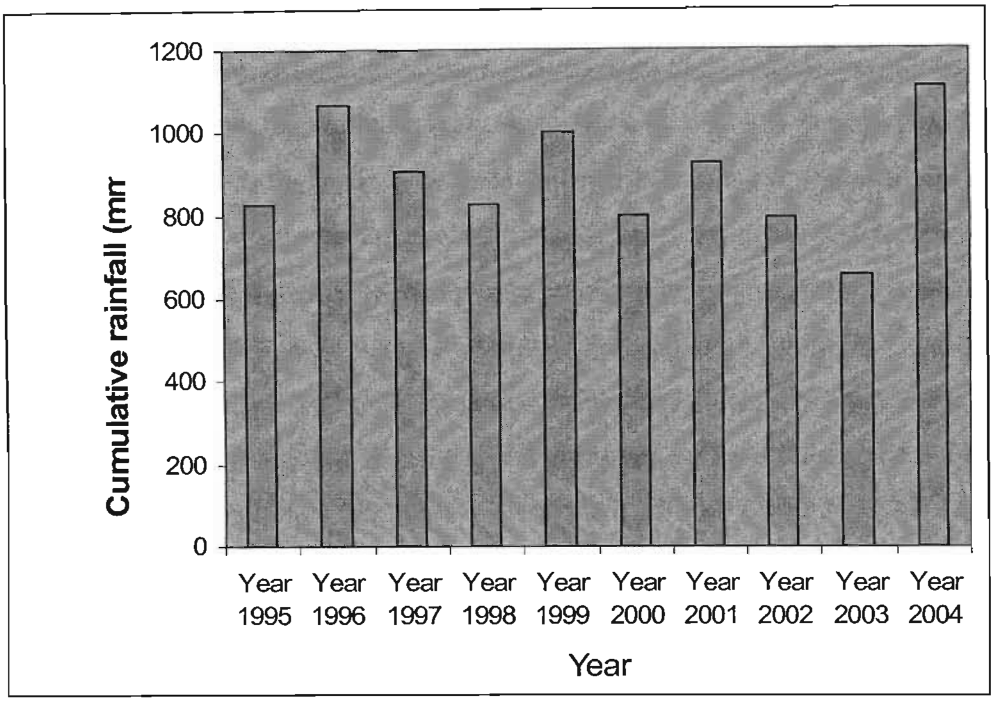


Figure 3.4. Cumulative rainfall distribution from 1995 to 2004 (Sonneveld 2002; CSIR 2005).

Temperatures in the area vary substantially with a change in season from moderate summers to cool winters. High temperatures are experienced mostly from November to February with May to July experiencing very low temperatures. The mean temperatures are between 11.5° C and 16°C (Camp 1999). Frost occurs in the Drakensberg from late April to early September, but is almost a daily occurrence in winter (June and July). Although snow falls often at higher elevations, the Okhombe ward seldom receives snow.

According to Everson (1996) wind is an important climatic variable in the Drakensberg because it is prevalent during the dry season when fire hazard is at a maximum. From March to May the frequency of east and south-east winds decreases and the frequency of westerly winds increases. In winter (June-August) the prevailing direction is westerly and the south-east winds decrease to less than half their summer frequency. Between September to November south-east winds increase in frequency again, the west and north-west decrease and the frequency of calm falls below 20%. Berg winds are a characteristic feature of the Drakensberg occurring in late winter and early spring (Killick 1963). The Fohne or Berg winds which blow from the west during late winter and spring often attain great velocity. Strong winds occasionally accompany thunderstorms. According to Killick (1963) these rarely last for length of time.

3.1.6. Vegetation

The Drakensberg region is extensively covered by grassland with some patches of forests, shrubs and tree species. The vegetation is influenced by the burning regime and altitude and is termed fire climax grassveld (Tainton 1999). In these areas the grassland community is secondary, and has arisen largely due to the restraining influence of fire. These fire climax grasslands are often interspersed with patches of forest or clumps of bushes (Tainton 1999). The climax plant communities of the Drakensberg are associated with three distinct altitudinal zones (Killick 1963). These zones are the river valleys (1250-1800 m), the Little Berg (1800 – 2500 m) and the summit plateau (2500 – 3350 m). The corresponding vegetation belts of these zones are: the Montane Belt, the Subalpine Belt and the Alpine Belt.

The study site is situated between 1200 – 1800 m a.s.l. falls into the Montane Belt. The vegetation as classified by Acocks (1953) falls under the Highland Sourveld (Veld type 44a) or Moist Highland Sourveld, KwaZulu-Natal Bioresource Groups 8 (Camp 1999).

The Montane Belt extends from the valley floors to the lowermost basalt cliffs at the edge of the Little Berg. The greater part of the belt is occupied by tussock grass species, chiefly *Themeda triandra*, but also *Hyparrhenia* species, *Miscanthidium and Cymbopogon* species and other common species are *Tristachya leucothrix, Trachipogon spicatus, Eragrostis* species, *Digitaria* species, *Diheteropogon* species, *Panicum* species, *Monocymbium ceresiiforme, Harpochloa falx, Hyparrhenia hirta*, *Cymbopogon validus*, *Alloteropsis semialata* and *Miscanthus capense* (Killick 1963). Species of Protea are scattered through the grassland to form Protea Savanna (Killick 1963). As mentioned earlier, fire plays a crucial role in determining the structure of the vegetation in the Bioresource groups. Where fire is totally excluded from the system, shrubs and bushes begin to make an appearance, particularly in the cooler moister areas (Camp 1999; Killick 1963).

3.2. Ukulinga Research Farm

The agroforestry trial was implemented at the Ukulinga research farm situated in the interior midlands of the province of KwaZulu-Natal. The site is in the South-Eastern direction seven kilometres South-East of the University of KwaZulu-Natal, outside Pietermaritzburg, located at 30°24′ S and 29° 24′ E.

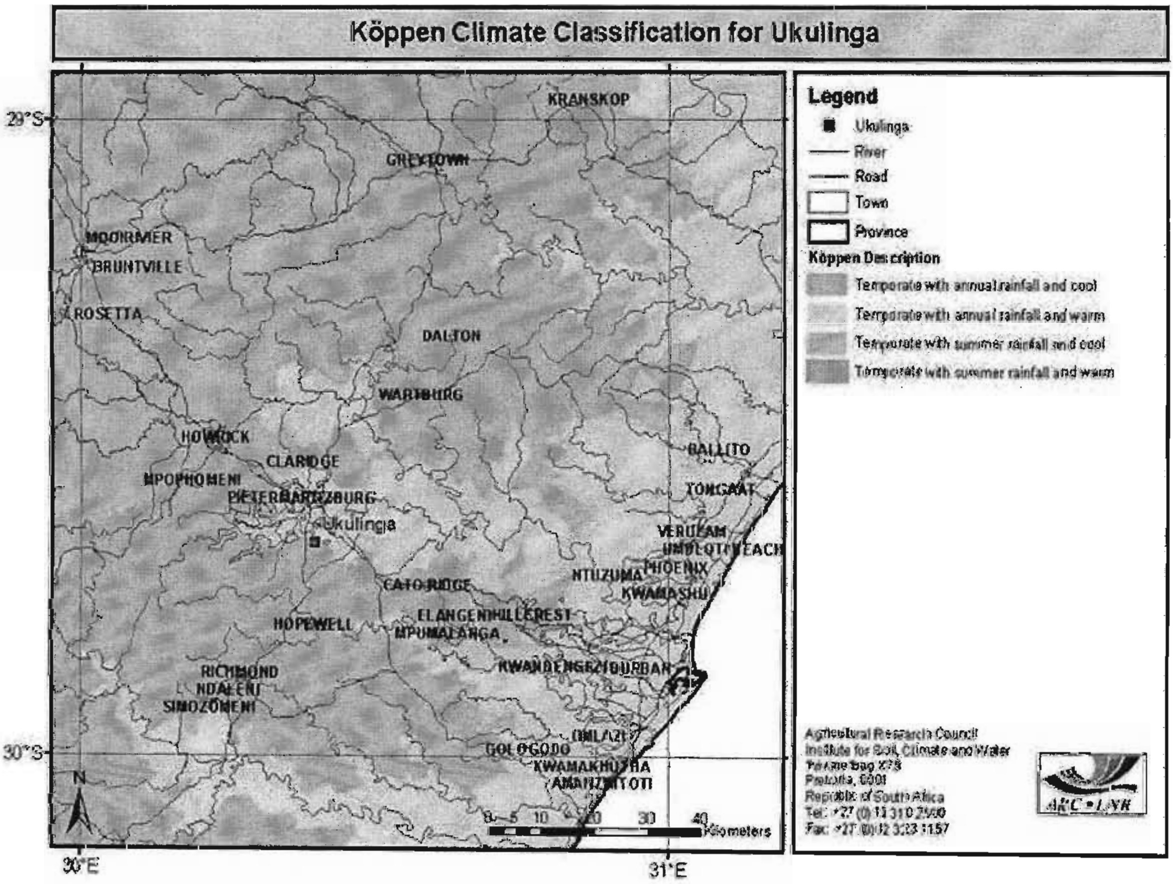


Figure 3.5. Locality of Ukulinga research farm situated near Pietermaritzburg (Agricultural Research Council 2005).

Summer rainfall is expected from September to April and varies in intensity from light showers to thunderstorms (Klug 1989). The long term mean annual rainfall is 735mm and droughts do occur. The altitude is 715 m a.s.l (Klug 1989). Occasional drought periods occur during the summer, frosts are moderate to severe, and hail storms are experienced (Morris 1999). Highest mean daily temperatures are normally experienced in February during summer, and lowest mean daily temperatures in June-July. Summers are warm to hot with a mean monthly maximum of 26.4 °C in February and winters mild with occasional frost and a mean monthly minimum of 8.8 °C in July. Mean annual maximum and minimum temperatures are 25.7 °C and 8.9 °C respectively (Morris 1999).

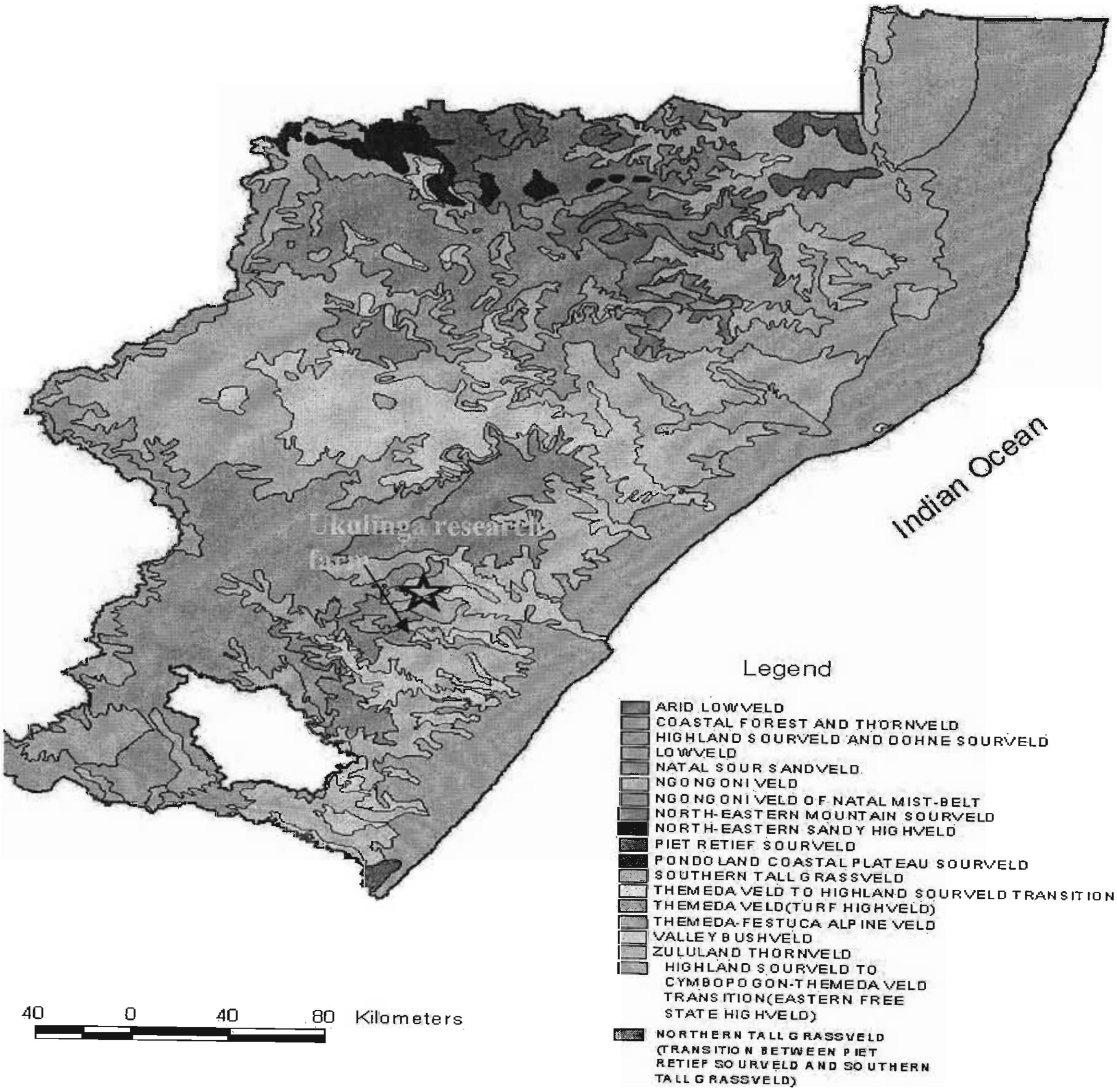


Figure 3.6. Map of the distribution of the Southern Tall Grassveld in KwaZulu-Natal (Acocks veld type 65, 1988).

The vegetation of the area has been classified as Southern Tall Grassveld, Group 65 (Acocks 1953) and is described by Camp (1999) as Moist Tall Grassveld (Bioclimatic Group 6a). It is dense grassland (0.5-0.75 m tall) with scattered trees of *Acacia sieberiana* and dominated by grass species such as *Themeda triandra*, *Heteropogon contortus* and *Tristachya leucothrix* and other common species are *Eragrostis racemosa*, *Cymbopogon validus* and *Cymbopogon excavatus* (Acocks 1988). On dolerite hillsides *Acacia caffra* woodlands and thickets occur. *Acacia karroo* is found occasionally on dolerite hills and along watercourses. According to Camp (1999) while bush encroachment in the form of *Acacia* species is limited to a few isolated areas, the alien weed *Lantana camara* is a problem plant.

Camp (1999) described the vegetation in general as short to tall, often with tall *Acacia sieberana* trees scattered throughout. Fire has also played a major role in maintaining the area as grassland, in the absence of which, it would initially become dominated by *Acacia* species such as *Acacia nilotica, A. karroo* and scrub forest species. Grazing also plays a role, and it is the interacting effects of fire and grazing that maintain the Moist Tall Grassveld as grassland suited to extensive livestock production (Camp 1999). The soil of the area is a Westleigh form, having a dark grey-brown clay-loam Orthic A horizon overlying a soft Plinthilc B horizon (Morris 1999).

CHAPTER 4: Participatory Approaches in Grazing Management

4.1. Introduction

The issue of overgrazing in rural areas has resulted in many State interventions, most of which have proved ineffective. In the past, the Government has tried to enforce State planning, which excluded community members because their knowledge of farming practices was believed to be inferior and unsustainable leading to depletion and ultimate ruin of communal areas (Mpofu 1990). In order to address the top-down approach of past interventions, a participatory project in Okhombe ward was initiated in 1999 as part of the national LandCare project, funded by the Department of Agriculture.

4.1.1. Australia's LandCare project

The LandCare project is an Australian approach to effective natural resource management which has been adopted by South Africa's National Department of Agriculture and adapted to South African conditions. Beale & Fray (1990) stated that by 1990 more than half of Australia's 7.6 million square kilometres were in need of soil conservation treatment and about 1.5 million square kilometres were badly damaged by agriculture. Land degradation due to vegetation loss, soil erosion, desertification, salinity and acidification affected over half of Australia's land area. Legislation to deal with land degradation was established in the early 80's but received much criticism as it treated natural resources management in a top-down manner (Lino-Grima & Berkes 1989).

The LandCare program was developed to change approaches to resource management, more particularly in controlling rapid land degradation in Australia. LandCare became a national initiative established in 1988. It was a Government-sponsored, community-based farmer led movement to reverse land degradation in Australia and to introduce information about sustainable land use to land users (Roberts & Coutts 1997). Its role was to educate the community to act on land issues and its concept of sustainability was centred on community responsibility. Integrated groups involved in LandCare were its citizen, schoolteachers and pupils, farmers, conservationists, Government extension officers and other land users. The approach of the project resulted in the rapid growth of a natural resource management programme in Australia. By 1990 there were more than 600 LandCare community groups and by 1997 the projects grew to more than 2000 countrywide (Roberts & Coutts 1997). Key activities of the programme were awareness and training (e.g. organising field days and workshops), resource inventory (mapping degraded areas and surveying fauna and vegetation), planning (developing local and catchment plans), trials and demonstrations, establishment of perennial pastures, soil conservation works, water re-use, protecting wildlife habitats and wetland management (National LandCare Program 1995).

The accomplishments of the LandCare program in Australia led to the adoption of the approach by South Africa's National Department of Agriculture in 1997, as an innovative approach for promoting sustainable land resource management. The program was adopted on the basis that the responsibility for managing natural resources should rest directly with those impacting on their resources (Department of Agriculture 1999). The first pilot LandCare project in KwaZulu-Natal was initiated in Okhombe to implement resource management projects that focused on rehabilitation of degraded areas, grazing management, improved food security and income generation initiatives through environmental management. This study focused on the development of grazing management strategies with the community.

4.2. Project objectives

- To develop and strengthen local institutional structures pertaining to communal grazing management in Okhombe.
- To develop an appropriate grazing management plan with the Okhombe community.

4.3. PRA exercises

The service providers held a series of participatory workshops with the community in an effort to better understand community resource use patterns, needs, constraints and opportunities as part of the participatory approach. Details of the workshops are summarised below, extracted from reports by the Farmer Support Group (1999), von Maltitz (1999) and Everson (2000).

4.3.1. Mapping

Social mapping was used to determine the number of households in each subward and the number of livestock in each household. The exercise was done by community members on a large flat area on the ground and coloured powders were used to depict the homesteads, main boundaries and streams, while goat droppings were used to depict the number of cattle.

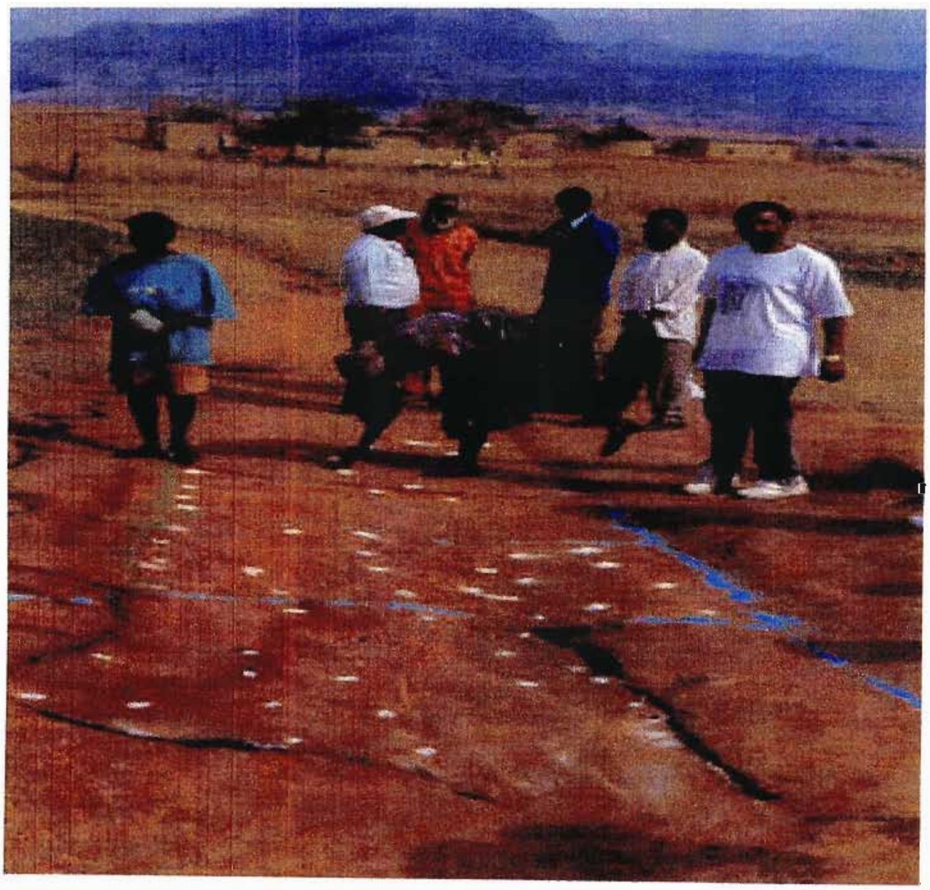


Plate 1: Mapping exercise (Everson 2000)

The map was copied on a paper sheet for future reference (Farmer Support Group 1999; Everson 2000). Land use maps was also drawn on the ground using coloured powders and objects to depict different land uses (e.g. sticks to indicate grazing areas, blue powder to indicate water). Resources that were mapped included location of households of participants each giving their names, location of grazing areas, fences, cropping fields, vegetable gardens, trees, springs, water pumps and dams. The map was copied on a paper. The techniques encouraged active participation and debate among community members when attempting to demarcate resource areas. The advantage of this technique was that everyone was able to relate drawn features to their land and reach agreement on allocation of land use areas (Farmer Support Group 1999; Everson 2000).

4.3.2. Historical analyses

In timelines or time trends a chronology is made of major events and activities in the area over as long as can be recalled by local informants. The time trends recorded from Mpameni subward are presented in Table 1.1.

Table 4.1. Time trend of Mpameni ward (Everson 2000)

Year/s	Important Occurrence
1960	Forced removals from the upper slopes to the present valley, loss of land for residential and farming, shift away from woodland and water resources
1967/68	Destruction of the betterment fence, high cattle theft
1971	Concerted community effort to repair fence, more crop destruction by cattle
Early 70's	Late rains, late planting, Poor crop and fodder yield, Stock losses
1978	High increase in stock death, outbreak of tick borne diseases (sore ears in calves, Red water fever)

1978/ 79	Devastating drought, poor crop production, and stock losses.
Early 80's	Overpopulation due to immigration of those evicted from white farms, increased number of cattle, overcrowding of dipping tank, lack of control of dipping patterns, outbreak of tick borne diseases, crop destruction on the increase around dip tank.
Late 80's	Increase in the number of school going children, lack of herders, uncontrolled stock resulting in an increase in crop damage.
Early 90's	Increase in the number of cars in the community.
Present	More cars, big gullies, shortage of winter fodder, dry perennial streams

In Okhombe, the key informants of this technique were elderly people, who have used the resources in the area at least seasonally for several decades. The time trend activity was made in a plenary session to involve the whole community in a discussion of the history of the area, listing significant events and trends through time. Various significant events were mentioned and recorded on a flip chart, with their approximate dates. The trend was used to show history of cattle management, heavy droughts, crop yields, and state of roads. The technique is important in identifying development trends, and showing how major events (from traditional practices to introduction of schools and planned roads) have changed over time to help local people analyse what happened in their lives and why (Waters-Bayer & Bayer 1994).

4.3.3. Catchment modelling exercise

The exercise aimed at developing a holistic picture of the catchment with the community to identify problems and address solutions. The model was done by digging a soil wall to represent the 'Little Berg' plateau. Community members then participated by adding houses, the betterment fence, springs, streams, and gullies in the ward. Degraded cattle routes, and eroded slopes were built into the model.

Plate 2: Catchment modelling exercise (Everson 2000)

Analysis of the model with the community identified soil erosion problems occurring along the slopes and cattle paths following heavy rainfall. This contributed to a common understanding of catchment hydrology in relation to current land use (Everson 2000; Everson & Koelle 1998).

4.3.4. Transect walk

This technique involves systematically travelling (usually walking) with local people through the area they use, and observing, asking and listening. Particularly important are the informal discussions along the transect, both with the local people accompanying the team and with people met along the way (Waters-Bayer & Bayer 1994). The technique was undertaken in Okhombe to identify problems, opportunities and solutions to degradation in the catchment. The community walked through the catchment with the team members showing various eroded gullies, the position and condition of the old 'Betterment' boundary fence and the severely eroded cattle access routes which had been identified on the catchment model. Sheet and rill erosion were also identified along the transect. The emphasis was on direct observations and discussing what was observed. This gave an important indication of the problems with cattle management, particularly in relation to cattle movement, shortage of grazing and dipping (von Maltitz 1998; Everson 2000; Everson & Koelle 1998).

4.3.5. Venn diagram

This technique is open to individuals, households or groups and can be done with separate ages, genders and ethnic groups. The purpose of the method is to investigate local perceptions of the relative importance of the different institutions and the relationships between them, to discern the interdependency of various organisations. This is useful for delivery and maintenance of facilities and services as it can identify weak or lacking interactions where linkages need to be established or improved (Waters-Bayer & Bayer 1994). The technique was used to identify the functions and importance of the various institutions in Okhombe. Each institution was described in terms of the name of the institutions, policy developed and responsibilities, implications (both negative and positive), problems associated with the policy, potential problems of the absence of such policy and how could such problems be overcome with the help of the Ward Chief and Councillors (von Maltitz 1996). The findings of the institutional arrangements in Okhombe were presented under section 4.4.5.

4.3.6. Ranking matrix

This exercise was used to reveal differences in priorities of different social groups. Due to the increase in the number of female-headed households in the rural areas, women's role in the cattle industry is becoming more important. The technique was therefore used to understand women interactions with regard to cattle management. The ranking matrix by women in the Oqolweni subward of Okhombe is shown in Table 4.2. The highest rank (6) was allocated to the biggest problem and the smaller problem was allocated a rank of 1. In terms of household security, each rank implies the importance or value attached to each for addressing food security.

Table 4.2. A ranking matrix of women's issues in Oqolweni (Von Maltitz 1996)

Problem	Rank	Household security
Shortage of milk	1	5
Permission to sell cattle	2	5
Unable to trace stolen cattle	3	5
No money to buy medicines	4	3
No money to pay fines	5	4
Herding	6	2

The group identified the main problems as no herding of cattle, shortage of money to buy medicines for livestock, shortage of milk, no money to pay fines, no ability to trace stolen cattle, the need for permission to sell cattle. In terms of household security, women ranked shortage of milk among the most important problems due to its impact on food security. The involvement of women in cattle management was ranked high mostly on herding as this was no longer done by migrant workers and young boys now have to attend school. Inability to pay fines impacted mainly on relations with the Tribal Council and other members of the community. These kinds of rankings are important to understand the community needs and priority in managing cattle (von Maltitz 1996).

4.3.7. Visioning exercise

This was an open-ended discussion and drawing exercise to depict what the community would like Okhombe to look like in 5-years time. This was done through discussions in small homogenous groups, followed by feedback and plenary discussions. The main focus was on understanding of the LandCare project and the expected outcomes. The pictorial representation of the communities' vision reflected: People with enough grass to thatch their houses, improved soil for ploughing and cropping, palatable grasses for cattle, fence boundaries, gully rehabilitation, lush vegetable gardens and selling of outputs, women collecting water from the nearby springs throughout the year and women carrying plenty of firewood over only short distances. The exercise generated profound enthusiasm amongst the community members and resulted in a feeling of solidarity (Everson 2000; Farmer Support Group 1999; Everson & Koelle 1998).

4.4. Issues around communal grazing that emerged during PRA.

There are a number of issues that emerged during PRA exercises facilitated in all six subwards of Okhombe. There were a number of issues voiced by the community related to grazing management. These issues mentioned below were also emphasised during the initial planning of the grazing management in 2001 (Farmer Support Group 1999; von Maltitz 1999; Everson 2000).

4.4.1. Fencing

The community stressed the need for building fence boundaries to control cattle movement and the need to develop a formal grazing plan that would increase land productivity in the area. They stated that fences would assist in lessening stock theft in the upland, resting demarcated areas and preventing cattle from wandering off. Although the fence built by the 'Betterment' programme did prevent cattle from wandering off, the boundaries were marked by the state without community involvement. This resulted in reluctance by the community in maintaining the fence and ultimately the total destruction of the programme (von Maltitz 1999; Farmer Support Group 1999).

4.4.2. Fodder and water shortages

The timeline technique indicated a concern over fodder and water availability during the dry season. Most elderly people described times whereby there was plenty of fodder throughout the year and enough perennial streams in the area. The area is currently experiencing fodder and water shortages during winter, which is a major constraint to livestock productivity. Although cattle were rotated to the crop fields for access to maize stover after harvesting this was not enough to maintain condition and milk production (von Maltitz 1999; Farmer Support Group 1999).

4.4.3. Diseases

Dipping cattle was previously a compulsory process whereby all individuals took their cattle for dipping with vaccines provided by the state. The dipping was conducted twice a month at a single dip tank at the centre of the valley. The system of moving cattle to the dip tank was reported as one of the major causes of erosion. It also decreased crop yield as cattle damaged crops as they crossed the fields to the dipping tank. Following a decision by the Government to stop the provision of dips, the dipping process had largely collapsed and only individuals who could afford to buy their own dips used the dipping tank. Cattle owners reported major problems with cattle diseases and difficulty in sourcing veterinary supplies as the main constraints to production (Von Maltitz 1999; Farmer Support Group 1999).

4.4.4. Soil erosion

It was clearly observed and agreed upon during the transect walk that cattle routes were the major cause of soil erosion. Cattle in Okhombe were abundant and grazed in unconfined land. This uncontrolled cattle movement resulted in the development of cattle paths susceptible to erosion and damage to the vegetation cover on the slopes by trampling. On the steeper slopes distinct tracks have developed up the mountain side and some big gullies have developed down the fragile soil. This is mostly due to uncontrolled cattle movement without any effort to prevent erosion along the cattle access routes. Many of the slopes are left bare as a result. Not only are some of the steeper slopes of the grazing areas badly eroded but also the increased run off from these slopes often has fairly drastic effects down slope. Huge gullies (dongas) have formed which cut through fields and residential areas (Everson 2000).

4.4.5. Institutional structures

During the PRA process the community identified all existing institutional structures developed by the Okhombe community for serving their diverse needs and implementing regulations.

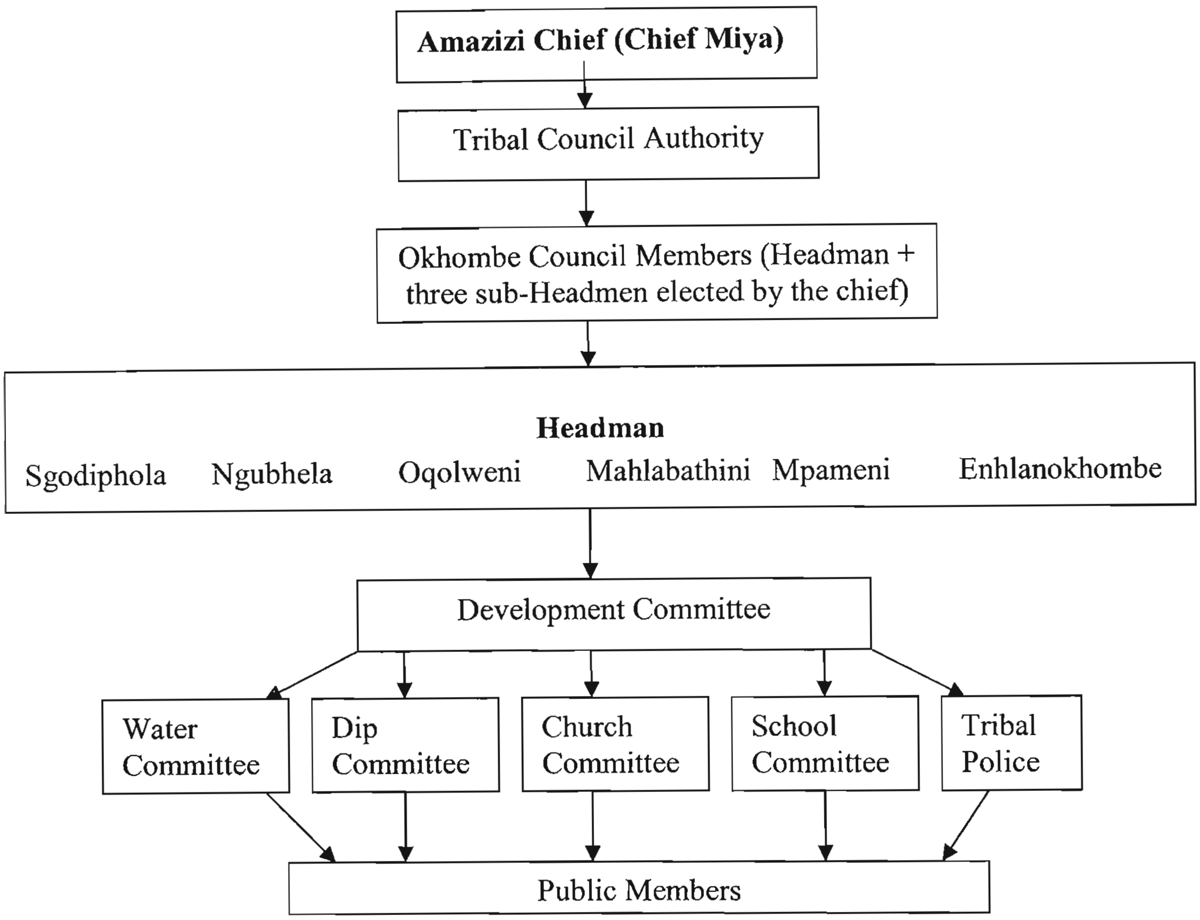


Figure 4.1. Institutional arrangements prior to the launch of the LandCare project

The institutions were recorded in hierarchical structure using a Venn diagram (Fig 4.1). Of all these institutions there is no specific structure that deals with grazing management, except the Dip committee that comprises volunteers who present the community's interest and needs to the agriculture department.

4.4.6. Women in cattle management

In Okhombe women's role in cattle management is becoming more and more important. Discussions during the ranking matrix revealed that cattle management is influenced to a large extent by lack of men in the area. The absence of men through the migrant labour system, and the unavailability of school-going boys have resulted in women increasingly becoming herders, owners and managers of cattle. It is therefore necessary that women kraal their cattle every night, because they do not have time to trace stolen cattle. Calves of the milking cows are kept in kraals everyday to keep their mothers near the homesteads. This results in increased erosion along cattle paths as cattle move up and down the slope in the morning and late in the afternoon (See Chapter 5: Cattle management practices).

4.5. Grazing plan workshops

It is essential in every participatory study involving the community to engage in capacity building before the kick-start of any development planning. This is part of empowering the community in decision-making. In Okhombe, the community attended training workshops facilitated by the State's Agriculture Department (DoA) and the University of KwaZulu-Natal. The DoA offered training workshops on land husbandry and land care. More awareness was raised on the relationships between soil erosion and cattle movement. Issues discussed with the community included the influence of topography on land cover and cattle access routes, different soil types and grazing pressure. Training workshops offered by the University of KZN were on veld management particularly on veld burning, overgrazing and selective grazing, veld rest and their effects on species composition. Field activities were also done to familiarise the community with desirable grasses and undesirable grasses, and options of eradicating the unpalatable species were discussed on site.

Ostrom (1992) suggested that communal management could be sustainable on common property if sufficient institutional structures are in place. Through grazing workshops held with the community, a Livestock Committee was established comprising of 12 members. The members selected were each representing the six subwards of Okhombe. The primary criteria of the selection were based on stock owners which are not migrant workers. With the institutional structure responsible for co-ordinating the grazing management project formed and capacity building gained during training workshops, the next phase of the project was to address grazing management with the community. The sustainability and maintenance of development projects rely on community involvement in decision-making in the initial phase of the project. It was therefore crucial for the LandCare project to involve and support the community in the planning stage of the grazing management project. This involved analytical workshops, feedback and planning meetings and brainstorming on ideas related to cattle movement and management (See section 4.4.1)

Analytical workshops are open-ended public discussions to explore issues and analyse problems jointly. The purpose of these workshops was mostly to analyse local problems and reach consensus about priorities for action. Feedback and planning meetings were used to review, analyse and evaluate consensus reached with the local people through public discussion and brainstorming. Contradictions and differing interests between subgroups were discussed in meetings to encourage wide participation. All people attended were asked to express their views on ideas that come up in the brainstorming session. For instance, camp planning was listed on the flip chart during brain storming and full community discussions were held on this.

4.5.1. Development of the grazing plan

At the initial phase of the grazing plan workshops, the CSIR produced satellite imagery of the Okhombe ward to enable people to relate to the area and discuss current grazing regimes. The Okhombe ward occupies 3024 ha of the Amazizi tribal area. There are no physical boundaries to prevent grazing of cattle across the subwards. The lack of physical boundaries also enabled cattle from neighbouring wards like Mnweni, Busingatha, Ogade and Amangwane to cross into the Amazizi tribal area. During the analytical workshop held with the entire community, the need for camp establishment was raised as a major priority of the grazing project. With low availability of grass in the area especially during the dry season, they agreed on a rotational grazing system whereby grasses would be allowed to regenerate after continuous grazing in the previous season. A total of four camps was proposed, two camps for the three subwards adjacent to the Amangwane tribal area and two camps for the other three subwards (Figure 4.2)

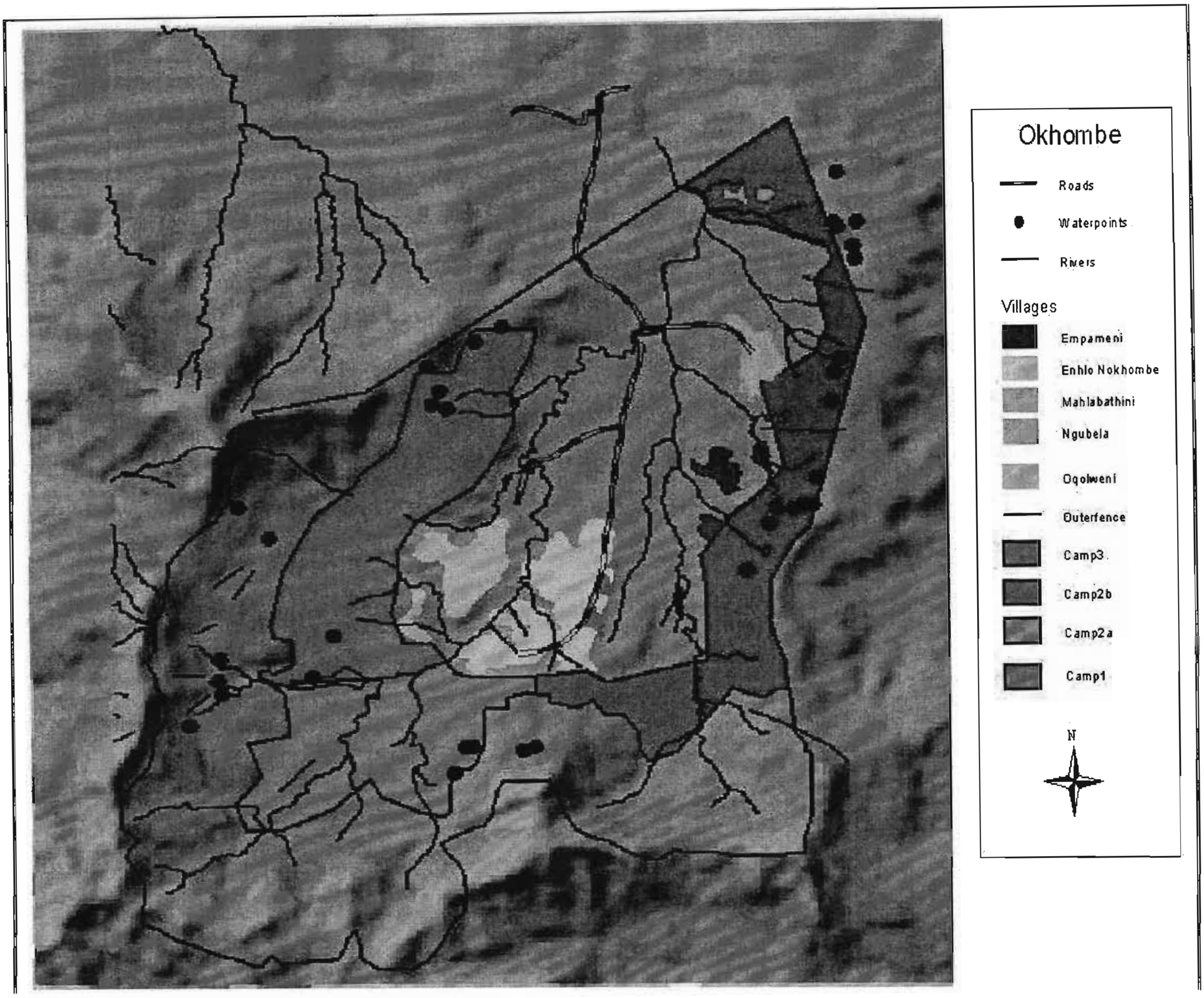


Figure 4.2. Two system cattle camp map

However, during the feedback sessions, the committee reported that the three subwards neighbouring the Amangwane tribal area rejected the proposed camp system. Livestock from these subwards used grazing and water resources in the Amangwane area. These subwards (Ngubhela, Mahlabathini and Mpameni) had the lowest rangeland (424 ha) and most of the land these subwards utilise for grazing is in the Amangwane area. The remaining area of the Okhombe land belongs to other three subwards (Enhlanokhombe, Sgodiphola and oQolweni).

These subwards have an additional 2600 ha of grazing land, a huge area of land that can be used for implementing the camp system.

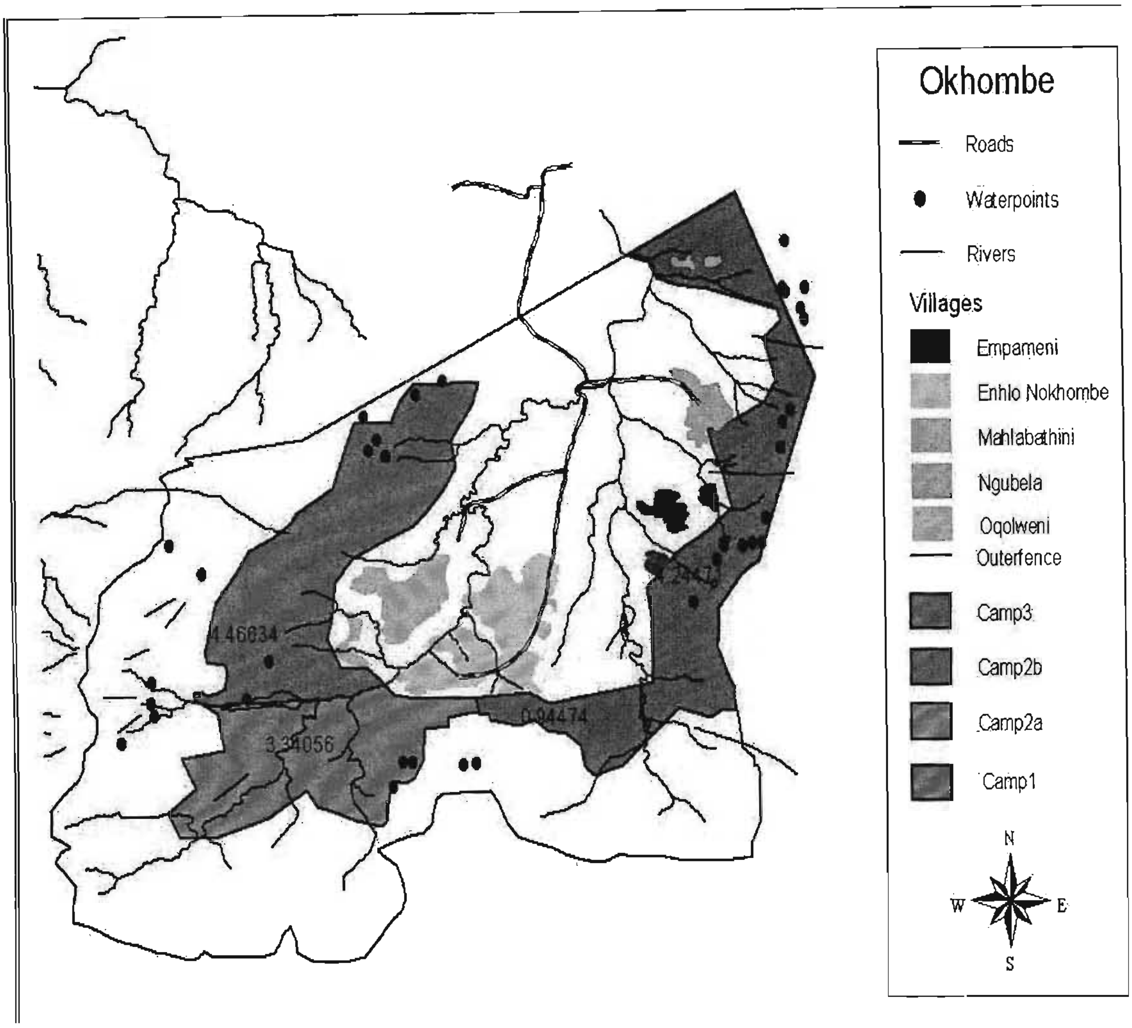


Figure 4.3 Camp sizes indicated in km².

A high percentage of the area in Ngubhela, Enhlanokhombe and Mpameni is characterised by steep slopes and lack of spring water. The flat plateau, with plenty of pastures and spring water, serves as the main grazing land for their cattle but belongs to the neighbouring Amangwane ward. If the boundary was formally demarcated with a physical fence, cattle would be cut off from available water resources and potential grazing. The three subwards (Ngubhela, Mahlabathini and Mpameni) therefore agreed to delay the implementation of a grazing plan until they could solve the problem of access to water and good grazing with the neighbouring community. This decision highlights the importance of involving communities in the management of their natural resources. The participatory approach used in this study prevented potential conflict between the two tribes. The Okhombe community agreed to proceed on developing the grazing plan with the other three subwards.

4.5.2. The Grazing plan: Sgodiphola, Oqolweni and Enhlanokhombe subwards

The cattle numbers in the area are very important when in the initial stages of developing the grazing plan. A destocking program was not considered in this plan as this goes against the reasons that the people keep livestock. Reasons for keeping stock were explained in details on Chapter 5. The Livestock committee recorded cattle numbers taken during dipping as part of the animal health program (Table 4.3).

Table 4.3: Livestock numbers in the Okhombe ward, KwaZulu-Natal (Provided by the Okhombe Livestock committee, 2002)

Sub-ward	**Bulls and Oxen**	**Cows**	**Total**
Ngubhela	25	83	108
Mahlabathini	50	118	168
Mpameni	54	72	126
Enhlanokhombe	249	354	603
Oqolweni	153	237	390
Sgodiphola	68	82	150
TOTAL	**599**	**946**	**1545**

The three subwards participating in the grazing plan occupy approximately 2600 ha of grazing land. Twelve workshops and public meetings were held with the communities from these subwards and the Livestock committee to develop the Okhombe grazing plan. An understanding of the response of grass plants to defoliation is essential for the planning of a grazing management system. In particular, knowledge of the effect of stem apex and leaf removal in different seasons, intensity of defoliation and effect of resting on plant growth is required to develop a sound management plan. A series of training workshops and field trips were held with the community to build capacity on the effects of defoliation by veld fires and selective grazing on fodder production. Field activities were held to examine the effect of selective grazing by cattle on grass species composition and basal cover.

Initially the community discussed the implementation of a 2-camp system in which livestock from the three adjacent subwards would graze in one camp while the other one was rested. When the grass in the grazed camp was approximately 10 cm high livestock would be moved to the next camp. However, through analytical workshops, the community agreed that their grazing plan would be ineffective in controlling cattle movement and allowing grass regeneration. Rotational grazing in a two camp system does not allow full regeneration of grass in the reserve camp for the next season. The community altered their grazing system to allow the subward, Enhlanokhombe to have its own camps due to more cattle in the area than the other two subwards combined.

The community then proposed having two camps for Enhlanokhombe and two for Oqolweni and Sgodiphola combined. The question was then which camp should be allocated for use during the dry season when there is critical shortage of grass? Through brainstorming whereby individuals came up with ideas, analysed them in a discussion and reached consensus, it was deemed necessary by the community to have a three camp system to allow resting of one camp for the entire year for use the following growing season. The community agreed on dividing their veld into an upper-region for non-milking cows and a bottom-region for milking cows. The idea was to have more utilization of the higher, flatter pastures to reduce cattle movement and subsequent soil erosion. To limit pressure on the lower lands, they agreed on putting up the upper boundary to keep non-milking cows in the higher pastures and the milking cows that required milking every morning nearer to homestead. The plan would also ease pressure on the routes as many cattle spend nights in the upper land of the area.

The grazing management system should incorporate periodic long-term rests as a means of compensating for vigour loss caused by grazing. According to Tainton & Danckwerts (1999), resting is probably the most critical element in any grazing management programme and deserves greater prominence than it has had in the past. It is stated that much of the unavoidable damage caused to plant vigour and survival during grazing can be mitigated by appropriate resting procedures. The effect of leaf removal on plant growth is dependent on whether the whole or only part of the leaf is removed, the stage of development of the leaf which is removed and the extent to which the leaf area of the plant as a whole is reduced. The apical meristem is usually situated at the base of the tiller while the meristematic regions in young leaves are also situated at their base. If veld is grazed continually without rest, plant vigour may be terminated as a result of the removal of the meristem base due to intense defoliation (Tainton & Danckwerts 1999).

The community therefore drew up a 6-camp system, with Enhlanokombe range being divided into three camps and the other two subwards into three camps. The Livestock committee held meetings with the whole community to discuss and reach consensus on the proposed six camp systems. A full community meeting was then held with the project team to discuss details of the plan. The Enhlanokhombe group and the Oqolweni-Sgodiphola group agreed that before final decisions were taken on camp utilisation, a resource inventory needed to be undertaken to assess the availability of water and grass in all the proposed camps.

In addition, it was necessary to mark out the major boundary for milking cows and non-milking cows and mark the internal camp boundaries. It was agreed that the use of a global positioning system (GPS) would assist in this task and provide data for future reference and production of maps by the CSIR. Following capacity building by the CSIR of volunteer community members and of the Livestock committee in the use of the GPS and the support of the service providers, an inventory covering 2600 ha was carried out. The inventory was used to map the resources available and produce maps indicating proposed camps (Figure 4.4.)

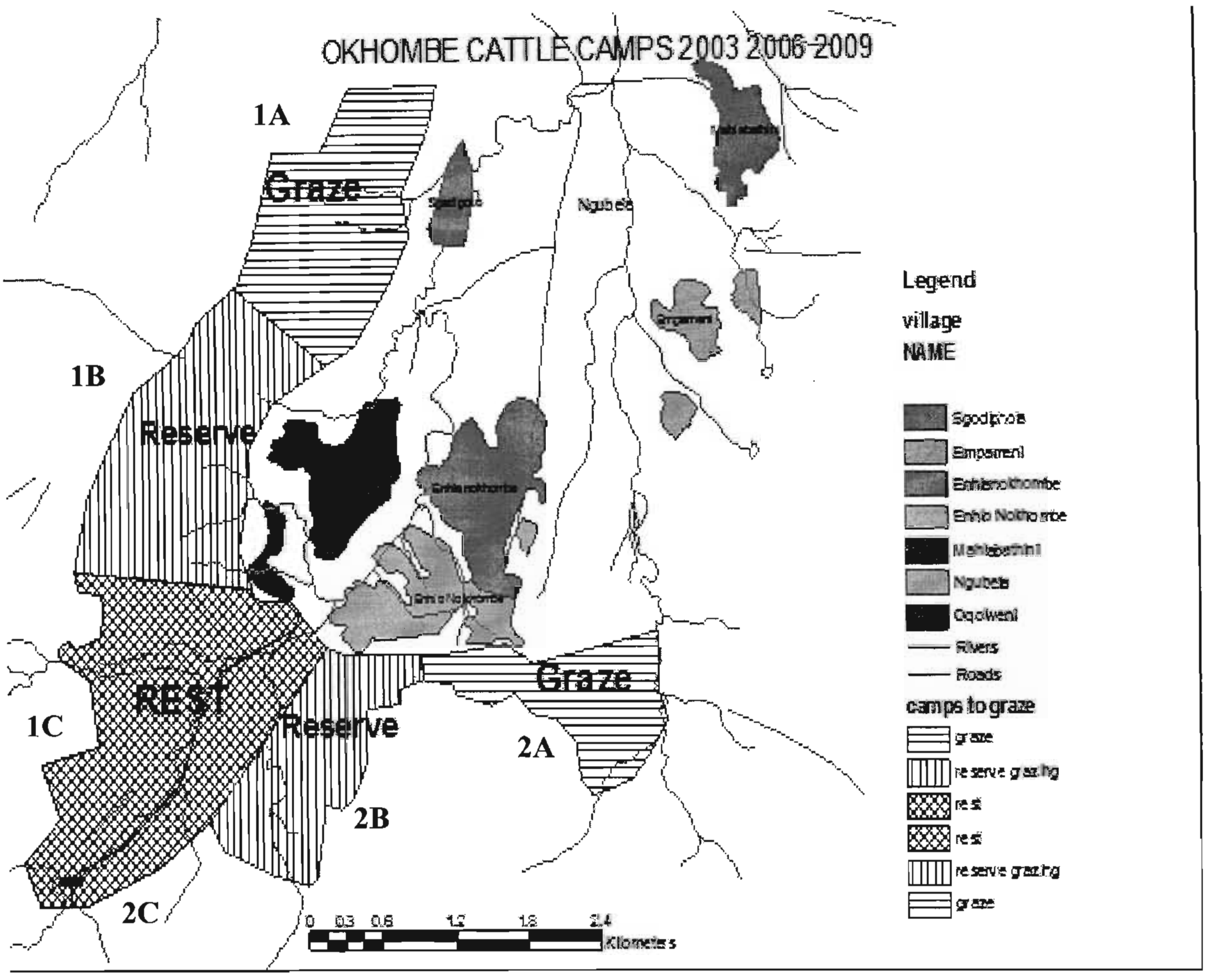


Figure 4.4 Proposed rotational grazing program.

To ensure the support of the Tribal Council, the committee presented the plan during Local Council meetings and gained approval and support for this pilot project in the region. The entire planning process took six months to accomplish. Once the allocation of camps was approved a number of workshops were held to decide on the management treatment of the camps. The three main management options are grazing, burning and resting. Kirkman (1999) stated that any grazing pressure (intensity and frequency) has both positive and negative effects on veld vigour depending on the grazing plan. It is through the judicious use of the veld that such detrimental effects can be lessened. Frequent leaf removal reduces the capacity of plants to produce tillers and reduces the size and depth of penetration of the root systems due to lack of carbohydrates reserve to stimulate new growth. Since the inflorescence of a grass plant develops directly from the apex of the stem, the effect of removing the apex is that of terminating stem growth and preventing flowering and seed production. Although negative effects may result from leaf and stem apex removal, this varies according to the preferred species. For instance, Kirkman (1995) recorded a reduction in the production of palatable grasses (e.g. *T. triandra*) varying from 50% to 60% as compared to that of the palatable grasses in the ungrazed control.

Loss of vigour of the preferred species means the vigour of unpalatable grasses would be stimulated as a result of reduced competition from the palatable grasses. Tainton and Danckwerts (1999) stated that much of the unavoidable damage caused to plant vigour and survival during grazing can be mitigated by appropriate resting procedures. A full season rest is the most preferred rest in which all the plant's physiological functions are allowed to proceed unhindered for a full growing season. Hence, rather than follow an early season rest period with grazing, the rest is continued to the end of the season and the veld is cleaned off in the following spring (Tainton and Danckwerts 1999). Rest promotes vigorous tillering, and an adequate supply of carbohydrates reserves. This rest should be followed by defoliation (burning and grazing) with the first rains in spring to stimulate the development of lateral daughter tillers from the base of the older tillers.

Controlled burning of sour grasses during the early spring is an accepted management practice in South Africa. The main objectives are to provide herbage free of dead material, to prevent or reduce continued patch grazing and to prevent loss of vigour of the desirable grasses caused by an excessive accumulation of dead herbage (Trollope 1999). It has generally been recommended that sour grassland burnt in spring, should not be grazed until it has grown to a mean height of 100 – 150 mm (Tainton 1999). The rationale is that grass growth in spring is initially made at the expense of non-structural carbohydrate reserves which will have accumulated late in the previous season. Defoliation after burning allows uniform grazing of the species sward and promotes non-selective grazing of grass species. Everson (1999) stated grasslands of the Natal Drakensberg are typically burned in a two-year cycle to maintain them in a vigorous condition. However the frequency of burning in sour grassland areas depends on the species composition.

After workshops on grassland management (rest, burn, and graze), the community were able to design their own management system (Table 4.4) showing a clear understanding of the grazing and burning management concept.

Table 4.4. Okhombe camp design (Refer to Figure 4.4)

Sgodiphola and Oqolweni Camps			**Enhlanokhombe Camps**		
Camp 1A	**Camp 1B**	**Camp 1C**	**Camp 2C**	**Camp 2B**	**Camp 2A**
Graze	Reserve	Rest	Rest	Reserve	Graze
Burn & graze first	Burn & graze second	Full season rest	Full season rest	Burn & graze second	Burn & graze first

The community agreed on putting up the physical boundary between both camp 1A-1B and 2A-2B, and between 1B-1C and 2B-2C and to use a natural boundary (Okhombe river) for camp 1C and 2C (Figure 4.4.). A full season rest followed by a burn treatment was allocated to two adjacent camps (1C-2C) so that burning could be implemented at the same time. The community then allocated two camps for burning and grazing treatments which would be grazed in the rotational resting system. They stated that this would assist with the practical aspects of burning as no firebreak would be required between the camps. The idea was that if burnt camps were not adjacent, there would be a problem with herding as livestock would move to the closest burnt area. The full grazing camp system is shown on Figure 4.4.

The plan indicates the importance of involving the community in the decision making process and development of the grazing plan. The community would be responsible for the maintenance of the system, and agreed on when to rotate cattle to another camp based on when the grass was short in the area.

4.5.2.1. Agreements on fence erection and labour.

Fencing of camps is generally labour intensive and requires high human input. The issue of labour was discussed during interactions with the community. It was agreed that due to the high number of people required on a voluntarily basis, the job of erecting the fence would be slow as a result. People becoming weak due to hunger was the other reason raised for not having the entire community volunteering. They decided to choose a score of strong men from the three subwards to assist in putting up the fence. The number of people required would depend on the workload and accessibility to the sites. The livestock committee would assist in appointing labour. It was also their responsibility to ensure the entire community, stock and non-stock owners contribute a small amount of money towards purchasing of lunch foods for effective manpower. They agreed on contributing R5.00 per household towards the labour fund. Details on strategies agreed to address fence theft are presented in Chapter 5. An agreement between the community, the Livestock committee and the LandCare partners was drawn up and signed by the *Inkosi*, to ensure commitment and responsibility of both parties towards a successful grazing management project. A copy of the agreement is shown in Appendix 1, page 196.

4.6. Institutional structures in the grazing management project

Previously in South Africa law enforcement occurred through tribal police or rangers appointed by the state, who patrolled the commonage, arresting and fining rule breakers. Monies accrued from fines were used to finance the needs of the tribal authorities. Consequently relationships between the local communities and the state were often uncooperative, with many of the practices, rules and regulations (for example, the regulation prohibiting the cutting of live wood without a permit, erection of fences limiting livestock movement) being perceived as unfair and unrealistic (Shackleton 1996).

Ostrom (1992) suggested that communal management could be sustainable on common property if sufficient institutional structures were in place. Cross, Luckin, Mzimela & Clark (1996) stated that until the last 20 to 30 years, chiefs and headmen exercised considerable control over the orderly use of natural resources, by fining people who abused the resource base. For instance, grass burning was socially organised, and people who set fires without permission could be fined. Livestock movements were controlled in terms of boundaries set in time and space by traditional leaders, with fines for offenders who allowed their stock to interfere with growing crops. These are some of the examples of developing local institutional structures to deal with social issues. The LandCare project therefore focused on building institutional structures governing resource areas. Through the PRA exercises held with the community a Livestock committee was established to oversee and co-ordinate the grazing management project and actively liaise with the Amazizi Tribal Council. The committee comprised of two representatives from each of the six subwards.

A major challenge for South African service providers is the question of how to ensure the sustainable and equitable management of local natural resources held under a common property regime, such that all community members' benefit and rural livelihoods are enhanced and sustained. Hatch (1996) and Cross *et al.* (1996) stated that under traditional communal tenure, property rights are conferred on individuals through Tribal law while tribal leaders legally hold the land in trust. Land may be allocated to individuals for residential or cropping purposes, although these rights may be revoked by the community, for example through non-use of the land. Cross *et al.* (1996) stated that weak governance structures that use a top-down approach make it difficult to gain institutional support for resource management attempts. The LandCare project therefore focussed on building institutional structures governing resource areas in Okhombe so that the community could take full 'ownership' of the project activities, and continue them into the future. The broader aim was for the community to assume full responsibilities for sensitive and appropriate management of their natural resources, particularly the land, and through this to improve their own quality of life. It was discovered during the PRA exercises that most of the rules imposed by the Tribal Council have long been degraded, and only few were respected. For instance, a rule no longer operational was if cattle were found grazing in land declared by the *Inkosi* as rested veld, they would be impounded and ultimately sold. Community members owing the Tribal Council fines were not allowed to participate in traditional community activities. If a community member was not satisfied with the punishment he was able to challenge the Council in Western Court.

In Okhombe, the Tribal Council is responsible for land allocation, registration, collection of land tax, impoundment of cattle found damaging crops, allocating associated penalties and compensation, and regular meetings to discuss policy issues and regulations. Traditionally one of the responsibilities of the chieftainship is the management of rangeland. However, currently almost no true control takes place on cattle management practices other than specifying the date when grazing animals must be moved from the upper rangelands to the fields during winter and from the field to the upper rangelands in spring following planting of crops.

Local people must have a dominant role in decision-making for managing their environment. Technical assistance from service providers and agricultural extension staff is also necessary to build their capability to make correct decisions. During this study the Livestock committee was established to build institutional capacity in grazing management. Through grazing workshops held with the community, the Livestock committee were able to co-ordinate activities involving the grazing management. The committee played an important role in building a strong relationship between the community, Tribal Council and outsiders in the promotion of natural resource management to the community.

The time trend analysis of Mpameni ward (section 3.4) indicated that in the early 80's herding became a problem as most herders were school children who now had to attend school. This lack of herders resulted in an increase in crop damage. The lack of a physical boundary separating the grazing land and the crop fields was another contributing factor. Von Maltitz (1998) stated that this led to a great deal of conflict between cattle owners and crop owners. Cattle found damaging crops were impounded and owners were fined approximately R50 per cow. When the LandCare project was initiated the community strongly motivated for fencing to separate the cropping and grazing land. Fencing material was then purchased with funds from the project. Selected community members attended a fencing training course and volunteered to put up the fence. A total of 22 km of fencing was erected between the cropland and grazing areas. The fence line closely followed the previous 'Betterment' fence line.

The community also attended a workshop organised by the Farmer Support Group on writing community proposals for development projects. The workshop was mainly on how to draw up budgets, estimate the duration of the projects and motivate for livelihood improvement and to acquire funds for further projects in Okhombe. After the workshop, the Livestock committee put in a funding proposal to Ezemvelo-KwaZulu-Natal Wildlife (formerly known as the Natal Parks Board) for purchasing fencing materials for the grazing management project. The KZN Wildlife is a nature conservation organisation that charges a levy to visitors of their nature reserves which is used to fund development projects in the neighbouring communities. The Livestock committee successfully obtained funds of approximately R50000.00 from the organisation. In a meeting between the Livestock committee and the community, they both agreed to use the money for defining the major boundary between Mnweni (Amangwane Tribal Area) and the Enhlanokhombe subward. The committee managed to organise volunteers from the community for putting up the fence. However, fence theft has been a major constraint in implementing the grazing management plan (Details in Chapter 5).

Another problem faced by livestock owners is poor animal health and low productivity; good animal health is among the priorities in cattle management. Some of the diseases recorded in the time trend analysis included tick borne diseases such as red water fever. To overcome poor animal health, the previous Government declared dipping cattle twice a month a compulsory activity (Von Maltitz 1998). There was a single dip tank at the centre of the valley and all cattle from the six subwards had to be dipped every two weeks. As discussed early on in this chapter, the single dip tank had negative effects on soil erodability and crops. Discussions were held with the community to address animal health in the area. It was agreed that more crush pens for treating livestock were required in the area and should be built in each subward.

Training was provided on animal health care by District Veterinarians from Ladysmith. More training was offered during a Farmers day organised by the University of KZN with the Grassland Society of Southern Africa. The workshop was mainly on options of medication (spray, dips), and most importantly the costs. Options were given on different techniques of maintaining good animal health using cheaper medicines purchased by groups instead of individuals. The Livestock committee organised volunteers to assist in building the crush pens and the whole program was facilitated by FSG. Sites for the crush pens where identified within the rangelands near homesteads. Five crushes were built in Ngubhela, Mahlabathini-Mpameni, Enhlanokhombe, Sgodiphola and Oqolweni. Cattle are currently sprayed on an individual basis and there is an ongoing effort to obtain vaccines from the Government. The community had recently obtained funding from the Department of Agriculture to rebuild the dipping tank and 15 people comprising of men and women were temporarily employed to complete the renewing of the dipping program. The community will continue using crush pens and cattle will only be taken to the dipping tank when necessary.

The Livestock committee is active and takes the initiative in resource management decisions without outsiders' assistance. For instance, the committee is active in keeping records of fence theft, stock theft, and animal numbers (Table 4.3) are some of the roles of the committee.

The LandCare project has gained huge popularity from the community due to its job creation scheme. There is an ongoing debate among funders, NGO's and the Government about the role of incentives in development projects. Some advocate that people need incentives because they are poor, while others are against incentives, for the reason that they make people dependent on help (Mollel & Mahlakoane 1998). An important role of institutional structures in every project is to develop a sense of ownership of the project among land users without cash in return. The ongoing efforts by the community and the Tribal Council in preventing fence theft show some responsibility and commitment of the community towards grazing management. After the LandCare's job creation budget was finished in October 2001, the Livestock committee continued to work with service providers and encouraged community participation and commitment without incentives. The committee is still interested in applying for further funding for improvement of their grazing plan.

4.7. Lessons learnt

The establishment of a communal grazing management system is not a one-day event but rather a slow, continuous process that needs considerable time to be implemented. In this project the establishment of the Livestock committee, the training of its members in grassland management, capacity building of members in project proposal writing, and the participatory process to involve the whole community to design the grazing plan took two years. While training was necessary for an understanding of the technical issues, considerable effort was spent on resolving social issues within the community.

It is important for service providers to serve as facilitators, help bring people together, stimulate discussions, encourage farmers to analyse their problems and provide advice when asked. However, they should leave the planning initiative with the land users themselves to develop their grazing plan. This ensures that farmers build their own confidence in the planning design. For instance, the rotational grazing and the separation of the milking cows from non-milking cows to encourage utilization of higher pastures confirm the confidence farmers had in optimal use of their land. It is therefore recommended that facilitators in community projects build the capacity of the community to make their own decisions. To become a successful facilitator, training in participatory management within communities must be offered to all service providers prior to their involvement in community projects

CHAPTER 5: Cattle Management Practices

5.1. Introduction

Traditional keeping of livestock plays a central role in the economic and social welfare of rural inhabitants throughout the Southern African region (Portillo, Weaver & Motsamai 1993). The ability of pastoralists to respond to commercialization and market-related forces is profoundly regulated by their own subsistence requirements and internal priorities like school fees for the children. By contrast in commercial farming the livestock sector is production based, commercially-oriented and centred on private land ownership. Livestock in rural areas provide meat, milk, hides, and skins for subsistence needs; they also provide draught power and transport in remote areas, they are used for ceremonial and traditional purposes; and the sale of livestock and livestock products generate a relied upon source of income (Portillo *et al.* 1993).

Hatch (1996) indicated that these reasons for holding stock in communal areas are likely to vary between regions and households. Soil and climate (which influence cropping potential and the demand for stock for draught power), distance from urban centres (which influences patterns in employment and the proportion of income generated in urban centres), markets (which influence off-take and purchasing), and the stage of development of the household (which would influence the demand for market goods) are some of the reasons for keeping stock.

Although livestock plays positive role in the livelihood of rural communities, communal farmers experience major constraints in their daily lives. Among the constraints are shortage of water, poor animal health service, shortage of fodder mostly during dry periods and understaffed extension services. According to Motsamai (1993), a major constraint faced by rural farmers is an inadequate marketing system. Despite traditional keeping of cattle, farmers are reluctant to sell cattle because prices of their cattle on the market are determined by outsiders and can decrease while butchers and commercial farmers maintain the same high selling prices. The management of rural cattle and grazing land has been seen by scientists as too informal to yield improved veld condition. This chapter therefore, reviews traditional keeping of cattle in Okhombe and the cattle management practices that have sustained communal livestock for years.

5.2. Role of cattle in Okhombe

Despite the apparently small cash contribution of livestock to the rural economy, cattle play an important role in the lives of people in KwaZulu-Natal. In the commercial sector, livestock are regarded primarily as a source of income, while their role in communal areas is largely non-commercial. Tapson (1993) found that cattle keeping in the former KwaZulu region were mainly for prestige and social exchange and secondarily for milk, draught and live sales. These are the reasons why rural farmers are reluctant to sell cattle (Hatch 1996). The livestock sector and the importance of livestock to households remain poorly understood. In the past, perceptions of cattle ownership under communal tenure was that cattle owners attach importance to simply holding stock, which holds that resource degradation is the invariable outcome of communal land tenure. As mentioned before, the 'Betterment' destocking program failed to achieve its goals of controlling land degradation mainly due to the fact that it did not take into account the reasons for holding stock in rural areas.

Cattle management in Okhombe is also largely for non-commercialization reasons. A survey from forty Okhombe stock owners indicated a variety of reasons for cattle keeping in Okhombe (Fig 5.1). The survey revealed that cattle kept for traditional purposes are of greater importance than commercial purposes (e.g. live sales, selling milk and slaughtering for meat). The use of cattle skins seemed to be low in Okhombe (6%). This may be due to the replacements of skins by blankets and clothes which happened overtime. Skins are not a source of income. Their prices are very low, ranging from R5.00 to R10.00 per hide and is determined by customers, mostly white farmers and Indians. Regarding other reasons of keeping stock, (ceremonies-12%, lobola-12%, ploughing-11%, milk-10%, live sales-7%, transport-7%, slaughtering-2%) the study revealed that accumulation of cattle in Okhombe is important for dowry when sons reach the stage of marriage and is an investment for unexpected functions such as funerals, weddings, and ancestral ceremonies.

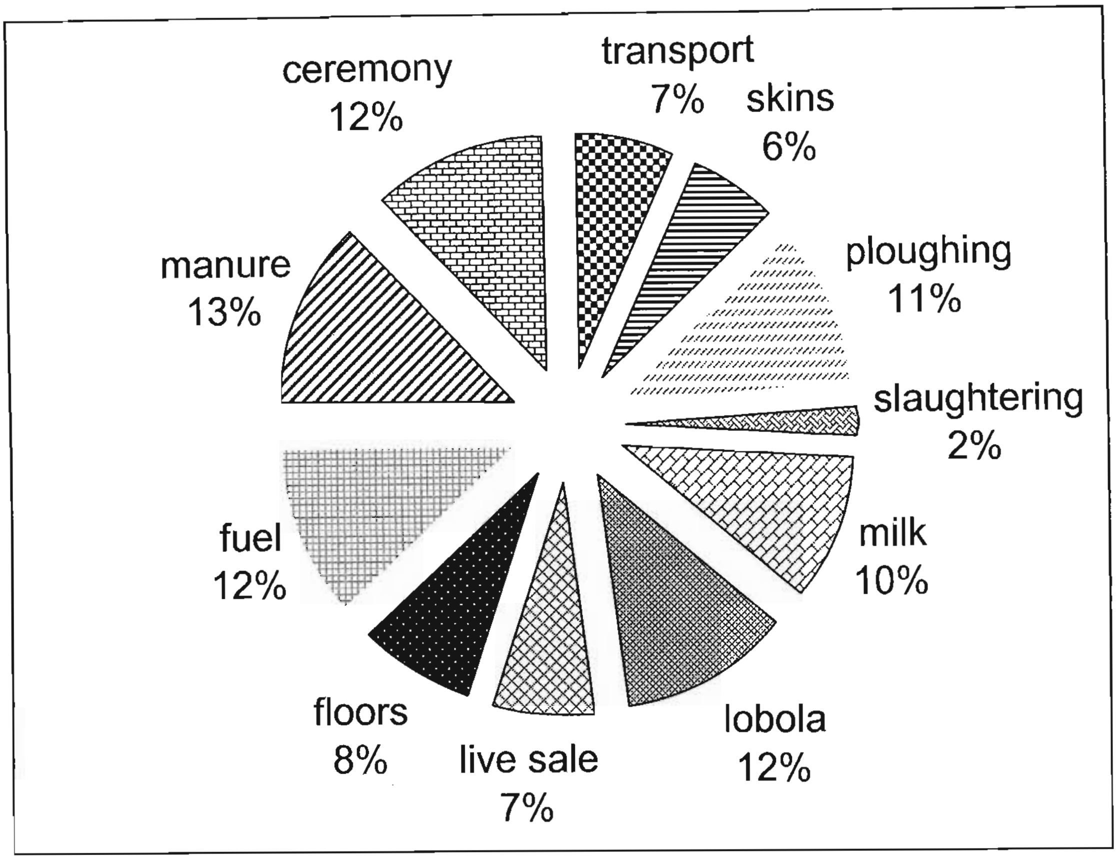


Figure 5.1. Reasons for keeping cattle in Okhombe

The multiple use of dung (manure-13%, fuel-12%, floors-8%) had high value (33%) in Okhombe when compared to Zimbabwe where it was rated as 7% (Danckwerts 1974). Although cattle dung can be collected free from the fields, people reported that owning cattle for dung was beneficial. It was stated that during the winter season when cattle dung is required for heating, the non-stock owners are at a disadvantage because they cannot collect enough from the field and have to request it from stockowners' kraals. With high costs of fire wood and fertilisers, the community prefers applying dung manure to improve soil fertility (the area is sourveld with highly leached acidic soil) and using dung as a fuel. Most of the huts in Okhombe are built of soil clay mixed with dung. To maintain the house and prevent cracking, the soil is mixed with dung (which serves as cement) for plastering and for floors. This is done mostly during summer to protect huts from heavy rainfalls. Cattle dung is also important in autumn and winter when it is collected for fuel in the cold weather. In spring, dung is collected for land preparations as manure.

Ploughing by cattle is considered important since no cost is involved. Ideally, farmers use a span of six to eight strong oxen as a draught power team. No cost is incurred as stock owners combine stock to assist each other. This saves money as tractor owners charge about R350 ha^{-1} to plough land. However, people felt it was more cost effective to pay a tractor owner to transport crops at a cost of R60 a trailer. People considered this more efficient than the use of cattle for transport. Non-stock owners provide labour to stockowners during ploughing as an in-kind payment for the use of cattle at their fields.

One of the constraints to cattle production is that Okhombe is situated in the sourveld region which is characterised by low quality fodder and fodder shortages in winter which tends to affect cattle breeding and milk yield. The 10% of people milking their cows reported low yield, with little for selling, and milk therefore has to be bought from the market. Most people do not milk due to low yields which are not enough for calves.

A direct live sale for cash income is regarded as a last resort for people short of money. People therefore argue that more cattle provide financial security as it may become necessary to sell an animal (e.g. to pay for school fees) and the more cattle you have the more security you have. Many farmers seemed to be afraid of having little stock due to constraints experienced every winter season (low fodder quality, fodder shortage, extreme weather). Abel (1993) and Tapson (1993) gave several reasons for the keeping of large numbers of cattle and people not co-operating in destocking plans in rural areas of southern Africa. One reason is security against drought in communal rangelands. It is rational for herd owners to enter a drought with as many animals as possible, because the chance of survival of at least some cattle is higher. Another reason is fear among those who already lack sufficient animals that a reduction in animal density may mean that fewer people can be supported. A third reason is that pastoralists frequently do not accept that their pastures are degraded. A fourth may be the typically inequitable distribution of livestock among pastoralists: for those who already have insufficient to reduce their livestock further would sink them into extreme poverty (Tapson (1993).

By having only a few cattle means that the probability of dying of all stock is high. Slaughtering for home consumption is rarely practised. Farmers responded that it is done under special circumstances such as when cattle are skeletal during the dry season, or badly affected by snow. Snow during winter has devastating impacts on cattle. Cattle have low energy, no quality forage for consumption and no shelter during periods of snow. Very thin cattle end up not recovering.

Unlike Okhombe, draught provision (44%) and milk (35%) were reported to be the major reason for keeping stock in Lesotho (Lawry 1986). This may be attributed to good grazing management practices influencing milk yield and increasing energy yields of oxen. In Zimbabwe, the value of output from cattle was accounted by 41% for ploughing, 32% by domestic consumption of milk and meat (not major value in Okhombe), 20% from the sale of stock and 7% from the value of manure (Danckwerts (1974). Tapson & Rose (1984) stated that in KwaZulu-Natal cattle are kept primarily for milk production while social exchange, draught and consumption are secondary reasons for keeping stock. As stated, some farmers in Okhombe are not milking their cows but rather rely on milk purchased from commercial farmers.

The use of stock varies per season. For instance, ploughing is done mostly during the months of November and December; crops are transported after harvest in May-June. Slaughtering depends on the cattle's condition which is usually lowest at the end of winter. The sale of skins is most likely at this time. Other activities like funerals are unexpected functions that may occur at any time, whereas an investment for paying dowry is a long-term activity that happens over a long time.

The conclusion from the Okhombe survey suggests that approaches to communal grazing plans must consider community cattle practices. Community participation in PRA exercises or any other form of collecting data is essential. This could be done through interviewing individuals or group discussions with farmers. The effect of ignoring traditional practices was apparent in the 'Betterment' programmes which failed in their destocking plans as they did not consider the reasons for traditional keeping of cattle.

5.4. Cattle management

The community largely controls cattle movement and grazing locations in Okhombe. To an extent grazing practices in the area are strongly influenced by the topographic division of the area into lowlands, hill slopes and the Little Berg plateaux. In winter, following harvest, the cattle graze on the cropping fields. The grazing system is related to the cropping cycle. During summer and the cropping season the cattle are moved on to the hill slopes and plateaux. All maize stalks are deemed to be part of the communal winter grazing resource. Seasonal rotation of cattle is the only prevalent grazing plan limiting the pressure on the veld during the dry season.

Traditionally household activities by women include fetching water, which is mostly done everyday and firewood. Other activities include meal preparation, planting, weeding and harvesting. Other activities, like washing, and plastering walls and floors are performed less frequently. Men's duties are aimed at generating income, while women undertake all other non-farm household activities (Ngqaleni & Makhura 1996). Oxen and bulls are required by men to graze near homesteads during the onset of summer to provide draught power. This results in a high grazing pressure on the steep hill slopes close to the homesteads. The plateau areas at higher altitude are less susceptible to erosion and receive less grazing pressure. The community planned to separate the milking cows from non-milking cattle and keep them close to the homesteads.

Section 4.4.6 (Chapter 4) outlined that women in Okhombe are increasingly involved in cattle management. Malijeng & Makhura (1996) supported the PRA findings that the role of women in agriculture has increased with labour migration which primarily involved men. In traditional Zulu culture women are not allowed to interact with cattle. They may not take certain decisions such as slaughtering in time of potential starvation; they may not sell in times of need, or administer treatment when the animal is sick. However, their involvement is mounting due to herders attending school and men working in towns. The burden of cattle management has largely fallen on them. As a result they consider the upland unsafe for cattle due to stock theft and long distances for herders after school hours. This has led to the kraaling of cattle every night and a preference for keeping grazing animals near homesteads.

Facilitators of grazing management plans therefore need to ensure active participation of women in cattle management decision-making. Although the Okhombe Livestock committee is comprised of twelve men participating in management planning and co-ordination, women played a crucial role in general discussions and brainstorming during community meetings. Their exclusion from the Livestock committee was influenced by their culture (Zulu culture) rather than the current reality whereby their role is popularly known. Lack of ownership of land or stock is among factors that negatively impact on women in grazing management. Land allocation is traditionally in the hands of chiefs biased towards men which hinder women's voice in grazing management. Domestic responsibilities limit women's participation in extension training and advice programmes (Ngqaleni & Makhura 1996). It is therefore the duty of the service providers to ensure effective participation of women in cattle management practices, as cattle management is mostly their responsibility.

5.5. The use of fencing in grazing management

5.5.1. The Betterment fence in Okhombe

Originally during the implementation of the Betterment plan, Okhombe rangeland was fenced; with fencing separating the different subward's grazing areas. The camps comprised three parallel fences running along the contours of the mountain; the first fence was the bottom line separating grazing land from crop fields, the second was placed on the mid slope, while the third was at the top of the mountain along the watershed. The planned grazing practice of the Betterment planning, though still recognised by the community has largely collapsed. This has largely been from poor maintenance and theft of fences separating subwards. Where attempts were made to repair the fence, individuals or community efforts did not succeed in maintaining the fence. People who have been caught removing the fence were fined by the Tribal authority (Von Maltitz 1998). The community continued to remove the fence for individual use in their homesteads and no repairs were made. The fence separating the subwards was removed on a large scale as people were not consulted on dividing the subwards. The community viewed the boundaries as artificial barriers between residents from the same ward.

5.5.2. The LandCare fence in Okhombe

Success in cattle and rangeland management strategy requires some mechanism to control cattle movement. In most cases fencing is the most favoured option in accomplishing this form of management. Fencing assists in veld management as it is used to separate cattle from crops, controlling access to the cattle and preventing them from straying (Von Maltitz 1998). In the LandCare project the Okhombe community decided to control cattle movement through fence establishment. Although it was costly, it was advantageous in clearly demarcating the different resource areas. The LandCare fence was erected at the end of 1999 after the community requested the project partners to assist them to set up a community grazing management plan in the area. Chapter 3 indicated the community had successfully erected the fence boundary between the crop fields and the rangeland to protect their crops and further put up the top fence in the mountains. In order for the community to practise their designed rotational resting system, internal fencing was deemed necessary to ensure one-third of the grazing area would be given a full year rest.

In the past, before school was compulsory, children were responsible for herding livestock. An effective tool for range improvement was mobility of livestock. Herders used this form of management to provide access to alternative pasture areas, but the movement of livestock is also a form of a rest-rotation scheme (Hatch 1996). The mobility season was declared by the local *Inkosi* to allow regeneration of vegetation while accessing new pastures. Now, however school-going children no longer provide efficient labour as herders.

5.5.2.1. Fence theft

The establishment of the fence by the volunteers was seen as an accomplishment of the Livestock committee in indicating commitment to the implementation of the grazing plan. However, fence theft has been a major constraint in implementing the system. After two years of the fence being erected, some individuals from the three subwards started removing the fence. The Livestock committee reported the following fencing materials were stolen in three subwards: Ngubhela – 150 m; Sgodiphola – 350 m; and Oqolweni – 650 m of barbed wire was missing in December 2001. Much focus of the grazing management project was on strengthening local institutional structures to deal with social issues in the community. A critical factor in dealing with this problem is the capacity of the institutional structures within the community. A Venn diagram below (Fig. 5.2) indicates the local institutional arrangements pertaining to grazing and their relationship to the service providers.

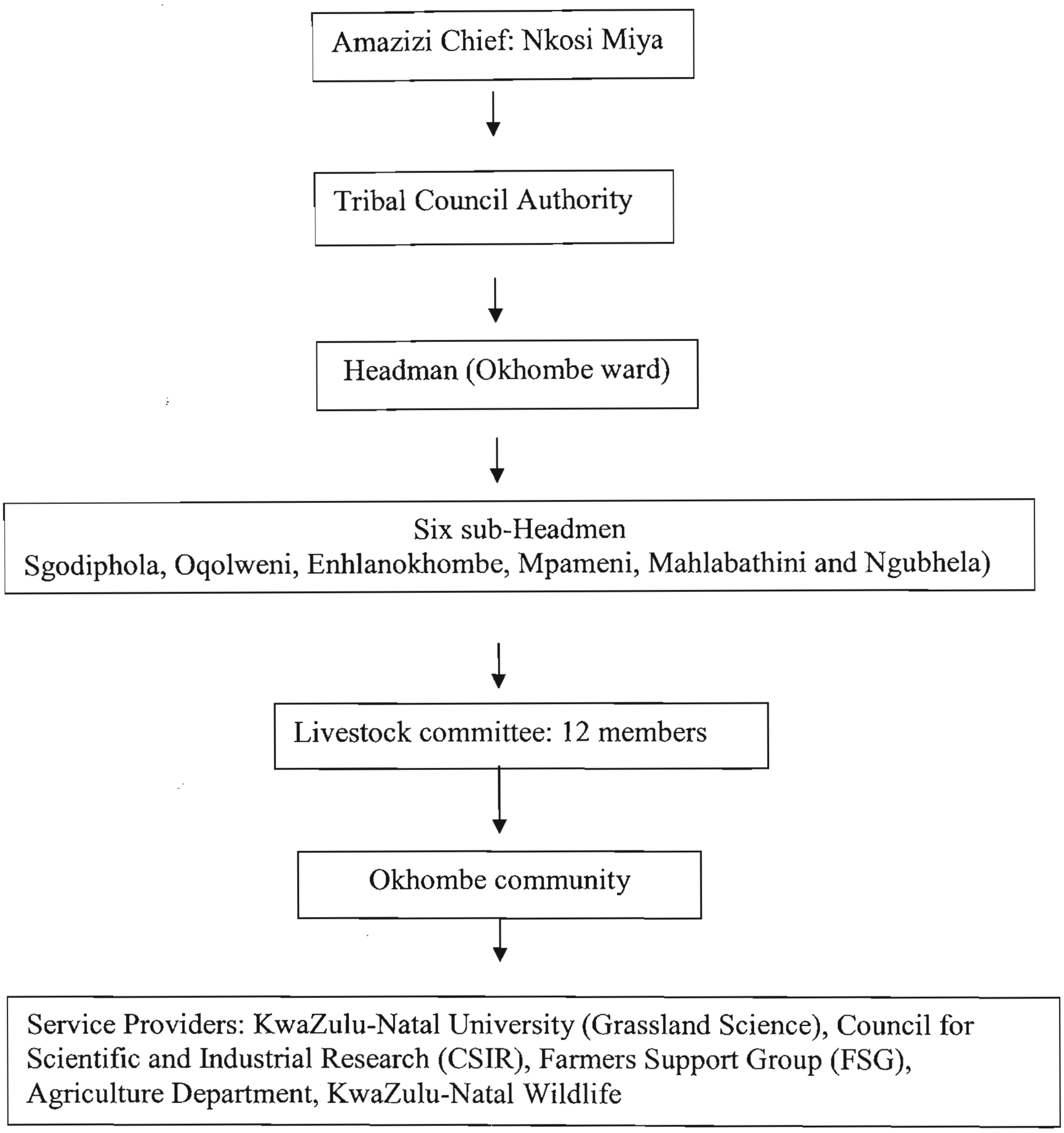


Figure 5.2. Institutional structures involved in the Okhombe grazing project

The process whereby the community dealt with the problem of stolen fencing is outlined below:

- The members of the public first reported the stolen fence to the Livestock committee who then reported it to the subward Headman and committee who reported it to the Ward Headman. A decision was taken between the Headmen and the committee to report the issue to the police and to the Tribal Council who take decisions on culprits if caught. The stolen theft issue was also reported to the partners of the LandCare project as part of grazing updates. This was a regular activity to enhance capacity building and encouraging community ownership of the project.

- A further decision was reached by the Headman committee that a representative from UKZN-Grassland Science should accompany the Headman and the Livestock Committee to report the issue to the Tribal council. Partners halted all activities pertaining to the grazing project until the fence was replaced. These activities included the continuation of erecting the parallel fence boundaries. The importance of seeking solutions from the Tribal authority was because it is the most powerful structure in the ward and it determined penalties and solved disputes.

- At the council meeting, it was emphasised that the theft issue was the most limiting factor for setting up the grazing plan. Lack of commitment by the community to solve the issue of fence theft would also be detrimental with regard to future opportunities of securing more job-creation development projects. The council also learnt that all fencing activities would be halted until the fence theft was resolved. The council requested the headman to address the theft at subward level. As the level of theft differed in each subward the council believed that community meetings at each subward could find effective solutions in replacing the fence.

The outcomes of the meetings held by the Headman at each subward were:

- Individuals with old fencing materials agreed to give fencing materials for free to close the gaps.
- Agreed on collecting money for purchasing the additional fencing materials.
- Any individual caught removing the fence should be reported to any member of the Livestock committee or to sub-headmen.

Achievements:

- The Sgodiphola community replaced the fence by using old barbed wire and old fencing standards supplied by individuals.
- Part of the Ngubhela fence was purchased from the money collected by the community and old fencing supplied by some individuals. In Oqolweni, the headman reported difficulties to successfully get commitment from the community and therefore couldn't succeed in replacing the fence.

It was six months after the last fence theft occurred in December 2001 when the Livestock committee reported in July 2002 that approximately 400 m of the barbed wire and some fencing standards funded by the KwaZulu-Natal Wildlife (KZN Wildlife) were missing.

The committee and KZN Wildlife reported theft to the police though no arrests were made. Meetings were held between the headmen and the community but they failed to reach an agreement on effective measures to replace the fence. LandCare partners and the Livestock meeting reported the theft to the council and requested even more effective measures on combating theft. As theft seemed to be mounting, the *Inkosi* agreed to convene a meeting to address his community.

During the meeting, the chief mentioned that any future projects would not be authorised (pertaining to grazing management activities) until the community accepted responsibility of their projects. Any future development projects may be halted if the theft continued. A plea was made for individuals to return the fence to the site where it was stolen or return it to the headmen's yard at night. Threats were made concerning suspected people that would face the council trial and questioning from the police. Following the *Inkosi*'s plea, 63 fencing standards were returned by an individual who stated he was planning to sell them to outside farmers.

The active involvement of the council and the headmen in replacing the fencing materials was acknowledged by the partners as one of the benefits of developing and strengthening local institutional structures. This is a long term process and much effort is still needed in ensuring complete responsibility by all individuals to look after the fence on their respective boundaries.

To maintain the fence and to ensure that no fence would be stolen again, workshops were held to explore options for overcoming the problem. The best option decided by the community was painting of the fence. The community requested the LandCare Partners to assist in payment of labour, because the area to be covered was huge. A total of 10 people were appointed by the community for painting the top fence (ward boundary fence) in five days at an estimated total cost of R1800. In Okhombe, major theft only occurred on the top fence, and none occurred from the bottom fence, implying the bottom fence has more value than the top fence. If there are gaps on the bottom fence, cattle may cross to the crop fields damaging crops. The community therefore decided to paint the top fence only and the bottom fence was left unpainted. The idea currently seems to be the most efficient as no theft was reported since the team finished painting in April 2003 till the end of the year 2004. A picture below (Plate 5.1) indicates the painted fence on the top of the hill slope.

Plate 3: Painted fence in Okhombe top hills.

To save costs the team decided not to paint the entire fence but rather leave a distance gap of one metre between the painted sections. Fencing standards, droppers and poles were also painted.

Rules followed after painting was:

- No community members would be allowed to paint their household fence.
- No burning of the fence because people may remove the project fence and burn to remove the white colour.
- Anyone with a painted fence similar to the project colour would be reported to the Tribal Authority, particularly if the fence is missing.

5.5.2.2. Mountain Rangers

The Okhombe Livestock committee's major concern was the sustainability of the project and to put effort in seeking ways of protecting the fence. Community meetings were called to address fence theft through in-depth discussions around best management options for cattle herds and rangeland. It was in these community meetings that the community herding system was proposed. It was based on modification from the traditional, individual herding system. The community drew up the management plan attached in Appendix 2. They agreed on setting up a herding fund from community contributions. Important facts were noted from these community meetings regarding the herders' fund. The fund would assist in the appointment of day-herders and night-herders to oversee maintenance of the grazing programme, control of veld fires, control of fence and stock theft and ensure all individuals followed the grazing rules.

- Three herders were agreed on to look after the fence and cattle, particularly the non-milking cows as they may cross to other neighbouring wards. They also had to check veld fires. Six night-herders would primarily look after the kraaled non-milking cows at three cattle posts (identified near forests to serve as kraals) and patrol the fence. Trustworthy, strong and healthy herders would be chosen from each of the three subwards.

- The idea of having herders was partly to reduce soil erosion, by reducing cattle movement as all cattle particularly the non-milking cows, would spend nights in the mountain. Milking cows would be kept in homestead kraals, although this would not be compulsory because people would be allowed to leave their cows within camps at the owner's risk. Preferred sites for the cattle post would be near dense forests, suitable for use as natural kraals.

- Old building materials contributed by the community would be used to establish three shelters near the cattle-post for herders. The shelters are for use mainly during extreme weather conditions, but not for sleeping purposes.

- All cattle kraaled in the evening would be counted by night-herders and in the morning by day-herders. This was to ensure that no cattle were missing, because the idea of having herders was to address stock theft. Stock-owners who wanted to use their oxen during planting season were informed to contact the Livestock committee of their intention and the number required would be recorded down to have knowledge of the remaining cattle.

- Herders would also be responsible for ensuring that cattle not adhering to the grazing rules would be impounded. It was stated that when the plan is in operation, it would not be the herder's duty to take cows to the relevant camp but rather the owner's responsibility. Cattle owners not adhering to the rules would be reported to the Tribal Council for punishment.

- The service providers pledged to contribute through provision of three cellular phones to herders. The phones would only be used for emergency purposes to contact other herders, the police and the community (e.g. when thieves were caught, reporting veld fires).

- Herders would be compensated through contributions from the community. The community agreed to contribute a minimum amount of R5 towards a herders' fund. Both stock-owners and non-stock owners had to contribute to the fund. Reason for contributions from the non-stock owners was that everybody in the community benefits from livestock (milk, meat, hides, dowry etc.) even if they do no own stock. Those without stock will in the future own through dowry for their daughters.

- The community are currently exploring some form of in-kind payments whereby livestock owners would pay herders for their services. For instance, herders in Lesotho were given small stock like goats and sheep as payments for looking after cattle (Motsamai 1993). Okhombe herders will only be appointed after the erection of the fence and when the grazing system starts to operate.

5.6. Lessons Learnt

- In communal grazing management projects, both stockowners and non-stock owners are affected and co-operation and commitment is required from both parties for the implementation of the programme. It is essential to involve both parties as they are land users. The presence of non-stock owners in meetings was important in decision-making. It is therefore recommended that an intense capacity building programme for both parties be carried out on range management and the benefits must be clearly outlined. As indicated above, in this project the community agreed that non stock owners would contribute to the planning of the fence and payment of herders. The project would not be sustainable if they were absent in meetings and if their contributions to the project had been ignored in all development stages.

- An effective extension service is needed to fulfil the information needs of small-scale farmers. The service must be offered in the local language to stimulate understanding and effective communication, because usually most farmers are discouraged to seek assistance if the communication is ineffective. The focus should be more on what can be done by farmers to improve their farming systems rather than just an awareness of environmental problems. For instance, the Okhombe community requested an effective service on income generation options from livestock they breed, information on the benefit of setting up community funds, and advice on animal health and veld improvement. Hence technical issues are an integral part of range management in communal areas.

- In range management projects, capacity building of institutions involved in the grazing management planning is essential not only for current running of the projects but also for future planning. These structures understand social issues from a traditional point of view, as they are made up of community members that live permanently in the area. Much success was achieved by the Okhombe institutions on managing stock theft through active liaison with the Tribal Council, encouraging community commitment, and an on-going effort to solve fence theft by individuals. These are some examples from Okhombe that could not have been achieved without the strengthening of the institutions by the service providers. Considerable effort by the KwaZulu-Natal University and FSG was therefore spent in engaging the whole community in the process. This involved building the capacity of the people to hold workshops, write reports, facilitate community meetings, deal with conflict and make decisions. The major achievement of this project is the development of a grazing plan with the entire community. The fencing of camps is nearing completion, and the plan will be implemented in the growing season of 2004.

- Ostrom (1992) stated that a resource with smaller boundaries is easier to manage and monitor than a large resource dispersed over a wide area. This project is one of the first grazing management projects in a communal area in KwaZulu-Natal. One of the main challenges in such a project is to develop and implement a plan with agreement from the entire community. In Okhombe the project was initiated on a large scale involving an estimated population of about 5000 in about 3400 ha. This proved difficult to manage and monitor as fence theft was occurring in different subwards at different times. It is therefore recommended that a communal grazing management plan should be initiated on a subward level, to serve as a pilot project for the entire ward.

CHAPTER 6: Okhombe Grazing Management – Ecological Study

6.1. Introduction: veld condition assessment

Trollope, Trollope & Bosch (1990) defined veld condition as the state of health of the veld in terms of its ecological status (its succession status), resistance to soil erosion and its potential for producing forage for sustained optimum livestock production. Most techniques used for determining and monitoring veld condition in Southern Africa require an assessment of proportional species composition and an estimate of basal cover for the sample site (Hardy & Tainton 1993). Veld condition assessment is essential for both commercial and communal range, for evaluating the effects of current management on veld condition and to monitor changes over time and also for evaluating veld condition relative to its potential in that ecological zone (Hardy *et al.* 1999). A vegetation survey was conducted to assess the veld condition, and estimate current grazing capacity of Okhombe communal range.

6.2. Research objective

- To determine the rangeland condition based on the altitudinal gradient for supporting the grazing plan established by the community.

6.3. Sampling procedures

6.3.1. Veld condition assessment procedure

The veld condition assessment was carried out in the six proposed camps of the three subwards (three camps for Oqolweni and Sgodiphola and three for Enhlanokhombe). The study was aimed at determining the vegetation composition in the camps that tend to be representative of different elevation sites ranging from 1200 m (bottomland), 1400 m (middle slope) to 1700 m (upland). The three elevations identified tend to be the most accessible grazing land for cattle. The other reason for using topographic differences was that the community planned to divide the area into bottom camps for milking cows and top camps for non-milking cows. It was therefore essential to determine the veld condition as a base-line for the response of the rangeland to the proposed management plan. All sites were surveyed with the aid of a Global Positioning System for future relocation. Variables measured in the determination of veld condition were species composition using the step-point method (Tainton 1988) and the basal cover using the distance/diameter method (Hardy & Tainton 1993).

6.3.1.1. Species composition: Step point method

The species point method provides a measure of the proportional abundance of the species composition of the veld. Sites were subjectively selected to avoid sampling near the stream or steep sites where the vegetation communities were not representative of the general rangeland. Three replicate sample sites of 50 m × 50 m where identified in each camp at the three different elevations. A metal spike of approximately 1.2 m in length was used to record the species composition at 200 positions. At each location of the spike, the plant nearest to the spike was identified and recorded. Grasses were identified according to their species names and herbaceous species and other non-grasses (sedges) were identified as a group called forbs (Tainton 1988).

The benchmark method (Hardy 1993) was used to compare the Okhombe data with the benchmark which is veld with the best possible botanical composition and cover (excellent condition) in relation to prevailing climate (Hardy *et al.* 1999). The Bioresource Group 8 (Moist Highland Sourveld) was used as a benchmark site because it is within the same ecological zone as Okhombe rangeland (Camp 1999). All the species recorded in the sample site were classified into their species categories: Decreaser species (species which decrease when the grassland is under- or over-utilized) and Increaser species, which increase with under-utilization (Increaser I), over-utilization (Increaser II) and selective grazing (Increaser III) (Tainton 1999). The veld condition score was calculated by multiplying the percentage of each species by its grazing value, totalling all the values for the site and expressing this total as a percentage of the benchmark value.

6.3.1.2. Basal cover: Distance/diameter method

Past researchers were estimating the basal cover from the number of strikes recorded as a proportion of the total number of point observations for a sample site. Hardy & Tainton (1993) stated that the method has major errors in estimating basal cover. For instance the probability of recording a strike is extremely low, therefore requiring a large sample size to achieve a precise estimate of basal cover. In this study an alternative distance/diameter method was used for determining herbaceous layer covering the ground. The method is relevant in Okhombe because the area is characterised by steep sites and measuring the distance between the tuft and the diameter of each tuft is essential for determining the run-off potential from the hilly sites down the slope.

At each of the sites, within the six proposed camps, 50 points were systematically placed over the sample site using the same spike used for recording species composition. The points were taken randomly within the 50 m^2 plot used for the step point method. At every second step, the distance from the point to the edge of the nearest tuft and also the tuft diameter were recorded and rounded up to the nearest centimeter.

6.4. Data summary and analysis

6.4.1. The Benchmark method

The veld condition score was obtained by multiplying the percentage of each species by its relevant grazing value and the total sum of these values was calculated as a percentage of the benchmark score. Table 6.1 represents the mean species abundance from the six proposed camps at three elevations (only mean values from three elevations are presented). The benchmark data are from the Moist Highland Sourveld. Variables analysed from the veld condition data were the species composition distribution, the species class (%) and the veld condition score across the topographic differences. Statistical procedures are detailed below.

6.4.1.1. Distribution of species composition across the landscape gradient

Correspondence analysis (an ordination technique) contained in the CANOCO 4 (Ter Braak & Smilauer 1998) package program was used to analyse species composition data. Correspondence analysis is an ordination technique that extracts axes of variation from species data, assuming a unimodal distribution of species along gradients. Such ordination axes are interpreted with external knowledge and data on environment variables. The approach is termed indirect gradient analysis (Whittaker 1978). Unlike the direct gradient analysis which is used to arrange samples in terms of pre-selected environment resource gradients, assuming an underlying relation between a species and an environmental gradients (the species response curve), the indirect gradient analysis (ordination) makes no assumptions about the nature of the gradient (except unimodal responses) but uses sample similarities or sample correlations (weighted averages approach) to derive abstract axes which may or may not correspond to environmental gradients (Ter Braak & Smilauer 1998). The objective is to generate hypotheses about the relationships between vegetation and environment (Ter Braak & Smilauer 1998), which in this study refers to the distribution of grass species along the topographic gradients.

6.4.1.2. Distribution of species class along the gradient

The species classes were categorized into four ecological groups explained in section 6.3.1. The species class percentages expressed as proportions were normalised using arcsine transformation and subjected to analysis of variance. This was mainly to avoid the skewness of the data, particularly on the species accounted for less percentage and others with higher values. In order to determine whether the species percentage values differed significantly, a distribution pattern of the species class along the elevation gradient (1200 m to 1700 m above sea level) were subjected to one-way analysis of variance (ANOVA) using Genstat (2002) statistical package. When the F-test of the ANOVA was significant (<0.05), least significant difference (LSD) tests were used to compare means among categories of species class.

6.4.1.3. Veld condition score across the landscape position

The veld condition score is of primary importance in indicating the long-term stability of the grassland (poor, critical, reasonable, and good to excellent). These data were subjected to one-way analysis of variance (ANOVA). The statistical analysis was to indicate any significant difference in veld condition from 1200 m to 1700 m. Statistically differentiated mean were further analysed using least significant difference (LSD).

6.4.1.4. Basal cover percentage across the landscape position

The percentage basal cover of each sample site was obtained by substituting the mean distance and the mean diameter values into the following regression equation developed by Hardy & Tainton (1993):

Basal cover = $19.8 + 0.39\,(\mathbf{D}) - 11.87\,(\log_e \mathbf{D}) + 0.64\,(\mathbf{d}) + 2.93\,(\log_e \mathbf{d})$; whereby **D** was the distance to the edge of the nearest tuft (measured in centimeters and rounded up to the nearest cm), points falling within the tuft were recorded as a distance of 1 cm and **d** was the tuft diameter (measured in centimeters and rounded up to the nearest cm).

6.5. Results

6.5.1. The Benchmark method

Table 6.1 indicates an increase in species class of high grazing value with an increase in landscape elevation. For example, Decreasers increased from 1.0% in the bottomland to 3% in the mid-slope region to 11.5% in the upland. The highest veld condition score (47%) was recorded in the upland. The veld condition scores were low (< 47%) for all study sites. Although *H. contortus* (13.5%) contributed significantly to the veld condition, it is classified under Increaser II species because is a hardy and fast growing grass, with a declining grazing value as the season progresses (Camp1999).

Table 6.1 Species composition and veld condition scores for the bottomland, mid-slope and upland areas.

Group	Species	Grazing value	Benchmark %	Score	Bottomland %	Score	Mid-slope %	Score	Upland %	Score
Increaser 1	*Alloteropsis semialata*	3	2	6	0	0	0	0	0	0
	Digitaria tricholainoides	6	0	0	0	0	1	6	3.7	22.2
	Eulalia villosa	3	1	3	0	0	0	0	0	0
	Trachypogon spicatus	3	2	6	0	0	0	0	0	0
	Trystichya leucothrix	9	20	180	0.2	1.8	2.8	25.2	8.6	77.4
	Sub-total		**25**	**195**	**0.2**	**1.8**	**3.8**	**31.2**	**12.3**	**99.6**
Decreaser	*Brachiaria serrata*	3	1	3	0	0	0.1	0.3	0	0
	Diheteropogon amplectens	8	1	8	0	0	0	0	0	0
	Melinis nerviglumis	2	0	0	0.5	1	0.4	0.8	1.7	3.4
	Monocymbium ceresiiforme	6	2	12	0	0	0	0	0	0
	Panicum ecklonii	2	0	0	0.32	0.64	1.3	2.6	4.4	8.8
	Panicum natalense	2	0	0	0	0	1	2	0.3	0.6
	Themeda triandra	10	45	450	0.2	2	0.2	2	5.1	51
	Sub-total		**49**	**473**	**1.02**	**3.64**	**3**	**7.7**	**11.5**	**63.8**
Increaser 11a	*Eragrostis capensis*	2	1	2	1.8	3.6	3.5	7	5.4	10.8
	Heteropogon contortus	6	4	24	2	12	4.6	27.6	13.5	81
	Harpochloa falx	3	3	9	0	0	0	0	0.3	0.9
	Sub-total		**8**	**35**	**3.8**	**15.6**	**8.1**	**34.6**	**19.2**	**92.7**
Increaser 11b	*Digitaria monodactyla*	1	0	0	0.4	0.4	4	4	7.75	7.75
	Eragrostis chloromelas	2	0	0	3.1	6.2	1.9	3.8	1.66	3.32
	Eragrostis curvula	5	1	5	7.3	36.5	6.9	34.5	2.91	14.55
	Eragrostis obtusa	2	0	0	0.8	1.6	0.4	0.8	0	0
	Eragrostis plana	3	1	3	12.9	38.7	13.3	39.9	4.2	12.6
	Eragrostis racemosa	2	1	2	11.2	22.4	7.9	15.8	8.8	17.6
	Hyparrhenia hirta	3	1	3	4.8	14.4	5	15	0.3	0.9
	Sporobolus africanus	3	0	0	8.6	25.8	5.6	16.8	1.82	5.46
	Sub-total		**4**	**0**	**49.1**	**146**	**45**	**130.6**	**27.44**	**62.18**
Increaser 11c	*Aristida congesta*	0	0	0	2.2	0	0.2	0	0	0
	Cynodon dactylon	3	0	0	0.08	0.24	0	0	0	0
	Forbs & Sedges	0	6	0	0	0	0.5	0	1.6	0
	Melinis repens	1	0	0	1	1	3.5	3.5	0.3	0.3
	Microchloa caffra	1	1	1	2.5	2.5	1.2	1.2	5.3	5.3
	Paspalum dilatatum	7	0	0	12.3	86.1	8	56	0.4	2.8
	Paspalum notatum	3	0	0	9.7	29.1	9.3	27.9	1.5	4.5
	Sub-total		**7**	**1**	**27.78**	**118.94**	**22.7**	**88.6**	**9.1**	**12.9**
Increaser 111	*Aristida junciformis*	0	0	0	10.4	0	7.3	0	0.16	0
	Diheteropogon filifolius	0	2	0	0	0	0	0	0	0
	Elionurus muticus	0	5	0	3.5	0	4.7	0	5.2	0
	Rendlia altera	0	0	0	4.2	0	5.4	0	15.1	0
	Sub-total		**7**	**0**	**18.1**	**0**	**17.4**	**0**	**20.46**	**0**
	Total		**100**	**704**	**100**	**285.98**	**100**	**292.7**	**100**	**331.18**
	Score %					**40.4**		**41.4**		**47.0**

The dominance of *Heteropogon contortus* in veld is not recommended. *Heteropogon contortus* has been classified as Increaser IIa in Moist Highland sourveld (Camp 1999). *Tristachya leucothrix* has a good leaf production and is generally well utilized in the young stage, with a variable grazing value. The elevations from 1200 m to 1400 m tend to be dominated by Increaser II species (less palatable plants with low grazing value that have an extreme drop in palatability during winter). The most dominant Increaser II species were *Sporobolus africanus*, *Eragrostis plana*, and the exotic *Paspalum* species. Their dominance has resulted in a poor veld condition in this elevation category, and veld management must consider reversing the current distribution trend.

The veld condition index (Table 6.1) revealed that lower sites have lost high proportions of desirable species when compared to the benchmark site. The proportional abundance of Decreaser species accounted for 1.02%, 3% and 11.5% of the bottom, middle and upland sites compared to the value of 49% in the benchmark (grassland in optimal condition). The higher percentage of Decreaser species will be beneficial for the survival of stock. The high loss of Decreaser species in the lower sites indicates the grazing quality is poor. The increase of diverse Increaser II species indicates long term overgrazing that eliminated the preferred Decreaser species. The composition of the less palatable Increaser II species was very high at all elevations (1200 m –80.7%; 1400 m – 75.8% and 1700 m – 55.7%) when compared to the benchmark (19%) and was attributed mostly to the species mentioned above. The species class (Increaser II) is an indication of range mismanagement. All the sites had an increase in Increaser III species ranging from 17.45% to 20.5%, which is largely attributed to *Rendlia altera* and *Aristida junciformis*. Both these species were absent in the benchmark site and their dominance indicates poor veld condition. Increaser III species accounted for only 7% of the benchmark scores (Table 6.1). These grasses are described as hard, wiry leaved, unpalatable grasses with no grazing value and indicate the veld was selectively grazed in search of desirable species. Their distribution in veld could be effectively eradicated through resting and burning (Everson & Tainton 1984). The lower veld condition scores are largely attributed to the predominance of Increaser II and Increaser III species with their lower grazing values.

6.5.2. Species composition across the Okhombe landscape position

The Correspondence analysis (CA) biplot (Figure 6.1) indicates a distinct difference in species composition with the bottom and middle slope being divergent to the upland plateau. This was revealed by a positive overlap and similarity in species composition between the middle and the bottom slope as compared to the upland being characterized by distinct species composition in all the proposed upland camps.

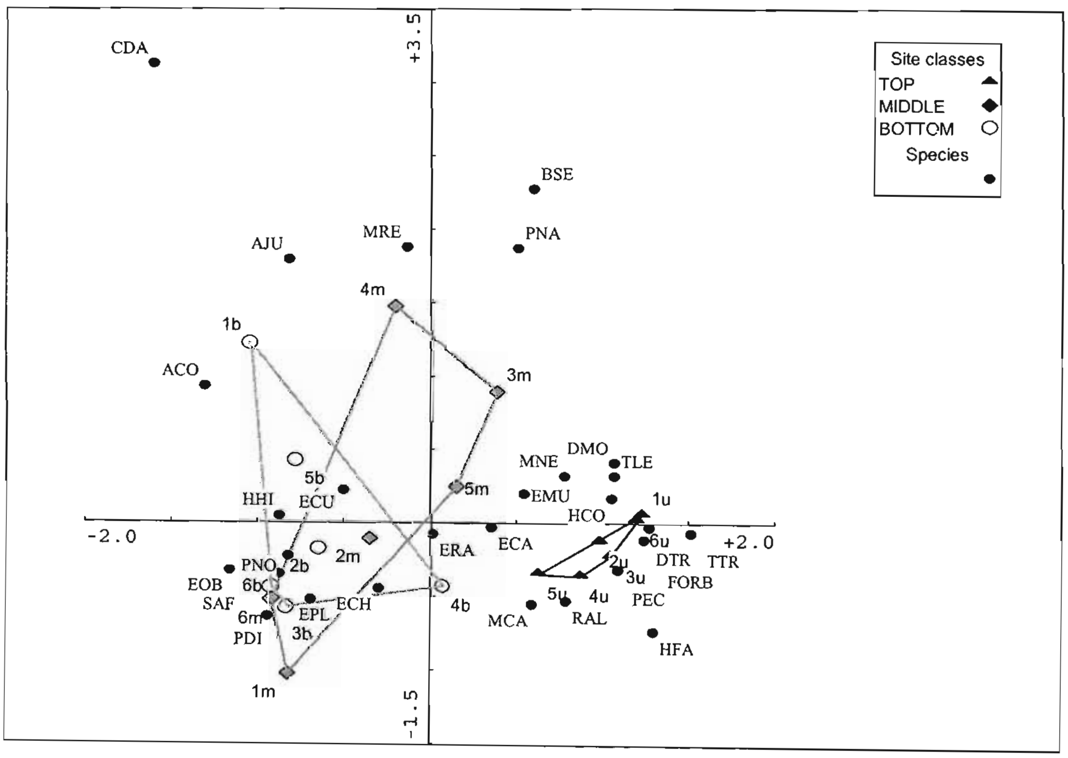


Figure 6.1: A plot of sites and species along the first two axes of a correspondence analysis with landscape position indicated (Camp 1b to Camp 6b - bottomland, Camp 1m to 6m - middle slope and Camp 1u to 6u - upland). **Species names: CDA (*Cynodon dactylon*), BSE (*Brachiaria serrata*), MRE (*Melinis repens*), AJU (*Aristida junciformis*), PNA (*Panicum natalense*), ACO (*Aristida congesta*), DMO (*Digitaria monodactyla*), TLE (*Tristachya leucothrix*), MNE (*Melinis nerviglumis*), EMU (*Elionurus muticus*), HCO (*Heteropogon contortus*), ERA (*Eragrostis racemosa*), ECA (*Eragrostis capensis*), DTR (*Digitaria tricholainodes*), TTR (*Themeda triandra*), PEC (*Panicum ecklonii*), MCA (*Microchloa caffra*), RAL (*Rendlia altera*), HFA**

(*Harpochloa falx*), ECU (*Eragrostis curvula*), HHI (*Hiparrhenia hirta*), PNO (*Panicun notatum*), PDI (*Panicum dilatatum*), EOB (*Eragrostis obtusa*), SAF (*Sporobolus africanus*), EPL (*Eragrostis plana*), ECH (*Eragrostis chloromelas*) and Forbs. The eigenvalues for axis 1 = 0.42, axis 2 = 0.155 and account for 14.4% and 8.9% of the variance respectively.

Sample sites (bottom and middle slopes) with no distinction in species composition are indicated on the second axis. These sites are the bottom slope of camp 1 and 4, and the middle slope of camp 4 and 5. Considering the proximity rule, the dissimilarity is due to selective grazing substantiated by the presence of *Aristida junciformis, Aristida congesta,* and *Melinis repens* (for instance in the bottom slope of camp 1 and the middle slope of camp 4).

Table 6.2. A summary table from the CA analysis of species composition data from three-landscape positions in Okhombe.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.42	0.155	0.096	0.083	1.080
Cumulative percentage variance of species data	38.8	53.2	62.1	69.7	
Sum of all unconstrained eigenvalues					1.080

The CA was used to extract the main gradients in composition and Figure 6.1 showed clearly how sites differed in their composition, as judged by their relative position along these main compositional gradients. The study therefore provides no ecological data because there were no environmental measurements done to evaluate attributing factors along the gradients. An indirect ordination was used to identify the main gradients of compositional variation among the environmental gradients and not detailed ecological interpretation to justify why sites differed. The study therefore observed differences attributable to position in the landscape.

CA axis 1 was interpreted as a landscape position with a diverse variation in species composition and describes the variation along axes in terms of species with the highest cumulative fit. CA axis 2 represents landscape with less variance in species composition. This is due to the large amount of variance in species data for axis 1 as compared to axis 2. The CA analysis accounted for a total of 69.7% of the species variability within the first four axes (Table 6.2). Axis 1 accounted for the largest amount of variance when compared to the other axes. The large variation on axis 1 was noted on the groupings of species, by eigenvalues presented in Table 6.2. The table substantiated that the larger variation along the axis 1 ordination is due to similarity or overlapping in species composition along the gradient, with landscape position along axis 2 indicating dissimilarity in species abundance in relation to other sampling sites.

The CA biplot (Figure 6.1) revealed that the dominant species on the bottom (1200 m above sea level) and the middle slope (1400 m above sea level) of Okhombe rangeland are mainly Increaser II species (axis 1), an indication of overgrazing (Tainton 1988). These species increase under grazing pressure partly because of reduced competition from the palatable grasses. The upland plateau, which is about 1700 m, is characterized by diverse species classes ranging from unpalatable Increaser species to a group of palatable species (e.g. *T. triandra and T. leucothrix*). Increaser III species, *Elionurus muticus* a characteristic of selective grazing also occurred in the upland site.

Hardy *et al.* (1999) stated that as a result of spatial variation in factors such as slope, elevation, soil and aspect, sour grassveld is characteristically heterogeneous. Such heterogeneity is often expressed in variations in floristic composition and growth pattern of the veld. This was the case in Okhombe as a result of distinct differences in floristic composition across the topographic differences. Their distribution varied in abundance across the landscape composition.

6.5.3. Species class across the landscape position

The results from the CA biplot (Figure 6.1) indicated the different distribution patterns of the species but did not indicate the significant difference of the botanical composition along the different elevations. Figure 6.2 shows a non-significant difference in distribution (P > 0.05) of the highly unpalatable, 'wiry' Increaser III species across the topographic difference.

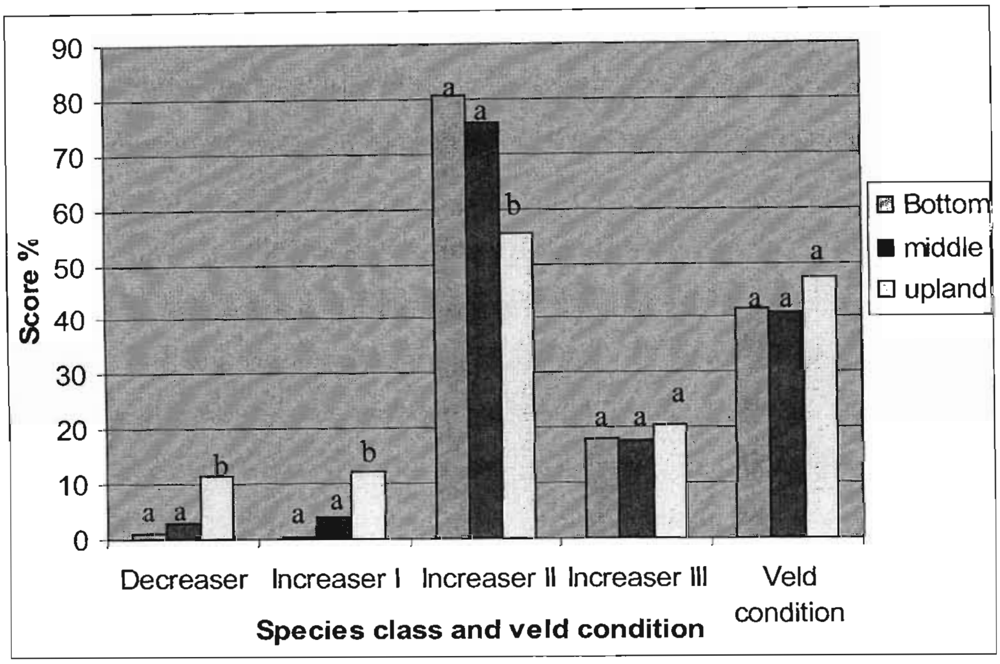


Figure 6.2. The veld condition score (%) and the species class (%) distribution along the altitudinal gradient of Okhombe rangeland.

Dissimilar letters designated in each species class show significant differences. (P > 0.05)

LSD: Decreaser – **10.38**, **Increaser I- **6.01**, Increaser II– **11.51**

The results corroborate the CA biplot in that Increaser III species were not noted as key species in Okhombe from the CA axis 1 (species with high cumulative fit of more than 48%). A marked decrease in *T. triandra* and *T. leucothrix* (Table 6.1) along the bottom-middle slope when compared to the top plateau resulted in a significant distribution (P <0.05) of Decreaser and Increaser I species across the landscape difference. The abundance of other species groups in the upland resulted in a significant difference in distribution ($P < 0.05$) of Increaser II species on the upland (55.7%) and on the lower slopes (80.6%). The results show a reduction in species abundance of Increaser II with an increase in altitude. The unpalatable Increaser II dominates the area compared to a low of 19% in the Benchmark site. Decreaser species dropped from 49% in the Benchmark to 11.5% in the upland site.

6.5.4. Veld condition across the landscape position

A veld condition assessment is essential as an input for management decisions. The ANOVA table revealed a non-significant ($P > 0.05$) difference in range condition of the three slope classes (Figure 6.2). The veld condition of the sites ranged from poor (40.7%) in the bottomland to an average of 47.0% in upland sites ($P=0.23$). These low values indicate a great need by the community to engage in appropriate grazing management practices that will eventually reduce Increaser II abundance. Most of the species characterizing the upland are not species of sustained quality. For instance, *H. contortus* is described as a relatively good, hardy and fast growing grass, with a declining grazing value as the season progresses (Van Oudtshoorn 1992). *T. leucothrix* has a good leaf production but is generally only well utilized in the young stage, and *D. monodactyla* has a disadvantage of very low grazing value and low leaf production (Van Oudtshoorn 1992). The dominance of these species will not provide sustained long-term grazing.

6.5.5. Basal cover pattern across the slope

Basal cover was high from the bottom to the upper plateau (Table 6.3). The basal cover along the gradients ranged from reasonable (14.6%) to excellent cover of 18.1%. The three slopes had similar cover percentages that averaged 16.9%, 16.7% and 16.8% for the bottom slope, middle slope and the upland plateau respectively. The basal cover standards used were recommended by Camp & Hardy (1999). Their basal cover standards are that, percentages ranging from 1 -5% are categorised as critical, 6 – 10% as poor, 11 – 155 as reasonable and 16%+ as good to excellent basal cover (Camp & Hardy 1999). The high basal cover in these areas of poor veld condition is attributed to the dense nature of Increaser II tufts and the larger number of stoloniferous grasses such as *Paspalum* species.

Table 6.3 Basal cover percentages across the three elevation sites from six camps.

Bottom slope % (1200 m)		Middle slope % (1400 m)		Top plateau (1700 m)	
Camp 1	14.6	Camp 1	15.9	Camp 1	17.9
Camp 2	16.9	Camp 2	16.4	Camp 2	16.4
Camp 3	18.8	Camp 3	17.4	Camp 3	16.1
Camp 4	17.5	Camp 4	16.7	Camp 4	16.7
Camp 5	17.1	Camp 5	15.8	Camp 5	17.4
Camp 6	16.6	Camp 6	18.1	Camp 6	16.4
Average	**16.9%**	**Average**	**16.7%**	**Average**	**16.8%**

6.6. Discussion

The Highland Sourveld was described by Acocks (1953) as the veld of the eastern slopes and foothills of the Drakensberg from about 1350 m – 2150 m above sea level. The benchmark site for Okhombe rangeland (northern Drakensberg) is the Moist Highland Sourveld, which lies between the Moist Transitional Tall Grassveld or Moist Midlands Mistbelt and the Montane veld type (Camp 1999). The species distribution in this veld type was described by Killick (1963) as largely influenced by altitude (temperature) and available moisture. Other physical environmental variables that are considered to have the most profound influence on species distribution in the Drakensberg are rainfall, relief, and soil depth mainly because of its effect on both available moisture and temperature (Killick 1997).

The sites above 1700 m were dominated by species such as *Heteropogon contortus, Themeda triandra* and *Rendlia altera*. A study by AGRILAND (1988) on the vegetation composition of the Upper Thukela area indicated that north-facing slopes at above 1600 m were often dominated by *H. contortus* with *T. triandra* and *R. altera* usually co-dominant and occasionally dominant. The Upper Thukela covers the study area

(Okhombe ward). Other widespread and occasionally co-dominant grasses are *Digitaria monodactyla, Eragrostis muticus, Eragrostis racemosa, Panicum natalense, Tristachya leucothrix, Diheteropogon filifolius.* Species such as *T. leucothrix, R.altera,* and *H. contortus* all had their highest mean abundance at 1700 m, corroborating that distribution was due to altitude.

The influence of topography on species distribution has been indirectly responsible for structural formation of the soil (Sonneveld 2003). Sonneveld (2003) showed that removed materials from upslope areas have often been re-deposited in the lower parts of the valley, improving further deep soil character in the lower lands. Thus shallow soils occur mainly on hilly ground while deep soils are found near watercourses. The difference in soil types along the elevations contribute to the distribution of species in grassland. Granger & Morris (2003) reported that naturally, the lower elevations of the Drakensberg are characterized by mainly tall grassland (dominated by C_4 species) and short (< 0.5 m) dense grassland on the upper slopes, and summits where C_3 grasses are more common.

Walker (1987) reported similar results from his study in the Mdedelo Wilderness Area of the Cathedral Peak State Forest. Results from his study were similar in that *T. triandra, H.contortus, Alloteropsis semialata,* and *R. altera* were predominantly found on warm north aspects, while *Festuca costata*, occurred on cool, south aspects. The abundance of *H. contortus* on hilly ground was also indicated by Walker (1987) in that its frequency distribution ranged from 2% to 4% at 1500 m and a rise in abundance from 5% to 7% at higher elevation (2000 m to 2200 m elevation). In the Okhombe study, *H. contortus* increased from 2% on the lower elevation to 13.5% at upper ground. Walker (1987) indicated a drop in proportional abundance of *T. triandra* with an increase in elevation. In Okhombe, *T. triandra* accounted for 27% at 1500 m altitude and decreased to 12% at 2100 m elevation. It had fairly abundance distribution of 21% – 24% between 1700 m to 1800 m. Walker's (1987) study corroborated the Okhombe result in that the site has lost a high proportion of *T. triandra* at the lower elevation. The Okhombe study recorded a low of 0.2% accounted at 1400 m when compared to 11.5% at 1700 m. Walker (1987) recorded an increase of 21% – 24% at the same upland elevation with low values accounted at lower elevation.

Rendlia altera increased from 4.2% in this study on the lower elevation to 15.1% at 1700 m. Killick (1963) noted that this species usually occurs at high altitude. This grass species may be an indication of selective grazing but this is unlikely as the proportional abundance of *T. triandra* is higher at this altitude. Its abundance in the upland is likely to be due to elevation. *Digitaria monodactyla* and *Eragrostis racemosa* are both Increaser II species that were found in Okhombe to have a higher proportional abundance of 7.75% and 8.8% respectively at higher elevation. These two species occupy mostly rock outcrops and hilly ground which explains their higher percentage at 1700 m. Other species that were found in shallow stony soils occasionally interrupted by basalt outcrops on these ridge tops and plateaux were *Eragrostis capensis, Harpochloa falx, R.altera, and H. contortus.*

Similar results were obtained and discussed by AGRILAND (1988). AGRILAND (1988) indicated that the valley floors from 1200 m to 1400 m of the Upper Thukela location were dominated by *Eragrostis curvula, Eragrostis plana* and *Hyparrhenia hirta*. Other common grasses were *Paspalum* species, *Sporobolus africanus*, *Aristida junciformis* and to a lesser extent *Digitaria tricholainoides* and *Eragrostis capensis*. According to AGRILAND (1988), *Eragrostis* dominated grassland occurs on the flatter area below 1600 m. *Eragrostis curvula* and *Eragrostis plana* tend to co-dominant, and other species often abundant are *Digitaria tricholainoides, Eragrostis capensis, Eragrostis Plana, Paspalum scrobiculatum.* Species such as *Tristachya leucothrix* and *Melinis caffra* persist in small numbers as indicated in Table 5.1. Killick (1963) indicated that *Paspalum* species are only found at low elevation of the Montane Belt and are rarely found above 1870 m. The AGRILAND (1988) findings revealed from their study near Okhombe in the vicinity of Bonjaneni, that on the flat ridge tops and plateau below 1500 m close to settlements, *Aristida junciformis, Eragrostis* species, and *Paspalum scrobiculatum* grasses are dominant with *Eragrostis curvula, Eragrostis plana, Eragrostis racemosa* and

Sporobolus africanus common. These species prefer lower elevations where the soil is deeper.

Burgess (1991) conducted a study in the northern Drakensberg in which the species abundance was subjected to a correlation procedure to reveal the response of species to environmental variables corresponding to axes defined by the indirect gradient analyses. The results showed sites ordinated along complex moisture and altitude gradients through the sequence from high altitude dry sites, low altitude dry sites, to low altitude moist sites and high altitude moist sites. Environmental variables had a high correlation to the species abundance levels from low altitude to high altitude. Burgess (1991) considered aspect an important variable with an increase in altitude, particularly above 1830 m. At lower altitude, the presence or absence of *Eragrostis curvula*, *Eragrostis racemosa* and *Themeda triandra* were influenced by the slope. The conclusion therefore, is that environmental variables particularly altitude has the most profound influence on species distribution of the Drakensberg. The higher altitude sites in this study, that are often composed of dry shallow soils favoured *Tristachya leucothrix*, *Themeda triandra* and *Rendlia altera* while the lower altitude sites where much water runs through from the upland is composed of deep soils supporting tufted species such as *Aristida junciformis*, *Eragrostis* species and *Sporobolus* species (Burgess 1988; AGRILAND 1988).

A study conducted by Granger & Morris (2003) in the central part of the Northern sector of the Cathedral Peak-iNjasuti sector of the Natal Drakensberg concluded that elevation attributed more to species composition than land use practices. Data analysis from their study showed that the first principal component distinguished sandy, acidic soils from the more fertile, neutral to basic clays, whereas variation in soil carbon was more associated with topographic variation (altitude, slope, and insolation) along the second principal component. Land use was not evenly distributed across these gradients, with conservation site lying at higher elevations (> 1600 m) than those under subsistence or commercial grazing (< 1460 m). A comparison between conservation sites and communal sites were found to be confounded by Granger & Morris (2003) and Walker (1988). This was mainly due to reason that high elevation sites were mostly found in conserved sites whereas the lowlands were grazed and under subsistence. O'Connor (2005) found similar results from his study in that distinct differences in species composition were recorded between grazing under communal, commercial and conservation site. Coarse unpalatable perennial grasses (e.g. *Eragrostis plana, Sporobolus africanus* and *Sporobolus pyramidalis*) tended to be abundant while palatable productive grasses (e.g. *Themeda triandra*) were less abundant under subsistence grazing than under commercial and conserved areas. However, conclusion from Granger & Morris (203) study was that, although significant, land use differences were small, accounting for less than 3% of the total variation in composition in the study area. Topography was the main attribute to species compositions in the Drakensberg than soil mineral status and grazing practices Granger & Morris (2003).

6.7. Carrying capacity and destocking plan in communal rangelands

The need for establishing criteria and ways for determining the carrying capacity of African rangelands became more strongly felt in the 1960's and 1970's when several African regions were hit by droughts causing enormous stock losses (De Leeuw and Tothill 1993). South Africa in particular, adopted destocking programmes to curb communal range degradation and conform to the available supply and demand of grazing resources. Abel (1993) noted that the carrying capacity concept has been used as the scientific standards against which rangelands are judged to be overgrazed, and to prove that pastoralism, as practised in the majority of the world's rangelands, is inherently inefficient and environmentally destructive.

According to succession theory grazing reduces the competitiveness of the climax species, favouring plants of lower seres (Abel 1993). Excessive heavy grazing can cause irreversible change to soils, and the climax cannot be regained unless the soil re-develops. Rainfall has a similar effect with lack of rain preventing attainment of the climax, but the effects of rainfall can be countered by manipulating stocking rate (Abel 1993). Past development programs ignored the facts and viewed cattle numbers alone as the determining factor for overgrazing. Communal lands were perceived to be overstocked. Communal farmers always consider their land capable of supporting more animals. Their animals are not kept at economic carrying capacity due to traditional reasons, and are therefore maintained at ecological carrying capacity. Drought is considered the only option to the natural destocking process during which the stock numbers recover again in the wet season for multiple uses like draught power, transport and milking. Rural people tend to focus more on maintenance and survival of their cattle than on range improvement. The question therefore is; are communal rangelands overstocked? Are they currently capable of supporting rural stock? Do service providers have to be concerned about the destocking programmes and restricting cattle numbers in rural areas to their recommended grazing capacity (Abel 1993)? The veld condition of the Okhombe range was determined to estimate the grazing capacity of the area.

Camp (1999) attributed rainfall and veld condition as the main factors which contribute to veld production and their inclusion in the grazing capacity equation was considered essential. Under the current prevailing grazing management system, the area is heavily stocked at 0.5 ha AU^{-1}. This is four times the recommended grazing capacity estimates standards moist Highland sourveld. Camp (1999) recommended a grazing capacity of 2.0 ha AU^{-1} of the veld in good to reasonable condition and a potential standard of 1.5 ha AU^{-1}. The estimated herbage consumption by one AU in the Moist Highland Sourveld is 2 500 kg AU^{-1} $annum^{-1}$. Peddie & Luthuli (2003) simulated communal range conditions in a research farm to study the effects and consequences of communal grazing by setting up a six years trial practising continuous grazing at a high stocking rate (1 ha AU^{-1}), 3-paddock rotational resting and 4-paddock rotational resting stocked at 3.2 ha AU^{-1} . The high stocking rate camp resulted in the least herbage availability to cattle going into the winter (105 dry matter yield), while the 3-paddock (241 dry matter yield) and 4-paddock (311 dry matter yield) system had similar yields. This is a corroboration that under the prevailing grazing system in Okhombe (continuous grazing), cattle goes into with minimal dry matter availability. Given the fact that Okhombe rangeland is currently heavily stocked at 0.5 ha AU^{-1}, every year the area faces a major feed deficit.

The grazing capacity formula that includes rainfall and veld condition in the equation was used for this study. Figures from the formula recommended grazing capacity of 3.81 ha AU^{-1}. The commercial approach to range management (destocking) can therefore not be used in areas like Okhombe communal ward whereby multiple benefits are drawn from stock. Chapter 5 indicated the reasons for keeping stock in Okhombe were mainly for traditional purposes. Unwillingness to destock is somewhat due to disparities in herd size that tend to reduce incentives for community members to destock, especially those with small herds. Another factor that inhibits destocking during droughts is the low livestock prices followed by high restocking costs. Scientifically, the findings justified the reason for implementing destocking programme in Okhombe, but due to multiple uses of stock and the repercussions thereafter if stock is reduced; it is not advisable to consider reducing stock in communal rangeland. The failures of destocking programme were referenced in the literature review section.

According to Campbell (2000) economic implications of destocking, and lack of an authority to effectively enforce rules leave the decision of destocking to the discretion of individual households, yet full benefits of destocking can only be realised if destocking decisions are made at the community level. All these diminish the incentives for destocking and inevitably result in heavy stocking and excessive grazing. An alternative to destocking is improvement of the grassland through appropriate grazing management systems. This implies the recommended grazing capacity might be met through improvement of veld conditions.

6.8. Grazing management proposals

The management of the Okhombe rangeland should ensure better utilization of grazing whilst controlling livestock movement. Much of the lower elevations are dominated by Increaser II species and reducing grazing pressure at these sites should be a priority.

To ensure better grazing utilization, the community drew up a grazing plan in which the lower elevation sites were allocated to the milking cows (an estimated 946 cows). The major upper-grazing boundary was planned to divide the lower degraded elevations from the top land with a fairly high veld condition score. An estimated 600 cattle comprising bulls, oxen and heifers will graze the higher areas. As indicated in section 6.4, species of high grazing value dominated the top elevation. The grazing plan therefore aimed at incorporating correct utilisation of all accessible areas rather than putting more pressure at both sites.

The second part of the grazing plan developed by the community was the establishment of a three camp-rotational resting system. This involves resting one-third of the grazing area for a year. To restore vigour, particularly of the palatable species, one-third of the proposed camps would be rested for the entire year and utilized for winter fodder availability.

CHAPTER 7: Ukulinga Agroforestry Trial – Resource Yields

7.1. Introduction

Deforestation, soil erosion, declining soil fertility, disappearance of fuel wood supplies and loss of biodiversity are all consequences of inappropriate use of natural resources. The availability of nutrient content for livestock decline as a result. One of the most promising approaches to increase agricultural productivity is agroforestry (Jung, Buxton, Hatfield & Ralph 1991; Nair 1993). Agroforestry is frequently invoked as a solution to problems of land and water degradation as well as an answer to shortages of food, fuel wood, cash income, animal fodder and building materials in sub-Saharan Africa (Nair 1993).

Agroforestry offers at least partial solutions to many rural land use and production problems. The promise of nitrogen-fixing trees for improving soil fertility in cropland and pastures has been widely discussed as has the resistance of some trees to drought, the role of windbreaks in protecting croplands and the contribution of high-protein tree fodder to livestock production (Everson *et al.* 1998; Rocheleau, Weber & Field-Juma 1988). The potential of *Leucaena leucocephala Acacia karroo,* and *Morus alba* to increase agricultural production (fodder production, crop production and fodder quality) was investigated in an on-station agroforestry trial at the university research farm (Ukulinga).

The trees selected were indigenous nitrogen fixing tree (*A. karroo*), an exotic nitrogen fixing tree (L. *leucocephala*) and an exotic fruit bearing tree (*M. alba*). The selection criteria was based mainly on the rural farmers' constraints, namely, improvement of soil fertility, shortage of land, shortage of fodder, lower crop production and importantly fire wood for energy source. A similar trial conducted in the Northern Drakensberg revealed that indigenous *A. karroo* had the potential for fodder production, the fruit bearing tree, *M. alba*, had the potential for fuel wood production and *L. leucocaphala* increased its fodder production over time (Everson *et al.* 1998). The study examined their potentials under different environmental conditions presented on section 3.2 of Chapter 3. The study examined an indication of species response to intercropping and those tree species suitable for planting as hedgerows. The potential of these species to supply fuel wood for the rural poor was also determined. Competition for solar radiation is the most prominent above-ground competition between hedge-row trees and companion crops (Nair 1993). In this study therefore the competition was measured through the recorded yield of the trial treatments. That is the grain and the stalk yield which serves as a valuable fodder for cattle in rural areas particularly during winter.

The main principle of agroforestry is to ensure that intercropping of trees and crops together permits suitable yields of selected fibre and food crops. The intelligent application of agroforestry requires an understanding of the major physical factors determining plant distribution across the landscape, namely, light, moisture, temperature, nutrients, latitude and altitude (Nair 1993; Kang 1987). The aim of study was to quantify the potential of agroforestry to rural farmers. The study focused on the potential of alley cropping to meet rural people's daily constraints in farming systems in terms of fodder and fuel wood production.

7.2. Research objectives

- To identify suitable fodder tree species to address shortages of fodder and fuel wood.
- To evaluate the efficiency of alley cropping in crop production.

7.3. Materials and methods

The agroforestry trial was established in 2001 at the University Research Farm (Ukulinga farm). The site in Ukulinga was prepared by heavy discing followed by rotovating to attain fine form suitable for planting maize.

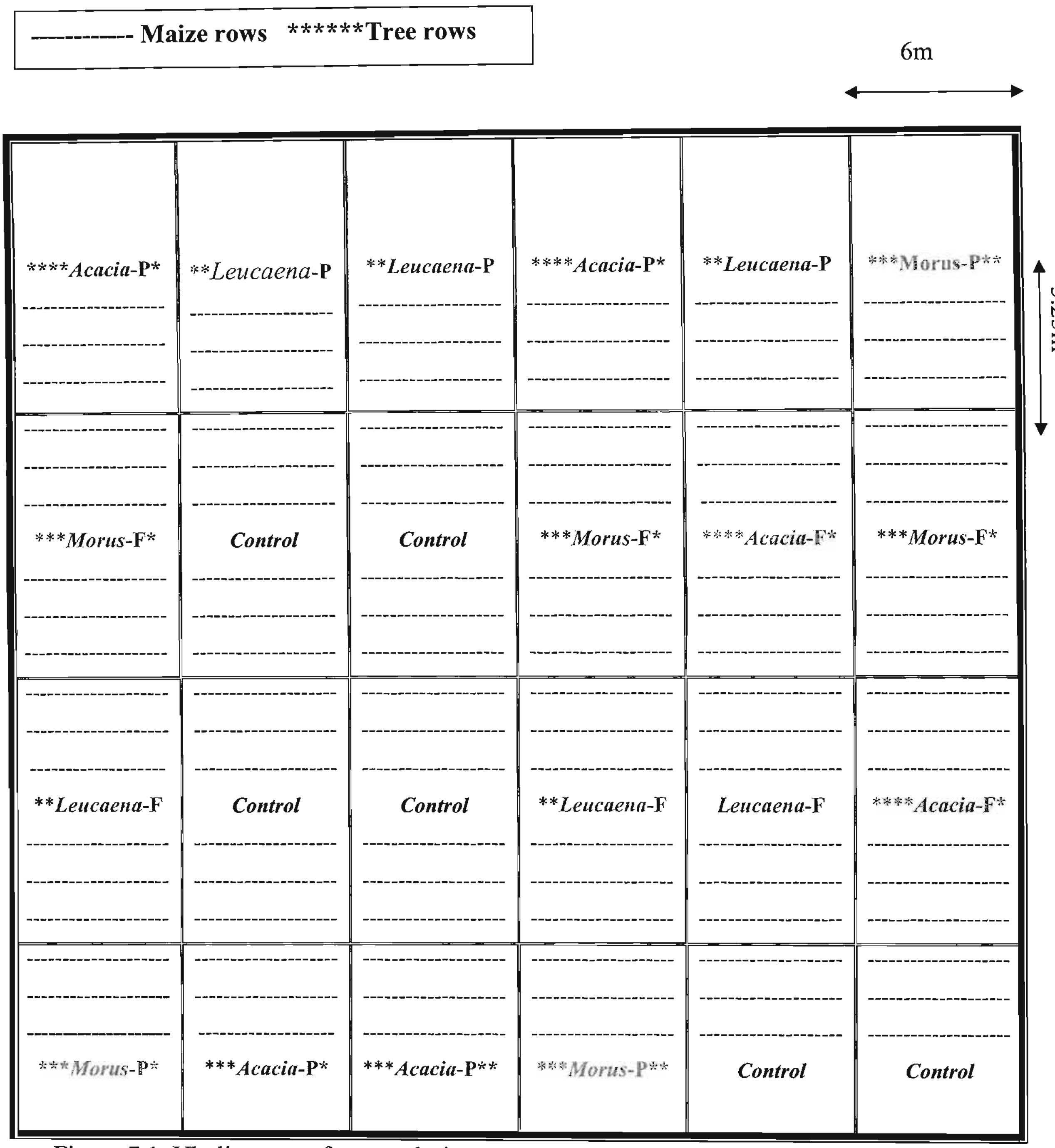
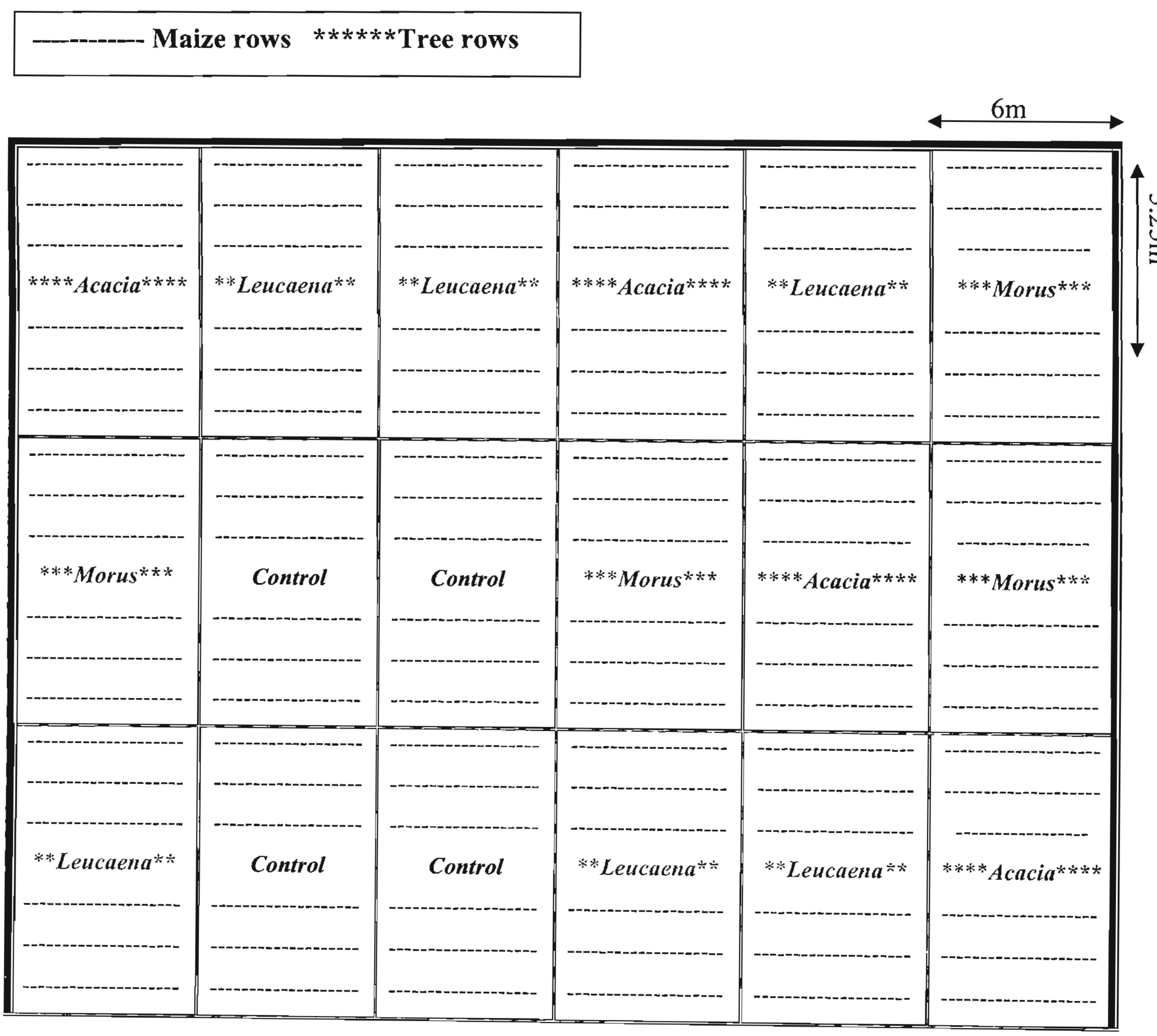


Figure 7.1. Ukulinga agroforestry design

An alley cropping trial was implemented (Figure 7.1) during the first rains of spring in August 2001. Maize was intercropped with fodder tree species in a 36 m × 21 m plot sizes. The intercropped plots were randomly allocated in the trial site. Due to initial errors that occurred during the first season, the trial resulted in two different designs varying from the first season to the following season of 2003. The design in Figure 7.1 therefore resulted in unequal replicates of treatments randomly allocated due to mentioned errors. The main effect was tree species (*L. leucocephala*, *M. alba*, *A. karroo*) based on their planting arrangements (full and partial alley cropping). The full alley cropping treatment (F) was a tree row intercropped on both sides by three rows of maize. The partially intercropped treatment (P) was indicated by one sided planting of three maize rows (Figure 7.1). This design originated from an error during planting in which the outer three maize rows were not planted.



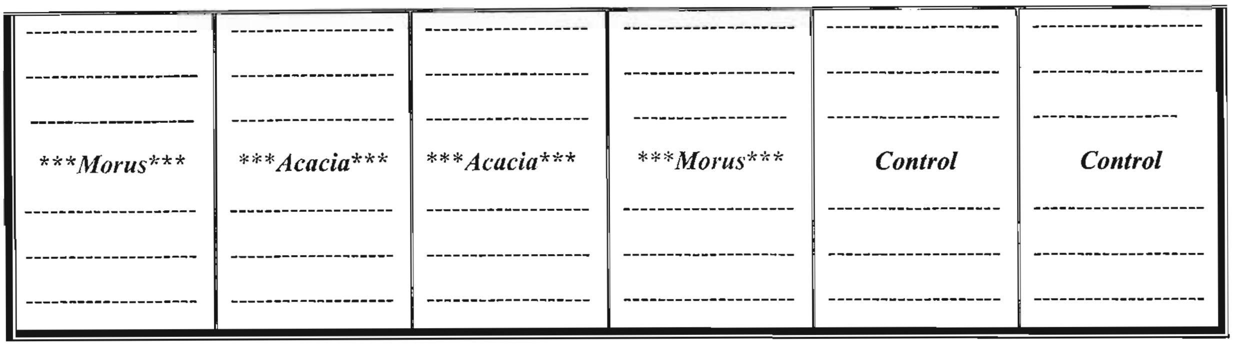


Figure 7.2 Ukulinga agroforestry design

In the second season the trial was altered to a full alley cropping system in which all tree species were fully intercropped (Figure 7.2). The treatments plots were randomly allocated with four treatments replicated six times. The interactions between fodder tree species and maize crops were determined in terms of crop yield and tree biomass. Both designs (Figure 7.1 and Figure 7.2) had control plots planted with maize sole for comparison purposes.

7.3.1. Tree species

Both the designs comprised 24 plots (6 × 5.25m). Trees planted were nitrogen fixing *L. leucocephala*, indigenous nitrogen fixing *A. karroo* and non-fixing (N_2) *M. alba*. The treatments from the two designs were as follows:

Table 7.1 Planting arrangements during first season

Treatments	Number of replicates	Planting arrangements
Morus alba-F	3	Fully intercropped
Morus alba-P	3	Partially intercropped
L. leucocephala-F	3	Fully intercropped
L. leucocephala-P	3	Partially intercropped
A. karroo-F	2	Fully intercropped
A. karroo-P	4	Partially intercropped
Control-F	4	Six rows of maize
Control-P	2	Three rows of maize

The trial during the second season comprised four treatments replicated six times. The table below shows the planting arrangements

Table 7.2 Planting arrangements during second season

Treatments	Number of replicates	Planting arrangements
Morus alba	6	Fully intercropped
L. leucocephala	6	Fully intercropped
A. karroo	6	Fully intercropped
Maize sole	6	Fully intercropped

These tree species were planted at a spacing interval of 0.5 m between trees and 2.26 m between rows. The trees were planted using seedlings germinated under controlled environment from the Grassland Arboretum (UKZN). Each plot had 12 tree species closely planted in rows. Trees were initially irrigated once a week, for six consecutive weeks to allow an even sprout rate. In rural areas where irrigation system is not feasible, it is recommended that farmers plant trees during rainy season to stimulate better growth.

7.3.2. Maize crops

During the first season, 18 rows of maize were planted at a spacing interval of 30 cm between plants and 75cm between rows. The spacing interval of maize rows in Okhombe, normally ranges from 20 cm to 40 cm. Maize was planted during the beginning of summer rainfall (November 2001) after two months of tree establishment. An approximate amount of 250kg ha^{-1} of fertilizer 2:3:2 + 5% Zinc was applied when planting maize and weeds were eradicated through hand hoeing when entering their third month of growth. In rural areas, this can be replaced by kraal manure or crop residues. During the second season the number of rows was increased to 24 to fulfil the fully intercropped design.

7.3.3. Tree growth

Stem diameter and tree height were recorded three times (September 2001, January 2002 and April 2002) before the initial harvesting of biomass. The harvesting of trees in this study refers to the cutting of tree branches at about 75 cm from the base and the cutting of twigs less than 4 mm in diameter using tree clippers. The April 2002 measurements were done eighth months prior to biomass harvesting. A consistent height of 10 cm from the base was used for measuring stem diameter using a calliper. In the multi-stemmed species which coppiced after harvesting, the largest trunk was selected for diameter measures. These measurements were repeated again in September 2002, five months after harvesting to evaluate after-harvest recovery. The last measurements were done in April 2003 prior to biomass harvesting.

7.3.4. Tree harvest

The time of harvesting was subjectively determined by means of visual observation, primarily when competition for light occurred between trees and maize crops, and also when trees start dropping leaves.

Eighteen plots were harvested in April 2002 after seven months of establishment to determine the browsable material and the amount of fuel wood produced. The second harvest was done 12 months after the first harvest in April 2003. The biomass was obtained by cutting the trees with machetes at consistent height of 75 cm from the base and only twigs less than 4 mm in diameter were cut, using clippers. The harvested edible leaves and twigs were weighed together as forage and tree branches were weighed separately as wood. The dry matter of all samples was determined; forage samples were oven-dried for 48hrs and fuel wood samples for 72hrs.

7.3.5. Maize grain and stalk harvest

The maize grains and stalk yield were also harvested in April, after six months of growth. Both maize cobs and stalks were hand cut weighed and air-dried for 30 days due to wet weather that prevailed during the harvesting season. The moisture content of the grain was determined using a moisture meter. The recommended accepted moisture content level in grains for safe storage is 14%. The samples were oven dried at 60^0 C for 48hrs and dry weight was recorded.

7.3.6. Data analysis

In order to determine whether the species growth differed significantly between treatments, tree species height and diameter data were subjected to one-way analysis of variance (ANOVA) using Genstat (2002) statistical package. When the F-test of the ANOVA was significant (< 0.05), least significant difference (LSD) tests were used to compare means among species tree growth.

7.4. Results

7.4.1. The effect of alley cropping on tree growth

September 2001

The height of the indigenous *A. karroo* (1.03 m) tends to be significantly slower than *L. leucocephala* (1.33 m) and *M. alba* (1.65 m) in intercropped treatments (Figure 7.3). The partially intercropped plots revealed similar results. *Acacia karroo* averaged 1.1 m against a highly significant height ($P > 0.001$) of 1.5 m and 1.7 m of *L. leucocephala* and *M. alba* respectively.

The data on tree growth was presented through the use of bar charts.

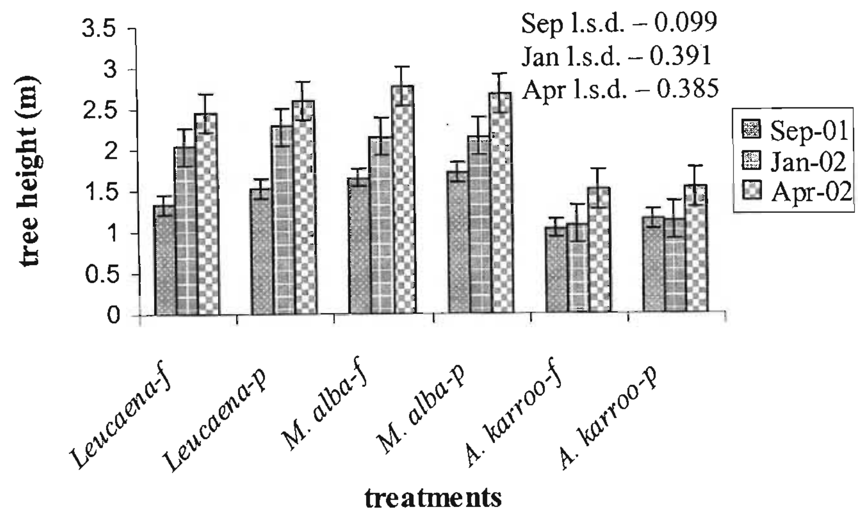


Figure 7.3. Tree growth from second month (September 2001) to the ninth month (April 2002) of establishment prior to harvesting.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

The increase in tree diameter after planting showed a similar trend, with *M. alba* having the greatest diameter ($P > 0.001$) when compared to species on two planting arrangements (Figure 7.4). *Acacia karroo* had a low growth of stem diameter from both planting arrangements as compared to other species. It attained a 17 mm and 14 mm diameter from both partial cropping and fully cropped respectively as compared to an increased diameter of 34 mm and 31 mm from *M. alba*, partial cropping and fully cropped plots respectively. *Leucaena leucocephala* had an averaged diameter of 29.0 mm and 18.3 mm from the partially and fully intercropped plots respectively.

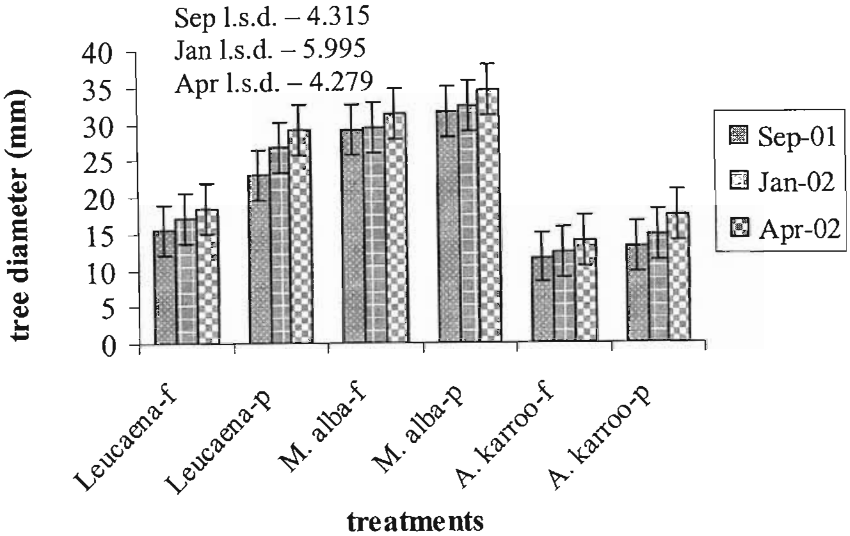


Figure 7.4. Tree diameter from second month (September 2002) to the ninth months (April 2002) of establishment prior to harvesting.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

January 2002 (see Figure 7.1 and Figure 7.2)

After five months of establishment the growth form showed similar trends, with *A. karroo* indicating having a significantly ($P > 0.001$) lower height. *Morus alba* and *L. leucocephala* became the fastest growing species in the trial. *Morus alba* attained an increased averaged height of 2.15 m and 2.14 m while *L. leucocephala* attained 2.2 m and 2 m from the partial and fully intercropped treatments respectively. *Acacia karroo* attained lower mean height of 1.1 m and 1 m from the partial and fully intercropped treatments respectively (Figure 7.3).

The stem diameter also follows similar trends of a significantly slow growth form for *A. karroo* in comparison to *M. alba* and *L. leucocephala*. For instance, data from the partial cropping treatments reveal an average low stem diameter of 12 mm for *A. karroo*, 22 mm and 31 mm for *L. leucocephala* and *M. alba* respectively (Figure 7.4).

April 2002

The April data is essential in this study because it shows the actual growth form prior to harvesting. The September and January data showed that *M. alba* is a fast growing species due to the significant difference in height and diameter in comparison to *L. leucocephala* and *A. karroo*. The April data shows no significant difference ($P < 0.05$) in growth form between *L. leucocephala* and *M. alba*. *Acacia karroo* prior to harvesting had the lowest significant ($P > 0.05$) growth rate when compared to other two species (Figure 7.3 and 7.4).

October 2002

It is important to note that all trees harvested in April were cut at a consistent height of 75 cm above ground. The after recovery therefore was expected to be similar due to the same growth height. The data revealed similar growth rate of *M. alba* and *L. leucocephala*, both being significantly different ($P > 0.05$) from *A. karroo* growth which was subjected to a slow recovery (Figure 7.5 and 7.6).

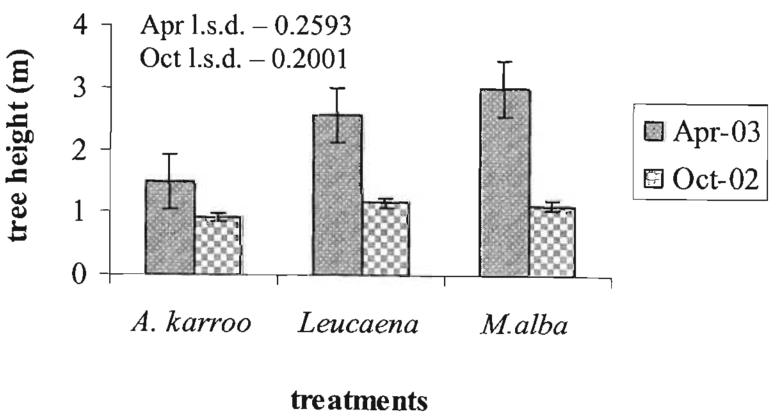


Figure 7.5. Tree growth after-harvest recovery (October 2002) and prior to harvesting in the second season (April 2003).

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

April 2003

Prior to harvesting trees in the second season, *M. alba* attained a highly significant growth (P > 0.001) in height and diameter in comparison to *L. leucocephala* and *A. karroo (Figure 7.5). Morus alba* was pruned at an average height of 2.9 m compared to 2.5 m and 1.4 m of *L. leucocephala* and *A. karroo* respectively (Figure 7.5 and 7.6).

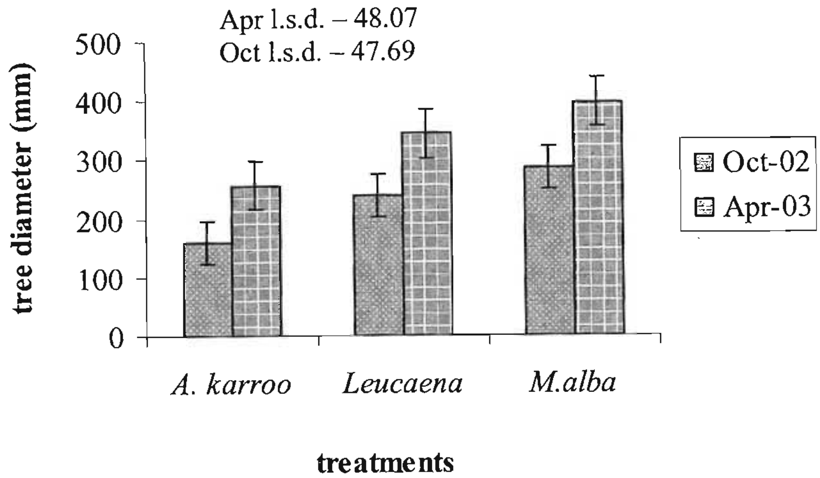


Figure 7.6. Tree diameter after harvest-recovery (October 2002) and prior to harvesting in the second season (April 2003).

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

7.4.2 The effect of alley cropping on tree biomass (forages and fuel wood)

Due to unequal replications in the trial during first season of the study, the data was subjected to unstructured one-way ANOVA to determine the significant effects of alley cropping on tree species. The data was also subjected to Post Hoc Turkey's HSD (Honest Significant Different) test to confirm ANOVA results, whether there were significant differences in tree biomass. It is not advisable to rely on ANOVA results only given unequal replicates of treatments.

April 2002

Leucaena leucocephala yielded significant difference in forage production (665 kg^{-1}) when compared to *A. karroo* and *M. alba* which yielded 374 kg^{-1} and 345 kg^{-1} respectively from the partial cropping arrangement. Although *A. karroo* produced high forage, the different was not significant ($P < 0.05$) from *M. alba* fodder production. All the fully intercropped treatments yielded no significant difference in fodder production. Although there were no significant differences, *M. alba* yielded high fodder production (408 kg^{-1}) compared to *A. karroo* (210 kg^{-1}) and *L. leucocephala* (254 kg^{-1}). Data presented on Figure 7.7 below.

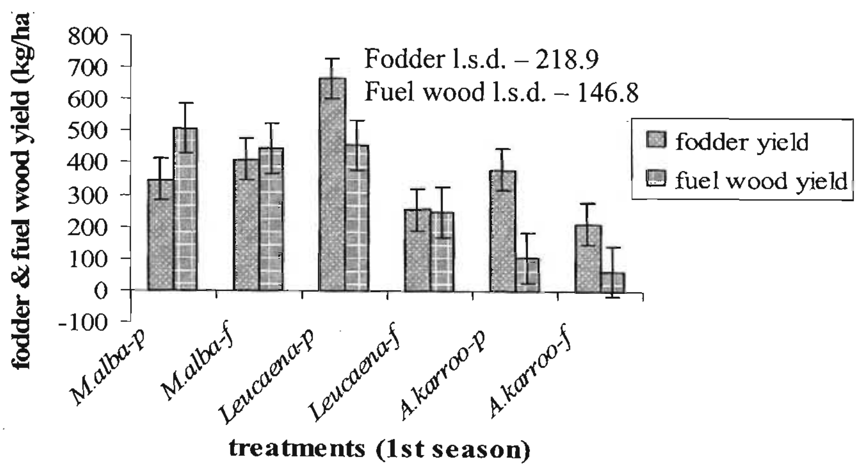


Figure 7.7 Averaged fodder and fuel wood yield in April 2002.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

There were no significant differences in fuel wood yield ($P < 0.05$) from the partially intercropped *M. alba* (507.9 kg ha^{-1}) and *L. leucocephala* (455.0 kg ha^{-1}) species, but the yield from both species varied significantly from the *A. karroo* yield (103.2 kg ha^{-1}). With regard to fully intercropped plots, fuel wood yield from all tree species varied significantly ($P > 0.001$) with *A. karroo* resulting in the lowest yield (63.49 kg ha^{-1}), *L. leucocephala* producing 243 kg ha^{-1} and *M. alba* (444 kg ha^{-1}) the highest yield.

April 2003

All species had increased fodder yield in their second season. During the second season of planting, trees species were all subjected to a complete alley cropping whereby six rows of maize where planted in between tree lines (Figure 7.2). Surprisingly there was no significant different in forage yield between *M. alba* (1101 kg ha^{-1}) and *A. karroo* (1140 kg ha^{-1}). While a high yield was recorded when partially intercropped, the 2003 data revealed that once *L. leucocephala* is well established, it becomes more productive. *L. leucocephala* (1715 kg ha^{-1}) yielded a highly significant ($P > 0.001$) fodder production in comparison to *M. alba* and *A. karroo* (Figure 7.8).

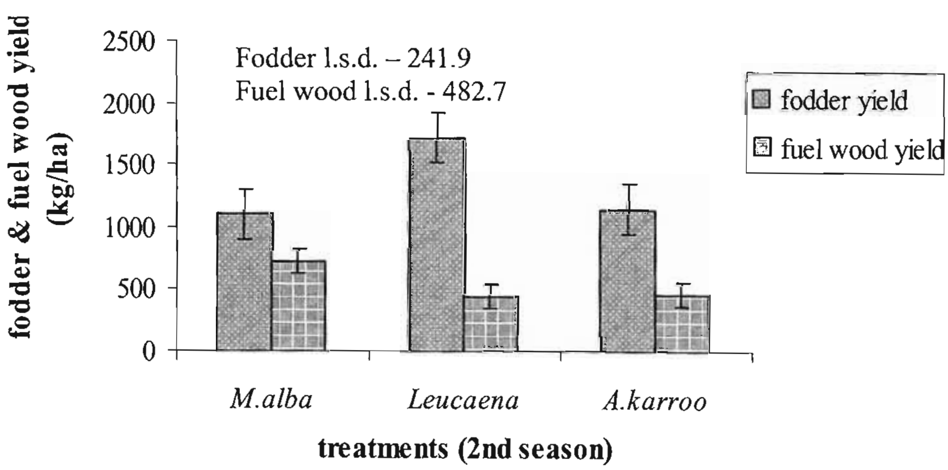


Figure 7.8 Averaged fodder and fuel wood yield in April 2003.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

In the second season of the trial, *M. alba* proved productive in meeting the needs of rural poor by producing higher fuel wood than other species. The yield increased from 444 kg ha^{-1} in 2002 to 728 kg ha^{-1} in 2003. Although a high yield was recorded, statistical tests revealed the difference in yield from three species was not significant ($P < 0.383$). *L. leucocephala* and *A. karroo* produced 456 kg ha^{-1} and 439 kg ha^{-1} respectively. For *A. karroo*, this was a significant increase in fuel wood yield in comparison to 63 kg ha^{-1} ha during the first season. The greater fuel wood yield of *M. alba* when compared to *L. leucocephala* and *A. karroo* make this species more suitable for fuel wood production.

7.4.3 The effect of alley cropping on crop yield

The data comparison was done firstly on the planting arrangement, which is the average yield from treatments without observing the crop distance, secondly on the yield comparison of crop distance from trees (for example, the maize yield from the 75 cm, 150 cm and 225 cm rows) and also compare yield from crop distance within treatments. The knowledge of correct spacing is important especially in the adoption of agroforestry practices by small scale farmers or rural farmers. It is advisable that proper spacing be negotiated into between the extension officers or community facilitators with farmers adopting this form of agricultural practices. The data analysis on tree-crop interactions based on distance serves as a basis for decision making with farmers. The data from the second season was statistically analysed using a no blocking one-way ANOVA from the Genstat Statistical Package. The reason for the use of no-blocking One-Way ANOVA was because treatments were randomly allocated on the design without blocking (Figure 7.2).

April 2002

- **Maize rows at 75 cm distance from the tree lines.**

The average grain yield and stalk yield of the first maize rows, (75 cm away from the tree lines) were statistically analysed to investigate the difference in production within treatments. In terms of grain yield, different tree species had no significant effects on the yield of rows adjacent to the tree lines. From the partially intercropped treatments, *A. karroo* had the highest yield (898 kg ha^{-1}) and the *M. alba* plots (579 kg ha^{-1}) yielded the least production (Figure 7.9).

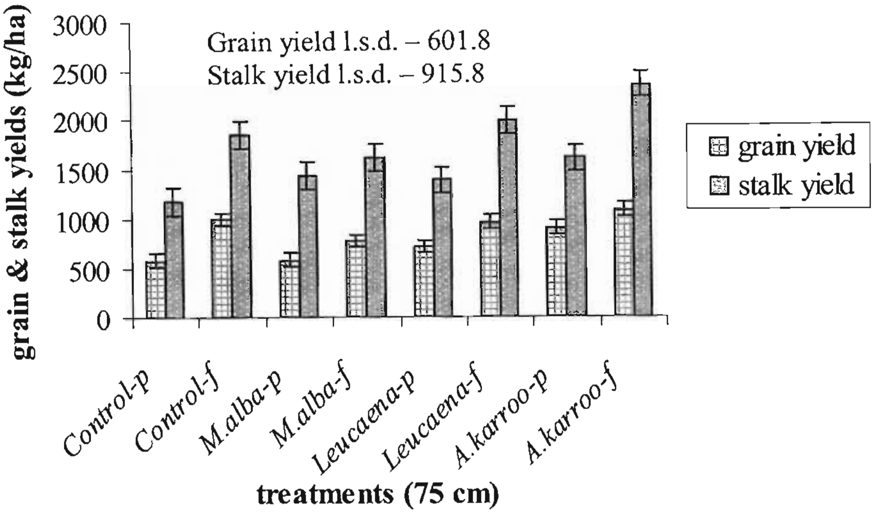


Figure 7.9 Mean maize grains and stalk productions (kg ha^{-1}) in April 2002.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

The same results were recorded from the fully intercropped treatments whereby *A. karroo* had the highest yield of 1078 kg ha^{-1} with *M. alba* recording the least production of 774 kg ha^{-1}. The results from the fully intercropped plots indicated the treatments yielded no significant difference ($P > 0.05$) in stalk yield from the first row (75 cm) adjacent to the tree lines. The maize stalk yield from *L. leucocephala*-f (1989 kg ha^{-1}) and *A. karroo*-f (2349 kg ha^{-1}) plots had higher production than the control plots (1849 kg ha^{-1}) while that of *M. alba* was low (1608 kg ha^{-1}). The highest stalk yields from the partially intercropped plots were recorded in the *A. karroo* plots. Although there was no significant difference ($P > 0.05$) in stalk yield, the *A. karroo* plots had the greater production (1603 kg ha-1) of mass per hectare compared to yield average of 1175 kg ha^{-1} from control plots (Figure 7.7).

- **Maize rows at 150 cm distance from the tree lines.**

The second maize rows which were 150 cm away from the tree lines had similar results in that it had no significant effects ($P > 0.05$) on crop yield. The control plots yielded no significant difference in yield when compared to treatment plots. The control plots had greater yield in grain outputs when compared to both partial and fully intercropped treatments, though the difference in yield was tested not significant.

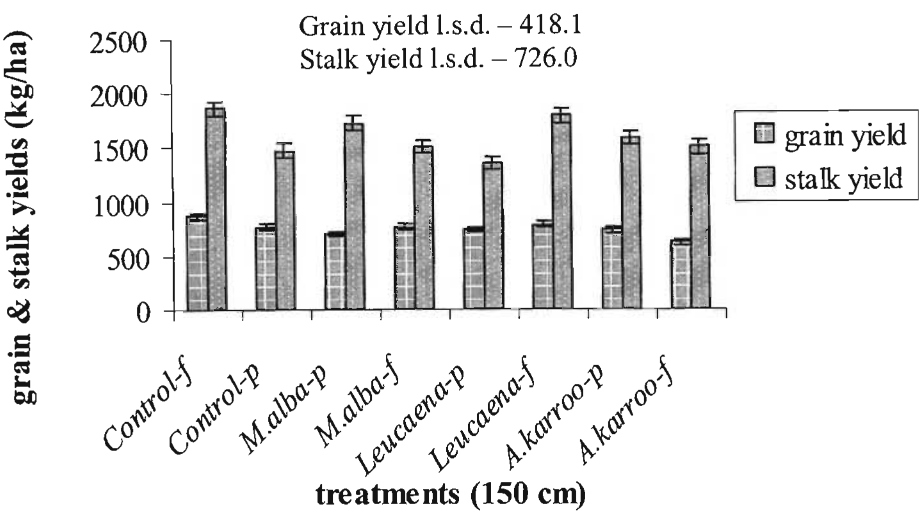


Figure 7.10 Mean maize grains and stalk productions (kg ha^{-1}) in April 2002.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

M. alba-p recorded a high stalk yield of 1725 kg ha^{-1} and *L. leucocephala* plots produced lower yield of 1354 kg ha^{-1} (Figure 7.10). In the fully intercropped plots, control plots had the highest yield (1861 kg ha^{-1}) compared to 1500 kg ha^{-1} and 1503 kg ha^{-1} from *A. karroo* and *L. leucocephala* respectively. Statistical test results showed both the planting arrangements had no significant effects ($P > 0.05$) on stalk yield.

- **Maize rows at 225 cm distance from the tree lines.**

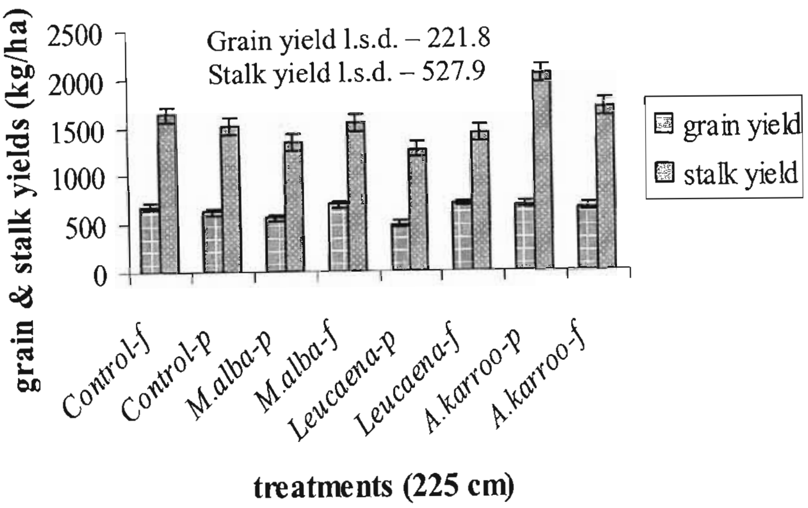


Figure 7.11 Mean maize grains and stalk productions (kg ha^{-1}) in April 2002.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

The crop yield at 225 cm away from the tree lines was not significantly different ($P < 0.05$) from the control plots, implying that at this distance trees do not have a negative effect on grain and stalk yields. For instance, *L. leucocephala* plots recorded the highest grain output (701 kg ha^{-1}) in comparison to other treatments, though the difference was not significant (Figure 7.11).

April 2003

In 2003, Pietermaritzburg region experienced a seasonal drought that resulted in low soil moisture content and high temperatures. These conditions had a negative effect on the crop yield in the trial. The maize stalks dried out and the growth form stunted before reaching the tusseling stage. The maize cobs data was therefore not available due to drought effects. As the maize stalks did not produce maize cobs only the stalk yield data was available.

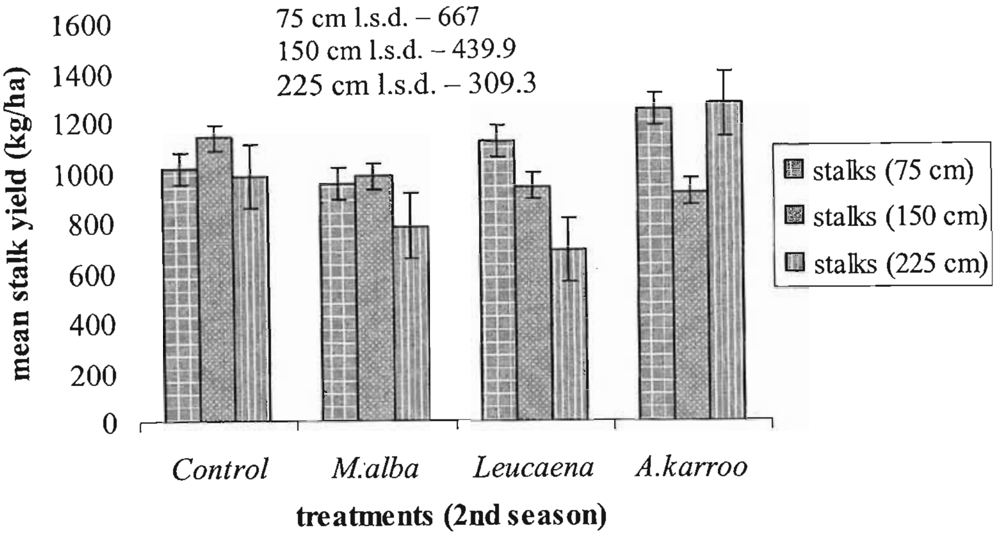


Figure 7.12 Mean maize stalk productions (kg ha^{-1}) in April 2003.

l.s.d. > Least significance difference

Error bars indicate standard errors of differences of mean

- **Maize rows at 75 cm distance from the tree lines.**

The average stalk yield from all the adjacent rows to the trees decreased from 1671 kg ha^{-1} in the first season (Figure 7.10) to 1078 kg ha^{-1} in the second season (Figure 7.11) of the trial. The *A. karroo* treatment had the highest stalk yield of 1238 kg ha^{-1} which had decreased from 1976 kg ha^{-1} in the first season. The stalk yield from all treatment plots decreased in the second season when compared to first season. The results from second season revealed there was no significant difference ($P < 0.05$) between treatments and when compared to the control.

- **Maize rows at 150 cm distance from the tree lines.**

The average stalk yield from the 150 cm distance in 2003 was lower (991 kg ha-1) than the first season (1619 kg ha^{-1}). The control plots yielded the highest of 1135 kg ha^{-1} with *A. karroo* plots producing the least production of 913 kg ha^{-1} (Figure 7.11). Although differences in production were recorded, the statistical analysis showed alley cropping had no significant influence on stalk yield ($P > 0.05$).

- **Maize rows at 225 cm distance from the tree lines.**

Stalk yield at 225 cm spacing from the tree hedgerows, like the other spacings decreased in all treatments when compared to the first season production (Figure 7.11). The 2002 mean was 1571 kg ha^{-1} and decreased in 2003 to 925 kg ha^{-1}. The *A. karroo* treatment yielded the highest averaged yield of 1259 kg ha^{-1} compared to the least production of 780 kg ha^{-1} from *M. alba* treatments. In general the stalk outputs were less variable between treatments, when compared to the 2002 results.

7.5 Discussion

Nair (1993) explained alley cropping as an agroforestry system that entails growing food crops between hedgerows of planted shrubs and trees, preferably leguminous species. The hedges are pruned periodically during the crop's growth to provide biomass and to prevent shading of the growing crops.

The increase in height and diameter of a plant species is normally a good index of its capacity for successful development, especially in the initial establishment phase. Foroughbakhch (1992) emphasised that when other factors such as spacing, competition, and soil quality later begin to take effect, the absolute importance of height increment diminishes and other criteria need to be evaluated for monitoring growth. This indicates the importance of monitoring height and diameter of trees at the establishment stage, to evaluate the effects alley cropping has on tree growth.

Tree species from this study showed significant differences in tree growth. An indigenous *species, A. karroo,* was the main focus of this study to compare its potential against two exotic species, *L. leucocephala* and *M. alba.* The perception about indigenous trees is that they are slow growing and expected outputs like biomass yield is only satisfactorily after a long period of time. These perceptions do not make indigenous species favoured by farmers especially if the fodder shortage is highly required for cattle.

Among some interesting characteristics of *A. karroo* stated by Barnes *et al.* (1996) and Teague (1989) are that it occurs naturally over a wide range of climatic conditions with rainfall distribution ranging from 200 mm to over 1500 mm. Once established, the tree becomes frost resistant and frost of -10° C may defoliate the plant but not kill the trees. This tree species grows on soil ranging from pure unconsolidated sand to heavy clays, also thrives on deep alluvial clay-loam soil and even on more acid soils. The tree has deep taproot and is independent of surface moisture where underground water is available making it drought resistant. Though locally adapted to the South African environment it has a significantly lower tree growth when compared to exotic species that may be perceived as not well adapted to the local environment (Barnes *et al.* 1999; Teague 1989).

The 2002 October data revealed that *A. karroo* did not have a strong coppicing power because during the recovery assessment, *L. leucocephala* and *M. alba* were readily recovering with new green shoots coppicing during winter. *L. leucocephala* is a fast growing species that thrives under repeated cutting and coppices readily. Similar results were recorded by Everson *et al.* (2003) from their alley cropping trial in the Highland Sourveld area. Their results indicated an averaged height of 1.5 m in *A. karroo* after 450 days of planting to an average of 3.0 m of *M. alba*. The same nature of growth was discovered from their trial in that *M. alba* reaches maturity faster than other species and *L. leucocephala* has a very slow establishment phase but once established increases its growth rapidly. Foroughbakhch (1992) reported *M. alba* showed a prodigious growth potential from the moment of planting, but suffered height reductions in winter. He noted that their rapid growth makes it ideal for silvopastoral and agroforestry purposes.

Fodder shortage, especially during the dry winter season, is on of the main problems facing cattle owners in the Upper Thukela region of KwaZulu-Natal. One option by Everson *et al.* (1998) was to grow fodder trees which supply palatable, nutritious material during winter when natural grassland is not nutritious.

Rural people in the Okhombe area have been using fuel wood as an energy source for years and do so even when they have access to power energy. Due to poverty the importance of wood is increasing dramatically. Agroforestry can alleviate fuel wood shortages by the planting of suitable multiple-purpose plants that have uses in addition to providing fuel. Trees suitable must adapt well to different sites and establish easily. This study investigated the potential of multipurpose trees that in addition to addressing fuel wood shortages can also address other rural needs such as fodder shortages.

Over the two seasons of the study, *L. leucocephala* (produced 665 kg ha^{-1}) proved to be a good potential tree species for use in alley cropping practices. Even during the dry periods that occurred in the second season of the trial *L. leucocephala* recovered well after harvesting and produced high fodder yield compared to other tree species (Plate 2).

Plate 4: Alley cropping during dry season (2nd season of the trial).

These factors are advantages when addressing fodder deficits in rural areas. Kruger (1998) also recommended the use of *L. leucocephala* for addressing fodder deficits from the results of his trial. He conducted a fodder bank trial in nine randomised blocks, with a row spacing of 2 m for *L. leucocephala* and 1 m for *Desmanthus virgatus* and a net plot size of 28 m^2 for *L. leucocephala* and 14 m^2 for *D. virgatus*, all cut at approximately 30 cm above ground level. The study recorded forage yields between 500 kg ha^{-1} (*D. virgatus*, 22 months) and 2500 kg ha^{-1} (*L. leucocephala*, 26 months). Cumulative forage yields for all the seasons were 13 488 and 6 243 kg ha^{-1} for *L. leucocephala* and *D. virgatus* respectively. Krecik, Lantagne, Gold & Roshekto (1993) reported *L. leucocephala* has high potential of addressing feed deficits during dry season. This was confirmed from the trial when yield of *L. leucocephala* (26000 kg ha^{-1} after 8 weeks of establishment) outweighed *Gliricidia sepium* (20000 kg ha^{-1} after 12 weeks of establishment) and *Calliandra calothyrsus* (7300 kg ha^{-1} after nine weeks of establishment) yields when planted with grass. Fodder yield of *L. leucocephala* varies due to differences in environment, plant type, harvesting interval, and frequency and planting density (Maclaurin 1982).

Morus alba may produce higher fodder and fuel wood yield but its fast growth rate make it less potential to address fodder deficits in rural areas and become integrated in alley cropping. *M. alba* reaches maturity at a maximum height within a short period of time and its growth nature results in less fodder during dry season. The highly branched trees in agroforestry are not applicable in alley cropping due to the shading effect when cropped with other plants unless frequent harvesting will be applied. Stewart and Salazar (1992) pointed out that aggressive branch expansion may inhibit the growth of other intercropped plants. According to Everson *et al.* (2003), *M. alba* put most of its energy into wood growth under the harvesting treatments applied, which may be a disadvantage for dairy farmers (Plate 3).

Plate 5: *M. alba* intercropped with maize. Note maize height on *M. alba* plot compared to control plot.

Although not well recommended from this study, good yields of *M. alba* were recorded from other studies. Makkar (2000) stated good yields may vary from 19000 to 28000 kg ha^{-1} of fodder in five seasons. Carlos (2000) recommended short cutting height of *M. alba* due to results from his study. Fodder yields dropped 37% (10000 kg ha^{-1}) from cutting height of 60 to 90 cm above ground height and 13% (2200 kg ha^{-1}) from 90 to 120 cm height. Depending on the farmers' needs, Shayo (1997) emphasised *M. alba* must be a considered tree species of high potential in agroforestry. The results from Shayo's study (1997) revealed that increasing plant density of *M. alba* increases forage yield. That is as planting density is reduced, yield per plant decreases owing to competition, but total forage yield per unit area increases. The study also indicated that when harvested twice, at the end of rainy season and in mid season, gave a considerably amount of fodder (Shayo 1997).

Acacia karroo, a slow growing indigenous tree species showed some potential although not as good as *L. leucocephala. Acacia karroo* spends much energy producing edible materials which is good for fodder purposes especially to small stock (Plate 4).

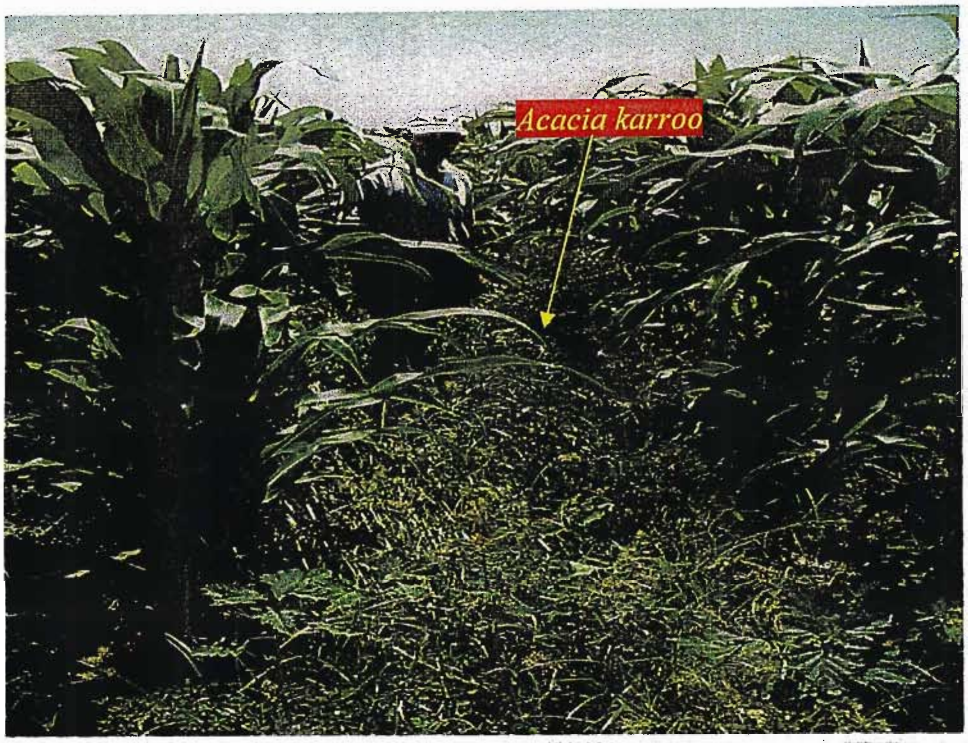


Plate 6: *Acacia karroo* intercropped with maize crop. Note the height of *A. karroo* compared to the *M. alba* height on Plate 2. *A.karroo* yielded satisfactory biomass though recorded short height.

The foliage and green pods of *A. karroo* are important sources of browse for livestock (Barnes *et al.* 1996).The tree species is more preferred by goats than sheep and cattle. The study by Teague (1989) indicated that when sheep and goats were allowed on a dense stand of *A. karroo,* sheep spent 6% and goats 50% of their foraging time feeding on *A. karroo* coppice shoots. Cattle also browse *A. karroo,* particularly when it is the only green forage in woodland at the end of dry season, but they do not browse it preferentially as do goats (Barnes *et al.* 1996). The literature indicates it is a good species for animals but preferentially small stock. Evaluating results from this study, it may be concluded that *A. karroo* has promising potential over the long term when compared to *M. alba.* The results from Everson *et al.* study (2003) conform to this conclusion on *A. karroo.* This tree when planted at 50 cm spacing produced more fodder than planted at 1 m spacing. *Acacia karroo* in its first year of establishment became the most productive tree (1600 kg ha^{-1}) in terms of available forage when planted with *M. alba*, *L. leucocephala* and *Gleditsia triancanthos* which recorded the lowest yield (< 300 kg ha-1). *A. karroo* at narrow spacing (50 cm) showed promising results when becoming more productive to the level of *M. alba* as it was not expected due to its slow growing form. The results from this study also indicated the species was producing even slightly higher than *M. alba*. This is an indication that the tree spent more energy producing more fresh coppice shots than wood production.

According to Stewart & Salazar (1992), wood production is a function of crown size in aborescent dicotyledons in which the lateral branches grow more quickly than the central apex. This growth habit gives rise to a broad dispersed canopy especially in poor dry sites. In most cases, more branched trees result in higher wood production than fodder materials.

In this study *A. karroo* produced a fairly consumable fodder resulting in less woody material. The opposite results were obtained from *M. alba* recordings which produced maximal yield within a short period of time; becoming more branched and becoming the most productive woody species (Plate 5). For fuel wood purposes, M. *alba* is a preferred species over other tree species. This also suggests a strategy that for fodder yield purposes, *M. alba* should be regularly pruned to avoid the development of woody materials.

Plate 7: Partial planting arrangements showing *A. karroo* and *M. alba.* Note the tree height of the two species.

Stewart & Salazar (1992) recommended that in a simple cook-stove, branch as small as 2-3 cm in diameter may be ideal. This tree may prove satisfactory for village fuel wood if it grows fast and produces a dense wood that burns with intense heat. Thus confirms the potential of *M. alba* for use as a wood producing species even when in its younger stage due to favourable wood diameter. Although the current reality is that in most parts of dry South Africa, rural people are using *A. karroo* woods for their energy source (Bembridge 1990).

The other species were also cited as good trees for wood production. For instance, *L. leucocephala* was cited by Loxton & Associates (1990) as tree species that produce very good fuel wood of medium density, burns well with little smoke and leaves little ash (1%). The fuel wood produces little ash produces high energy, and lasts longer, and is beneficial for heating purposes especially during winter due to little smoke produced. The study by Bembridge (1990) in rural Ciskei found that *A. karroo* ranked the cheapest, preferred form of energy by a staggering 73% of the population as compared to 16% preferring dung. The wood burns brightly and evenly with little smoke and no odour. It splits easily and, once dried, it does not easily absorb moisture again if left out in the rain. The long lasting wood is most preferable in rural areas for cooking and heating, implying the species is among the most popular for addressing fuel wood shortage.

Production of vegetable crops under conventional and intensive cropping systems relies on use for fertilizers. This may not always be feasible or economical in rural farming systems due to limited availability or high cost of fertilizers. Alley cropping as mentioned earlier is a form of agroforestry wherein food crops are grown in alleys between hedgerows of trees and shrubs. (Palada, Kang & Claassen 1992). The most significant advantage of alley cropping is the capability of legume trees to fix nitrogen, thereby improving soil fertility. Soil improvements by legume trees are economically beneficial to rural farmers because it replaces the cost of buying fertilizers to improve soil nutrients. The Ukulinga agroforestry trial was conducted over two seasons. As the second season was a moisture-stressed period, it was an ideal opportunity to determine the effect of drought lands on maize production in an alley cropping system. (Plate 6).

Plate 8: Alley cropping during dry season (February 2003)

The planting arrangements implemented during the first season showed no significant yields ($P > 0.05$) in crop outputs from different treatments. Details are given on the data presentation section. The idea of the planting arrangements was to investigate the effect of alley cropping given full intercropping and partial intercropping. The results from the first season were encouraging in that *A. karroo*, the indigenous tree showed the potential of being intercropped with maize. While producing more fodder than the fast-growing exotic *M. alba* tree, the adjacent rows near *A. karroo* had higher maize grain production than other tree rows. Adjacent rows from partial and full rows produced 1603 kg ha^{-1} and 2349 kg ha^{-1} compared to 1849 kg ha^{-1} and 11 75 kg ha^{-1} from full and partially intercropped rows of control plots. (Plate 6). The high grain outputs may be due to less competition as a result of its slow growing nature. (Plate 2). Although *A. karroo* plots recorded good production in some other rows when compared to other tree plots, the control plots recorded the highest grand mean production. However these differences were not significant. Unfortunately during the second year, no maize cobs were developed due to drought. However the stalk yields produced when combined with tree yields could be important in fodder production in rural areas.

Many studies indicated some promising results of intercropping crops with trees, especially leguminous trees. The trial conducted by Banda, Maghembe, Ngigi & Chome (1994) retained good maize yields for six years from alley cropping with *L. leucocephala*. The good yield was maintained without chemical fertilization without any adverse effects from *L. leucocephala*-maize root competition. The advantages of alley cropping were also expressed as essential in controlling soil erosion (Banda *et al.* 1994). The yields of maize obtained from this trial demonstrate the beneficial effects of the conservation system of closely spaced hedgerows in steep slopes. The control plot experienced a rapid yield decline as the result of irreversible soil degradation. Thus the control produced much lower yields than the hedge plots and the difference between the two reported widening over time (Banda *et al.* 1994).

Kang, Wilson & Sipkens (1981) increased maize grain yields from 1.9 t ha^{-1} in unfertilised control plots to 3.5t ha^{-1} in plots mulched with *L. leucocephala* from 4 m wide rows. Kang (1987) has demonstrated the long-term yield sustainability of alley cropping in trials conducted over 10 years in southern Nigeria. With minimal additional inputs of N, P and K fertilizer, maize yields in the *L. leucocephala* alley cropping plants were maintained at an average of 3.5t ha^{-1} while in fertilised control plots yield fell to 2t ha^{-1}.

In another trial by Kang (1987), the legume plots resulted in more maize grain yield than plots of non-legume trees. For instance, *Acioa batenii* produced 24.5 kg $ha^{-1}$of N yield from harvesting, and the N uptake by maize 12.6 kg ha^{-1} produced a maize grain yield of 2588 kg ha^{-1}. Plots planted with leguminous *L. leucocephala*, had N yield of 231.1 from harvesting, and had N uptake by maize of 41.9 kg ha^{-1} therefore producing 3210 kg ha^{-1} of maize grain yield. The experimental trial by Everson *et al.* (2003) also indicated the potential of alley cropping to rural traditional cropping systems. After two years of its existence, they have reported with the exception of *M. alba* at 50 cm interval, the maize grain yield from *A. karroo, L. leucocephala* and *Gleditsia triacanthos* was higher than the control plots. The highest maize grain yields were recorded in the *A. karroo* (6500 kg ha^{-1}) planted at 50 cm interval and *L. leucocephala* (6000 kg ha^{-1}) planted at 1 m spacing. They reported that it may be attributed to the nitrogen fixing properties of these to species. Everson *et al.* (2003) stated that the fast growing nature of *M. alba* and *G. triacanthos* had a negative impact on maize yield of the rows closest to the trees. In their report, they suggested the results may be attributed to the greater tree heights of these two species and the consequent negative effect of shading on crop yield (Everson *et al.* 2003). Their suggestions were from a long term study of alley cropping. The Ukulinga trial was only conducted for two seasons, and suggestions such as the shading effect could not be justified.

The yields from this trial were very low when compared to other findings in the literature. The yield from the first season was low as was attributed to the establishment of trees. Trees were still in their first year of establishment and their benefits to crops were in the early stages. In the second season, the yield of stalks was very low due to the drought effect. Legume trees in particular should be encouraged in cropping systems due to their ability to fix atmospheric nitrogen. Legume trees have small lateral roots that occur near the soil surface and bear the nitrogen-fixing nodules performing a symbiosis with rhizobium bacteria (Bischopp 1994; Nair 1993). Dzowella, Wandera, Were & Mohammed-Saleem (1998) stated that this symbiosis is exceptionally effective and rates of 500 kg N ha $year^{-1}$ have been reported from *L. leucocephala*. This is an equivalent to 1 785 kg LAN (28% N) fertilizer. This nutrient contribution was confirmed by Sanginga, Mulongoy & Ayanaba (1989) who used the N dilution method to make a precise evaluation of the nitrogen-fixation rate of *L. leucocephala* grown in an Alfisol, pH 6.1. The results showed that the species fixed 98 – 134 kg N ha^{-1} in six months. Maclaurin (1982) stated roots from *L. leucocephala* form symbiotic mycorrhizal association with certain fungi to influence nutrient uptake especially phosphorus from infertile soils.

7.6. Conclusion and Recommendations

The basic concept of agroforestry is that the choice of hedgerow species for alley cropping as stated by Gutteridge (1998) is extremely important and can often determine the success or failure of the system. Rachie (1983) and Nair (1993) suggested that the ideal hedgerow species should have the following attributes: rapid establishment and growth rate, ability to regrow after frequent cutting, nitrogen fixing capacity, low tannin content in leaf, deep rooted with a different root distribution to the crop and ability to withstand environmental stresses. Conclusion from the trial was therefore based on the above mentioned attributes.

Based on results obtained from two seasons, *L. leucocephala* and *A. karroo* have many of the attributes mentioned above. *Leucaena leucocephala* is very slow in its establishment but once established, the species has high rapid growth, and its coppicing power makes it an ideal tree in an alley cropping system. This is because if the farmer's objective is to address fodder, fuel wood crisis and enhance crop performance, then *L. leucocephala* maintains satisfactory growth even after frequent harvesting to minimise shading effects. The pruned branches therefore provide fodder and fuel wood to the farmer. *Acacia karroo* has good potential in alley cropping due to its high fodder production. Its slow growth makes it a recommended species because the tree itself tends to minimise the shading effect to crops (Plate 7).

If the farmer's intention is to maximise fuel wood production then A. karroo must not be recommended in the system. Its branches are very thin and edible to small stock preferably goats. The species poses no risks to the environment because it is an indigenous tree that tolerates adverse climate conditions. Kruger & Grossman (1998) emphasised that the benefits of *L. leucocephala* far outweighs the environmental risks stipulated by the Department of Water Affairs' Working for Water programme. The risks were stated as insignificant when compared to the enormous potential benefits. Invasions of badly degraded and eroded natural vegetation may take place if adjacent plantings should be abandoned by humans. The argument therefore is that the chances of invasion are extremely small since women spend between 300 to 500 hrs year^{-1} gathering firewood in rural areas (Kruger & Grossman 1998).

Plate 9: Alley cropping prior to harvesting in April 2002. The trial was in its 9th month of establishment.

The results from the trial showed that *M. alba* is a good species for fuel wood production, but is not a desirable species for use in alley cropping especially to maximise fodder production. The observation from the trial indicated that it has a rapid establishment and growth rate that develops into a branchy canopy. This may sound ideal for fodder production, but the problem observed was its poor coppicing base when compared to *L. leucocephala*. The tree reaches its maximum growing stage quickly which is not preferable for areas experiencing winter feed deficits. Fast growing *M. alba* has the potential of affecting crop production, in that its growing height influenced the growth height of maize.

The adoption of alley cropping is not only about ecological potential but rather it must have satisfactory outputs for addressing the farmers' economy. Though not investigated economically, the study looked at the introduction of trees in a production system. While the biomass outputs are an integral part for the adoption of agroforestry, more research is required to examine the economic benefits of agroforestry. Much research is required to assess the costs of agroforestry establishment in terms of labour and capital inputs since the high costs may discourage the widespread adoption of agroforestry by small-scale farmers. Information on marginal profit needs to be explored and presented back to farmers involved in adopting the system. Evidence of profitability will be major criteria for encouraging farmers to invest in agroforestry.

The concept of agroforestry is very broad and should be applied according to the individuals' objectives. For instance, apart from their beneficial effects on soils the tree species with rapid canopy closure may decrease the growth of weeds. This implies that the canopy characteristics of the trees will affect their suitability for inter-planting with annual crops and will dictate the management practices required when used in agroforestry systems (Montagnini, Jordan & Machado 2000). Choice of suitable crop species is also important for the success of alley cropping systems. Montagnini *et al.* (2000) gave an example of different crops, for example, maize and rice are more light demanding than beans or cassava and thus more affected by shade. The reality of this to the Ukulinga trial is that, trees like *M. alba* which are fast growing and branchy may be suitable to crops like beans while other trees that slowly develop huge canopies and have good coppicing power may be suitable for maize fields. Important to note in agroforestry is that the height of harvesting and the width of alleys can be adjusted to avoid excessive competition between crops and trees.

Montagnini *et al.* (2000) emphasised that given land with poor soil nutrients, the advantages of agroforestry may not be realised nor be profitable during the first years of establishment. A build up in nutrients and soil carbon may take years to the point where the system is profitable compared to monocultures. Gutteridge (1998) cited that in alley cropping in Indonesia, the results obtained were that a hedgerow system provided higher yields after 5 years and higher economic returns after 10 years. In a study conducted by Everson *et al.* (2003), the economic benefits of agroforestry were apparent within four seasons of establishment. They recommended that agroforestry with a high fodder production by the tree component is essential (Everson *et al.* 2003).

In a nutshell therefore, the adoption of agroforestry should be encouraged given suitable tree species and the right crops for alley cropping. The combination of maize stover and fodder from trees could be very essential to address feed deficits.

CHAPTER 8: Ukulinga Agroforestry Trial – Forage Quality

8.1. Introduction

"It is important to have a thorough knowledge of how to grow crops, but if the crops are to be used for feeding purposes, it is equally important that there is knowledge of their nutritive values" (Maclaurin 1982). The nutritive value was defined by Meissner, Zacharias & O'Reagain (1999) as the amount and types of nutrients the animal can derive from the feed. The feed value is one of the most important factors affecting ruminant productivity, regardless of whether animals are in a feedlot or grazing (Van Soest 1994). In sourveld particularly, where quality forage fluctuates with the season, is important to know the feed quality fed to livestock. In Okhombe cattle are traditionally fed on the available grasses during summer and entirely on roughages (crop residues) during winter.

The problem of roughages is the complications experienced by animals from these feeds because stomach volume normally restricts the intake of feed so that the animal eats less than its capacity to utilize nutrients (Orskov 1994). To stimulate feed degradability in the rumen it is necessary to supplement with high quality protein sources such as Lucerne, oil seeds, cereals, and high carbohydrate feeds such as molasses, germ meal, and bran. Supplementing of forage diets is aimed primarily at alleviating nutritional deficiencies in the rumen and thereby enhancing the utilisation of roughage (Nsahlai *et al.* 1998). The disadvantage of feeding cattle entirely on roughage is the low protein content crop residues such as maize stover has in their diet. The feed therefore tends to ferment slowly and must, by nature of its particle size, stay in the rumen for a considerable time until the particles, which are not digestible, are small enough to pass out of the rumen (Orskov 1994; Orskov 2000). The results are poor energy content in the body due to feed consumption restrictions, which may lead to illnesses such as pregnancy diseases as a result of mineral deficiencies (Singh & Makkar 2000).

The rumen is inhabited by symbiotic micro-organisms, whose function is to break down some of the fibrous feed components, since in general the animals lack enzymes that degrade cellulose (Czerkawski 1986). These micro organisms are bacteria, protozoa and fungi which mostly function in the absence of oxygen. They use mostly various sources of nitrogen, energy and minerals for their growth and any lack of these factors can limit their growth (Czerkawski 1986; Byebwa 2000). The rate of degradation of the feed depends solely on the diet fed to animals.

The relevance of the Ukulinga study is that poor diet is fed to cattle in Okhombe every year during winter. The hypothesis of this study is that poor nitrogen availability in roughage feeds and its deficiencies in the rumen reduces the efficiency of bacterial growth, and may reduce the rate and extent of digestion of organic matter in the rumen which may reduce feed intake, energy intake and efficiency of feed and protein use.

The potential of three fodder trees (*Morus alba*, *L. leucocephala* and *A. karroo*) was investigated for use as supplements for the supply of sufficient protein and required minerals and vitamins to poor fed diet. The value of roughages feeds was also investigated and determined by their nutritional value and palatability. The nutritive value is closely correlated to the voluntary intake of feeds. For instance the higher the protein the higher will be the voluntary intake and the higher the intake the better the animal will perform (Meissner *et al.* 1999).

A laboratory feed evaluation was conducted to find out the content level of crude protein (CP), digestibility (acid detergent fibre) and indigestible materials (lignin and crude fibre). Poor feed nutrition is commonly accepted as one of the most critical limitations to livestock production. The lack of minerals, energy and protein are often responsible for sub optimum livestock production. For instance, lack of minerals in the feeds result in wasting diseases, anaemia, and loss of appetite, bone abnormalities, tetany, and low infertility (National Research Council 1996). The general aim of this study was therefore to investigate the potential of *M. alba*, *L. leucocephala* and *A karroo* as supplements during winter (the supply of protein, minerals, and vitamins to the poorly fed diet). A recommendation was given that supplements must be provided when the crude protein of the feed ingested by the animal drops to 6% or less (National Research Council 1996).

The National Research Council (1996) recommended that a supplement of protein, phosphorus, salt, energy and any other nutrient can be beneficial only when the unsupplemented animal ingests too little of these nutrients. Important in supplementing is the insurance that there is enough roughage, even if it is of low grade, because the purpose of supplementing is to increase roughage intake and overcoming protein deficiency in winter roughage.

An experiment was conducted to study the rate at which dry matter loss of three different fodder samples and roughage samples were degraded under different diet ranging from poor *Eragrostis* hay to high quality diet of concentrates and less hay. This was performed with surgically prepared animals equipped with cannulae in the rumen. The principle in the *in situ* method is incubation of small feed samples in the rumen in fibre bags. The bags have pores small enough to retain the feed sample, but large enough to allow bacteria to enter the bags. Due to the small amounts of feed sample incubated, the feed under examination will not affect the rumen fermentation, and it is assumed that the conditions within the bag are similar to the conditions in the surrounding rumen content. The method is termed the nylon bag technique (Mehrez & Orskov 1977).

8.2. Objectives

- To determine the chemical composition and digestibility of foliage (*Morus alba, A. karroo,* and *L. leucocephala)* as supplements to low quality maize stover.
- To evaluate the nutritive value (chemical composition and digestibility) of roughage feed (maize stover) as the main diet to cattle during winter.
- To investigate the influence of poor *Eragrostis* hay and protein rich concentrates diet on the rumen degradability of roughage and protein feeds.

8.3. Materials and Method

The fodder and roughage (maize stover) samples used for this study were collected from the agroforestry trial after the grain harvest and fodder harvest from the first season of the trial (April 2002). The roughage samples were split into three sub-samples; the maize stalks sole, maize leaves sole and a combination of the two, to evaluate the preferred nutritional plant parts by cattle. The protein samples were *M. alba, A.karroo* and *L. leucocephala* foliage. To ensure representation from all replicates of the agroforestry trial, a handful of foliage were collected from each plot and a sample of 5 kgs was taken, put into a bag and taken for coarse milling.

After coarse milling, both the fodder and roughage samples were then milled through a 2 mm screen using a laboratory mill for the *in vivo* digestibility trial. Sub-samples from the milled samples were then subjected to a 1 mm screen for the *in vitro* feed value evaluation in the laboratory. The major chemical constituents evaluated were crude proteins, the fibre fractions (ADF and NDF) and the anti quality substances (condensed tannins).

8.3.1. Chemical analyses

Different laboratory techniques were used to determine protein, fibre and tannin composition of the feeds mentioned above. Neutral detergent fibre (NDF) is a laboratory procedure that accurately measures the amount of cellulose, hemicellulose and lignin in a feed (Meissner *et al.* 1999). The potential intake of forage by a cow is inversely related to its NDF content. In addition, the acid detergent fibre (ADF) which quantifies cellulose and lignin is a good estimate of the digestibility of forage. The (ADF) and (NDF) were measured by the method of Van Soest, Robertson & Lewis (1991). The crude protein content of the feed was determined using the Kjeldahl method (AOAC 1990). Condensed tannin, a quantitative secondary metabolite reduces the protein digestibility and inhibits digestion. Condensed tannin was determined using the proanthocyanidin method (Waterman & Mole 1994).

8.3.2. Rumen degradability study

8.3.2.1 Animal diets

Four fistulated non-lactating cows (Jerseys and Friesland-Holstein) were housed in stalls and fed on different rations based on 2% feed offered per live weight. Due to limited number of fistulated cows available, a Friesland –Holstein was also included in the trial. Each cow was fitted with a rumen cannula (8.0 cm internal diameter) for use in the incubation study (Mehrez & Orskov 1977). Diets were offered in three periods (i.e. three replicates) of 10 days each, comprising five days of adaptation, followed by five days of incubation. Adaptation is important in this study because it is the basal diets fed to the fistulated cow that determine the rate and final extent of dry matter disappearance from the nylon bag (Norton 1981). Three cows were used at each period, the Friesland-Holstein selected as representing the rural cow fed entirely on *Eragrostis* hay and one jersey subjected to adaptation of 80% concentrates and 20% hay and the other 60% of concentrates and 40% of hay.

Table 8.1 Feed offered at 2% of their live weight.

Period 1				
Cow type	**Weight (Kg)**	**Feed intake (kg)**	**Concentrates (kg)**	**Hay (kg)**
Holstein	445	8.9	0	8.9
Jersey[1]	415	8	6.4	1.6
Jersey[2]	381	8	4.8	3.2
Period 2				
Cow type	**Weight (Kg)**	**Feed intake (kg)**	**Concentrates (Kg)**	**Hay (Kg)**
Holstein	445	8.9	0	8.9
Jersey[3]	498	10	8	2
Jersey[2]	381	10	6	4
Period 3 was repeated on same cows used in Phase 1				

The degradability rate of the sub-samples was examined under various diets ranging from poor to protein rich diet. The poor diet simulated the rural cow's performance under protein herbage supplements. The protein rich diet was also used to determine the effect of an animal's performance. The concentrates ingredients composition and chemical analysis of the concentrate portion of the test ration were as follows:

Table 8.2: Ingredients composition (g kg^{-1}, as fed basis) and chemical analysis (g kg^{-1}, DM basis) of the diet used in the study.

	Rations	
Ingredients	**Diet 1**	**Diet 2**
Maize meal	630	430
Cane molasses	50	50
Cotton seed oilcake meal	85.4	85.4
Limestone	18.3	17.5
Urea	5.0	5
Salt	2.5	2.5
Vitamin & min. premix	2.0	2
Phosphoric acid	6.3	6.9
Monensin (mg/kg)	20	20
Sulphur (mg/kg)	358	486
Chemical analysis		
Dry matter	877	876
Crude protein	142	166
Crude fibre	52	57.2
Ash	56.8	73.6
Calcium	10.9	16.5
Phosphorus	4.9	6.4

Key

Diet 1: 20% ammoniated veld hay, 80% concentrate mixture

Diet 2: 40% ammoniated veld hay, 60% concentrate mixture

8.3.2.2. Incubation procedure

The bags were incubated in the rumen of the cows in duplicate following the method described by Mehrez & Orskov (1977). The study used nitrogen-free polyester bags, with an average pore size of 50 ± 15 μm for the experiment. Bags were cleaned, dried and weighed prior to use. Approximately 5 g of the milled samples was measured and transferred into the nylon bag and the weight of bag plus sample was recorded and labelled. The bags were tied to a round stainless steel disc (100 g, 6 cm diameter, 4 mm thick) with 10 evenly spaced small holes drilled around the outside of the disc to tighten the strings. The disc was tied to a nylon string and secured to the rumen cannula to avoid loss of bags in the rumen. Two bags per sample were placed in the rumen of each of the three cows for each incubation period. A total of 84 bags were placed in the rumen of each of the three cows for the incubation period. Samples were incubated in the rumen for 4, 8, 16, 24, 24, 72 and 96 hours. The procedure was repeated until all samples were incubated.

8.3.2.3. Withdrawal of bags

Bags were withdrawn on completion of the incubation period, placed in a bucket of cold water to prevent further fermentation and were washed thoroughly under running tap water to wash off the feed particles adhering to the outside of the bags. Bags were transferred into a semi-automatic washing water (cold water) for five cycles lasting five minutes each to wash off debris from the rumen attached to the bags. A constant volume of water was used to rinse the bags. Bags were drained and replaced by clean water after each cycle. All samples were dried in the oven at 60°C for 48 hours. Bags were removed after 48 hrs, cooled in desiccators, untied from the fishing line and weighed for DM loss.

The following equation was used to determine dry matter loss:

$$\frac{\text{Feed DM \%} \times \text{Sample Weight} - (\text{Bag Residues} - \text{Bag Weight})}{\text{Feed DM\%} \times \text{Sample Weight}} \times 100\%$$

8.4. Results

In order to determine whether the different diets have a significant influence on the degradability of forage and roughage samples, the data on dry matter disappearance from the rumen was subjected to one-way analysis of variance (ANOVA) using Genstat (2002) statistical package. When the F-test of the ANOVA was significant (< 0.05), least significant difference (LSD) tests were used to compare means of the DM loss.

8.4.1. Data presentation

The following abbreviations were used in **Table 8.4**, **Table 8.5** and **Table 8.6**:

Mulb – *Morus alba*

Acacia – *Acacia karroo*

Leu – *Leucaena leucocephala*

Stalks – Maize stalks

Leaves – Maize leaves

Stalks/Leav – Maize stalks and leaves.

8.4.1.1. Chemical composition (Table 8.3)

Sanchez (2000) stated the difference in nutrient values from an array of authors mostly is due to a difference in species variety, age of the leaves and growing conditions, season and browsing pressure.

Table 8.3 Chemical composition of forage and roughage feeds

Feed type	Chemical composition			
	CP (%)	NDF (%)	ADF (%)	CT (%)
Morus alba	11.71	42.86	36.96	0.65
Leucaena leucocephala	19.27	50.38	40.41	1.19
Acacia karroo	13.60	44.16	34.64	5.69
Maize stalks	1.60	81.60	50.30	
Maize leaves	2.63	77.92	46.92	
Maize stalks/leaves	2.12	79.02	49.29	

Key

CP – crude protein

ADF – acid detergent fibre

NDF – neutral detergent fibre

CT – Condensed tannin

A wide array of literature referenced in this chapter recommended *M. alba*, *A karroo* and *L. leucocephala* as among the most nutritious tree forages fed to ruminants. The results (Table 8.3) showed high level of crude protein (CP) content for *L. leucocephala* (19.27%) compared to *M. alba* (11.71%) and A. karroo (13.60%). The roughage samples (maize stover) as predicted have extremely low CP contents (1.60% to 2.12) which are below the acceptable range of 6 – 8% for host animal (Dalzell, Stewart, Tolera & McNeill 1998). This shows the nutrient consumption by rural cattle on maize stover during winter is below the minimal level recommended for animal performance.

In terms of digestibility, high proportions of NDF can suppress forage intake due to reduced rates of fibre digestion and passage through the rumen (Van Soest 1994). The cell wall residues remaining after neutral detergent extraction represent the proportion of plant dry matter made up of cellulose, hemicellulose and lignin (Van Soest 1994). The results (Table 8.3) showed that maize stover have high anti-digestibility percentages (77.92% to 81.60%). The feed intake for cattle feeding on maize stover is therefore very low compared to forage feed which had low fibre percentages (42.86% to 50.38%). Digestibility is very essential for nutritive value assessment because it is usually well correlated with digestible energy rate in the rumen. It has a direct effect on absorption of nutrients and influences the amount of feed consumed by the animal (Meissner *et al.* 1999). All fodder samples showed a high potential of digestible ADF material ranging from 34.64 to 40.41%. The high content of NDF in the roughage samples made this feed undesirable for livestock consumption and has therefore affected the digestibility rate of these feeds. Tannin, an anti quality factor in forage is capable of binding to protein, carbohydrates and minerals and thus resulting in a significant decrease in forage quality (Meissner *et al.* (1999); Makkar 2005). *A. karroo*, contained high levels of tannin (5.69%) compared to lower levels of 0.65% and 1.19% for *M. alba* and *L. leucocephala* respectively.

8.4.1.2. Eragrostis hay diet (Table 8.4)

Table 8.4: Dry matter loss (%) from the rumen of a Holstein fed entirely on *Eragrostis* hay diet during the experiment (P < .001).

				Feed Type (DM Loss %)				
Time	**Leuc**	**Acacia**	**Mulb**	**Leaves**	**Stalks/leav**	**Stalks**	**l.s.d.**	**SEM**
4 hrs	32.22[a]	27[b]	26[b]	15[c]	14[c]	13.3[c]	2.905***	0.943
8 hrs	34[a]	30[b]	27.67[c]	17.67[d]	17[d]	14.4[e]	2.935***	0.943
16 hrs	39[a]	32.67[b]	31[c]	22[d]	19.67[d]	17.1[e]	4.337***	1.408
24 hrs	43[a]	35[b]	45[c]	29[d]	27.33[d]	21.8[e]	6.105***	1.981
48 hrs	44[a]	50.5[a]	52[a]	37[b]	40.3[b]	28.2[c]	8.83***	2.86
72 hrs	52.2[a]	53[a]	60.6[c]	40.66[d]	44[d]	32.9[e]	6.800***	2.207
96 hrs	55[a]	61[a]	64[a]	42[c]	45.6[c]	37.8[d]	7.78***	2.52

Values in a row with letters in common are not significantly different at the 1% level.

Key

*** - highly significant difference (P <.001)

l.s.d. – Least Significant Differences

SEM – Standard error of the mean

Under this type of diet which is poor due to lack of proteins, the most readily degraded feed was *L. leucocephala.* At 4 hrs to 16 hrs, *L. leucocephala* had high DM disappearance ($P < 0.05$) compared to the other feeds. Its DM loss ranged from 32.22 to 39% compared to low DM loss of *A karroo,* for instance which ranged from 27% to 32.67% at 16 hrs. *Morus alba* degradability was better when compared to other protein feeds after 48 hrs ($P < 0.05$) and the rate of *L. leucocephala* degradability dropped after 24 hrs. The DM loss of *A. karroo* seemed consistent from the 4 hrs (27% DM loss) to the final 96 hrs (61% DM loss) of being incubated and its DM loss was in between the *M. alba* and *L. leucocephala* feeds. With regard to the roughage samples, maize leaves were better degraded within 24 hrs of incubation ($P < 0.05$). The maize leaves lost between 15% to 22.33% at 4 hrs and 16 hrs respectively and maize stalks lost between 13.33% and 17.33% at 4 hrs and 16 hrs respectively. Surprisingly, the degradation rate was not significantly different from the maize stalks/leaves (14% to 19.67% at 4 hrs and 16 hrs respectively) combination as predicted. The maize stalks, with a low dry matter degradability of 37.8% after 96 hrs of incubation were the least degraded ($P < 0.001$) compared to all feed samples incubated in the Friesland-Holstein rumen. It is important to note that jersey cows were not fed the *Eragrostis* hay.

8.4.1.3. *Eragrostis* hay (20%) and 80 % concentrates mixture diet (Table 8.5)

Table 8.5: Dry matter loss (%) from the rumen of a jersey cow fed 20% hay and 80% of concentrate diet ($P < .001$).

			Feed Type (DM Loss %)					
Time	**Leuc**	**Acacia**	**Mulb**	**Leaves**	**Stalk/leav**	**Stalks**	**l.s.d.**	**SEM**
4 hrs	33^a	28.67^b	28.33^b	16^c	15^c	12^c	3.138^{***}	1.018
8hrs	36^a	31^b	30.3^b	19^c	18^c	14^c	4.044^{***}	1.312
16hrs	43^a	34^b	36^b	22^c	25^c	19^c	8.57^{***}	2.78
24hrs	47^a	38^a	48.7^b	28^c	33^d	25^d	9.06^{***}	2.94
48hrs	56^a	52.3^a	60^a	35^b	42^b	34^b	9.41^{***}	3.06
72 hrs	59.7^a	55^a	72^b	41^c	49^c	37^c	8.77^{***}	2.84
96hrs	61^a	65^a	82.33^b	49.7^c	53^c	44^d	6.761^{***}	2.194

Values in a row with letters in common are not significantly different at the 1% level.

*** - highly significant difference ($P < .001$)

l.s.d. – Least Significant Differences

SEM – Standard error of the mean

The decrease in Eragrostis hay (poor nutrients) diet, with an increase in the concentrates diet (high protein feeds) resulted in high DM loss of the feeds. *Morus alba* had the highest degradability rate of 82.3% ($P < 0.001$) DM loss compared to 65 and 61 % for *A. karroo* and *L. leucocephala* respectively. This diet also showed some digestibility potential of *L. leucocephala*, because of its readily degradable DM ($P < 0.001$) compared to other feeds incubated within 16 hrs. The DM loss from *L. leucocephala* at 4 hrs was 33% compared to 28% for *M. alba*. The degradability rate remained unchanged with *L. leucocephala* DM loss of 43% at 16 hrs, the highest compared to least of 34% for *A. karroo*. After 16 hrs the degradability response of *L. leucocephala* and *M. alba* was similar ($P > 0.05$). Between 24 hrs and 96 hrs of incubation, *M. alba* DM attained high degradability rate ($P < 0.05$) of 48.7% at 24 hrs to 82.33% at 96 hrs of incubation. This was high compared to *A. karroo* DM loss of 38% and 65% at 24 hrs and 96 hrs respectively. The DM loss of *A. karroo* was fluctuating with time, picking up slowly and reaching 65% of degradability at 96 hrs, though the least compared to *M. alba* ($P < 0.001$).

With regard to roughage samples, very low DM loss was attained compared to the fodder samples. Emphasising on roughage samples only, maize leaves attained better DM loss (19%) after 8 hrs of incubation ($P < 0.05$), compared to maize stalks samples (14%). The DM loss of maize leaves dropped after 8 hrs and the maize stalks-leaves combination attained high degradability (33% and 53% at 24 hrs and 96 hrs respectively) compared to maize leaves (28% and 49.7% at 24 hrs and 96 hrs respectively) and maize stalks sole (25% and 44% at 24 hrs and 96 hrs respectively). The fodder feeds had high rapid DM loss ($P < 0.001$) with a maximum of 82.33% for *M. alba* compared to the maximum of maize stalks (44.33%).

8.4.1.4. *Eragrostis* hay (40%) and 60 % concentrates mixture diet (Table 8.6)

The third diet indicated a similar degradability trend except for *A. karroo* which had the least degradability loss (24.7% to 56% hrs at 4 hrs and 96 hrs respectively) within the protein feed sample.

Table 8.6: Dry matter loss (%) from the rumen of a jersey cow fed 40% of *Eragrostis* hay and 60% of concentrates diet (P < .001).

	Feed Type (DM Loss %)							
Time	**Leuc**	**Acacia**	**Mulb**	**Leaves**	**Stalk/leav**	**Stalks**	**l.s.d.**	**SEM**
4 hrs	31.33^{a}	24.7^{b}	27^{b}	13.35^{c}	13^{c}	12^{c}	5.594***	1.816
8 hrs	36^{a}	26.65^{b}	29^{b}	17.3^{c}	16^{c}	14^{c}	4.172***	1.354
16 hrs	41^{a}	30^{b}	33^{b}	23.34^{c}	20.33^{c}	16.5^{d}	3.558***	1.155
24 hrs	45.2^{a}	37^{a}	51^{b}	27.7^{c}	26.3^{c}	21.3^{c}	10.10***	3.28
48 hrs	51^{a}	41.2^{b}	59.3^{c}	32.3^{d}	36.7^{d}	33.7^{d}	8.91***	2.89
72 hrs	54.4^{a}	51^{a}	68^{b}	47^{c}	44^{c}	37^{d}	6.617***	2.147
96 hrs	57^{a}	56^{a}	71.33^{b}	54.6^{c}	51^{d}	44^{f}	5.563***	1.805

Values in a row with letters in common are not significantly different at the 1% level.

*** - highly significant difference (P <.001)

l.s.d. – Least Significant Differences

SEM – Standard error of the mean

A difference in degradability (P < 0.05) was between the *A. karroo* and the *M. alba* feeds. With respect to trend, *L. leucocephala* degrade readily, followed by *M. alba* feed (P < 0.05) with the latter attaining high degradability rate after 24 hrs of incubation in the rumen. Under this diet, the DM loss of maize leaf samples (DM loss of 23.34% at 16 hrs) differed significantly (P < 0.001) from maize stalk/leaves combination (DM loss of 20.33% at 16 hrs) and maize stalks (DM loss of 16.5% at 16 hrs) samples. Important to note from this study is that supplementation improves feed degradability compared to a roughage diet with the least DM degradability.

8.5. Discussion

8.5.1 Chemical composition

A major constraint to animal production in developing countries is the scarcity and fluctuating quantity of the year round feed supply. In more recent times, trees and shrubs have been introduced into cropping and grazing systems to provide green foliage high in protein to supplement the available low protein forage (Singh & Makkar 2000). The quality of natural grasslands is usually sufficient during the rainy season, but as maturity advances, the nutritive value of the grassland decreases. Therefore, available feed resources during the dry season are usually unable to provide sufficient nutrients for reasonable livestock productivity and livestock generally looses weight, become susceptible to diseases and have reduced breeding performance (Gerber *et al.* 2000; Ngwa *et al.* 2000).

According to Meissner *et al.* (1999) the protein requirements of an animal depend on its species, age, and the physiological functions being undertaken, such as growth or lactation and its level of production. In general a minimum of between 7 to 8 % crude protein is required by ruminants, but high producing animals require levels approaching 13% to 14% (Meissner *et al.* 1999). According to Dalzell *et al.* (1998) the recommended range for an animal is between 12 to 25% to maximise ruminant animal production.

Greater CP content of over 20% was widely referenced for *L. leucocephala* and *M. alba* foliage. (Wheeler, Chaney, Cecava & Brewbaker 1994, Kruger 1990, Bonsi *et al.* 1995 and Ngwa *et al.* 2000). Ngwa *et al.* (2000) compared the nutritive value of the pods of *L. leucocephala* and *A. karroo* with roughage samples of maize stover. The results showed a low CP content ($P < 0.001$) of 5.35% of maize stover compared to 24.69% and 19.32% of *L. leucocephala* and *A. karroo* respectively. Although nutrients content of foliage varies, *M. alba* and *A. karroo* are also well referenced in terms of chemical composition. For instance, Singh & Makkar (2000) recorded a range of 15 to 27.6% of CP content; Shayo

(1997) reported 18.6% and Gonzalez & Milera (2000) recorded 26.1% of CP. Similar results of crude protein (13.7 to 14.7%) content of *A. karroo* were reported by Barnes *et al.* (1996). Shayo (1997) reported that older leaves of *M. alba* contain lower concentrations of CP (14%) than young leaves (18.6%). Young leaves tend to degrade more readily than old leaves and bark. This fact should be noted when comparing feeds.

Roughages, especially maize stover are known to have low protein content. This was the case in this study whereby the maize stover of the protein content was extremely low to maintain ruminants during winter months. Similar results of low protein content from maize stover were reported by Ngwa *et al.* (2000) and Kabatange & Shayo (1991). The CP content in maize stovers from their results was 5.35% and 0.38% by Ngwa *et al.* (2000) and Kabatange & Shayo (1991) respectively. The CP content of maize stover was low compared to study by Meeske, Basson, Pienaar & Cruywagen (2000), whereby a range of 5.7 to 7.7% of CP content was reported from 12 different maize hybrids. Another study by Kriek, Du Toit & Fair (2000) revealed that some maize hybrids had high CP content ($P < 0.01$) in May during first grazing period, but as the period progresses to July, CP tends to decrease as the grazing progressed. For instance, maize hybrid PAN 6364 had 11.63% of CP content in May and the value dropped to 9.41% in July.

Low NDF content in *M. alba* foliage is comparable to values recorded by Singh & Makkar (2000), Shayo (1997), Gonzalez and Milera (2000). Singh & Makkar (2000) reported NDF content ranging from 33 - 46% from *M. alba* leaves. Shayo (1997) recorded 24.6% from *M. alba* leaves and 46.8% from its bark. Ngwa *et al.* (2000) reported lower NDF and ADF content of *L. leucocephala* compared to pods of *A. karroo*. Kruger (1990) reported an even lower ADF content in *L. leucocephala* foliage, about 21.8% and Byebwa (2000) reported 25.75% compared to 40.41% from this study. Important to note about fibre content in protein foliage, is that the variety from different authors probably is due to the type and physiological maturity of the sample tissues, which comprised older and more fibrous (stem) plant materials (Dalzell *et al.* 1998). According to Dalzell *et al.* (1998), browse forages have different physical characteristics from grass diets, confounding the interpretation of NDF measurements using empirical relationships generated for herbaceous species. The compound leaves of many tree legumes yield small particles sized ingesta, resulting in more rapid passage through the rumen than grass digesta with a similar NDF content. This forage intake of fodder trees is less affected by NDF than grass roughage, although it is important to keep it at a minimum in forages (Dalzell *et al.* 1998). The ADF content in their study had a tendency to increase as the grazing period progresses.

The high content of NDF and ADF in maize stovers is comparable with studies by Kriek *et al.* (2000) and Kabatange & Shayo (1991). Kabatange & Shayo (1991) recorded 73.3% of NDF content in maize stovers and Kriek *et al.* (2000) recorded a range from 23.54% of ADF from hybrid CRN 4512 in May and an increase of 39.04% in July. Kriek *et al.* (2000) concluded in their study that low percentage of DM utilized from one of the hybrids may be attributed to higher values for ADF and NDF. These are factors prevalent and known to inhibit feed utilization by ruminants. The very low values of CP recorded in the maize stover from this study (<2.63%) justifies the need to supplement protein foliage to increase feed intake by ruminants.

One of the few indigenous trees that have the potential to supplement fodder production is *A. karroo*. The results from this study showed that *A. karroo* had a high content of tannin (5.69%) which may decrease its utilization by ruminants. Studies have shown that high tannins content in feed results in poor performance of animals. Mbatha (2001) indicated that dietary intake of feed decreased significantly as tannin levels increased between the diets. Digestibility of DM tended to decrease while the digestibility of CP, organic matter, NDF, and ADF decreased significantly with increasing tannin levels. This can be a negative factor in promoting indigenous A. karroo for fodder production with small-scale farmers.

Shayo & Uden (1999) stated that a big advantage about *M. alba* is that in central Tanzania, the tree contains considerably lower level of condensed tannins compared to leaves and pods of other *Acacia* species. Singh & Makkar (2000) reported a very low content of total tannins (1.8% as tannic acid equivalent) and tannins by the protein precipitation capacity method were not detectable in *M. alba*. References for methods of reducing tannins content in forage are well documented in literature such as Makkar (2005) and Salem, Saghrouni & Nefzaoui (2005).

Tannins do not pose a threat to *L. leucocephala*'s digestibility (1.19%) but the foliage of the plants contains an amino acid mimosine, which can be poisonous if livestock are fed entirely on its forage (Akingbande, Nsahlai, Morris & Bonsi 2000; Byebwa 2000). As a result 100% of diet can produce poor results, with animals not gaining weight. Poor planned diet can result in an enlarged thyroid gland, reduction in fertility, loss of hair and even abortion. However mixed diets to ruminants with grass can be beneficial. Negative effects of *L. leucocephala* to ruminants were reported by Byebwa (2000), whereby high level feed of *L. leucocephala* to animals proved dangerous. *L. leucocephala* supplement to poor quality roughages at the rate of 75% of DM caused alopecia and a loss of body weight. But when the level was decreased to 50% of DM, *L. Leucocephala* had no deleterious effects on general body condition, semen quality of rams or on blood minerals. Positive results of controlled feeding diet were shown by Zacharias *et al.* (1991), Morris (2002) and Nsahlai *et al.* (2002).

8.5.2. Rumen degradability study

This section covers the potential of the feeds, their significance in contributing to alleviation of feed deficit and enhancing DM degradability in the animal rumen. The digestibility value of a feed is one of the best indicators of nutritive value. The extent of microbial degradation of protein supplements in the rumen is an indication of what proportion of the feed protein is available for microbial metabolism (Gerber *et al.* 2000; Fegueiredo, Mbhele, Zondi & Majola 2000).

The results from the *in vivo* trial showed that the high protein diets tend to actively degrade the feed rapidly when compared with the *Eragrostis* hay diet. *M. alba* was in general, across all the diets, the most effectively degraded feed. However, for a rapid energy booster to animals, *L. leucocephala* tended to out-compete *M. alba* and *A. karroo* during the first 24 hrs of feed supplement. *L. leucocephala* degradability declined after 24 hrs when compared to more rapid DM degradation of *M. alba*. The results clearly indicated that animals under hay roughage diet had low degradable metabolism compared to the protein supplement diet. This poor microbial activation in the dry season may account for loss of weight and poor breeding at this time.

Shayo (1997) recorded a high of 70 to 80% at 24 hrs of incubation of *M. alba* fed entirely on the same feeds tested. Shayo (1997) reported about 70% of DM loss after 72 hrs from *M. alba* bark. An indigenous *A. karroo* generally had low DM loss than other fodder samples used in this study, though at 13.60% of CP content. This was supported by *Ngwa et al.* (2000) in that high DM loss was reported from *L. leucocephala* ($P< 0.05$) compared to *M. alba* pods under a low roughage diet. The nitrogen of the *L. leucocephala* pods degraded faster ($P < 0.01$) than that of *Acacia* pods. Ngwa *et al.* (2000)'s results are similar to this study in that *L. leucocephala* pods degraded more rapidly than *Acacia* pods in most cases of the experiment. Ngwa *et al.* (2000), in his discussion noted that the nutritive value of feed could be linked to its rate of degradation. This was due to the high effective degradability of DM for the pods of *A. nilotica* and *A. sieberiana* due to their low ADF concentrations, since the effective degradability of the pods was found to be correlated to ADF ($r = -0.91$, $P < 0.01$). This study supports Ngwa *et al.* (2000)'s argument in that *L. leucocephala* had high CP content that might have resulted in it's readily degradability across the diets. This study therefore concludes that DM loss in every livestock is largely influenced by nutrient content of the feeds.

Ngwa *et al.* (2000) argued that the disappearance of N from the nylon bags ranged from 62 to a high of 71% for the pods of *A. karroo* and *L. leucocephala* respectively. The low extent of N degradability in the pods of *A. karroo* may be explained by the fact that a high proportion (0.31) of N is ADF bound. This might raise the question that *A. karroo*'s high content of tannins (5.69%) was an influence to its generally low DM loss. The results clearly indicate that to enhance microbial activity in the rumen, and to ensure effective DM loss from the rumen, the supplements with high protein contents are essential.

Singh & Makkar (2000) stated it was incorrect that low productivity of ruminants in developing countries was mainly the result of the low energy density (low digestibility) of the available forage. There is now abundant evidence that low productivity stems from an inefficient utilisation of the feed resources because of deficiencies of nutrients (mainly nitrogen, sulphur and minerals) in these diets. The protein feeds therefore being rich in N, sulphur and minerals, their supplementation could increase the efficiency of utilisation of crop residues by increasing the efficiency of microbial protein synthesis in the rumen leading to high rich protein supply to the intestines (Singh & Makkar 2000). The study by Gonzalez & Milera (2000) recorded high degradation of *M. alba* compared to *L. leucocephala* (values are given below). This was due to high protein content of 26.1% in *M. alba*, similar to tropical legumes like *Sesbania*. DM degradation of *M. alba* was 87.8% at 72 hrs of incubation and NDF degradation reached 78.6% in the same period.

Roughage contains high concentrations of cell wall constituents, which represent an important energy source for ruminants. However, because of its low digestibility and intake associated with low N and other nutrients, it fails very often to meet the requirements of animals. Several attempts for improving the nutritive value of roughages include supplementation with protein diet, urea, ammonia, legume forage. The discussion below reviews the effective degradability of roughage feeds under different diets from low protein to high protein diets. As shown under data presentation, the metabolic rate of microbes is very low under the *Eragrostis* diet compared to the protein-rich concentrates diet. This has in turn resulted in low degradability rate for roughage samples (maize stalks and leaves). Maize leaves sole and leaf-stalks combination had low NDF content and low ADF compared to maize stalks. This had largely affected the degradability rate of maize stalks due to high content of lignin, and cellulose in maize stalks.

A lesson from this study is that, feeding animals entirely on roughage diet will not enhance their energy level or general animal performance. Kabatange & Shayo (1991) conducted a trial in which rumen degradation of maize stover was investigated as influenced by *L. leucocephala* hay supplementation. The results showed that *L. leucocephala* had a positive effect on the rate of degradation of the maize stover in all diets. The results ranged from 21.7% from 6 hrs to 59.1% under maize stover + 2 kg *L. leucocephala* hay and 8% from 6 hrs to 55.85 after 72%. Under natural normal grazing, the maize stover degradation also improved and it was suggested that this is due to selective grazing or the hay was better balanced.

The relevance of this to the rural Okhombe area is that animals performs better under normal grazing (during the summer period), but the problem is mostly during winter when large herds are fed on maize stover. This brings to light poor performance by rural cattle during winter because voluntary intake of roughages in ruminants is largely affected by the rate at which digestion occurs. In this study therefore, given the *Eragrostis* hay diet and feed addition with maize stover, the higher rate of digestion will not be reached resulting in low animal performance. Similar results were reported by Ngwa *et al.* (2000) when investigating the potential of legume pods as supplements to low quality roughage. The maize stover had higher ($P < 0.01$) slow degradable fraction and potential degradability of the NDF, ADF and hemicellulose.

Jung, Buxton, Hatfield, & Ralph (1991) verified that maize stover had a large proportion of the potentially degradable cell walls and these are composed of very thick secondary walls that are very slowly degraded. Maize stover also has a high lignin content which is negatively correlated to hemicellulose degradability. Cell wall polysaccharides such as cellulose and hemicellulose (high content in maize stover) are slowly digested in the rumen (3 to 9% per hour) as compared to starch and protein, which are digested at rates of between 10 to 20% per hour (Jung *et al.* 1991). But *L. leucocephala* for instance, when supplemented, can promote high levels of rumen ammonia and rumen pH ranges between 7.14 and 7.24, the ideal optimal rumen environment for microbial growth and proliferation. It also leads to high levels of ammonia which provides N for the synthesis of microbial protein, in addition to minerals and volatile fatty acids.

Chemical treatments to enhance nutritional quality of roughages are very expensive. Examples of these chemicals are alkalis such as sodium hydroxide (NaOH) and anyhydrous ammonia (NH_3). They dissolve lignin and expose cellulose to rumen bacteria for fermentation. This increases voluntary feed intake, rate of digestion and the efficiency of the extraction of digestible nutrients (Devendra 1997; Meissener *et al.* 1999). These are mostly mixed with other feeds to form supplementary concentrates by commercial farmers. A substitute by these chemicals to poor rural farmers is certainly planting of legumes or plants rich in proteins and other essential minerals.

8.6. Conclusion and Recommendations

From the *in vivo* and *in vitro* experiments clearly *L. leucocephala* is recommended as the most favourable species for use in rural areas as a supplement to poor roughages. The species is highly soluble after ingestion, enhancing the animal performance readily after intake. High CP content (19.97%) and low NDF (50.38%) are good characteristics for a better feed for animals. It readily soluble material and high DM loss within a short period of time of just 4hrs proves it's potential. However it must be controlled as a supplementing diet due to its side effects when consumed in large quantity. Abdulrazak & Ondiek (1998) recommended *L. leucocephala* usage of up to 30% level as supplementary feed because this resulted in improved intake and live weight in ruminants. The results show that given different environmental and climatic characteristics, different authors will recommend different tree species with some potential as protein supplements. For instance, under different circumstances all three species used in this trial have enormous potential to alleviate protein-feed deficit. This is due to results from fodder production, chemical contents and rumen degrability rates.

Although *L. leucocephala* is known to be prone to frost, Everson *et al.* (2003) reported satisfactory results from an agroforestry study conducted in the frost-prone area of the Highland sourveld. The use of *A. karroo* and *L. leucocephala* as potential species for agroforestry purposes was recommended based on the fodder production. This is interesting and recommends the involvement of the farmer in agroforestry planning and implementation to find out precisely his needs from its establishment.

In 2001, the records from the local Bergville Department of Agriculture indicated Okhombe had approximately 4500 head of cattle in 1997. The number decreased to 1600 head in 2002. The community reported the decrease was due to stock theft and food deficit during winter. The relevancy of this study to the situation in Okhombe is that, not only is feed deficit a problem, but also forage quality. The results from this chapter should therefore be transferred to the rural communities to aid in raising awareness on ruminants' nutrition. And the need for planting forage trees should therefore be encouraged. Zemichael (2003) reported that urea supplementation to roughage diet increased the effective DM disappearance from 39.4 to 73.04% due to urea treatment in the rumen incubated with *Eragrostis* hay. Urea supplements could be replaced by planting legume plants resulting in cost saving to resource poor farmers.

Feeding animals on maize stover in the crop fields does aid in nutrient cycling, but the results from this chapter indicate that cattle have their feeding preferences. This is due to high NDF content in maize stalks. The study recommends the planting of fodder crops to aid feeding of stock on high fibre content of maize stalks with high protein feeds during winter. This will be a combination of maize stover and stalks of leguminous crops fed simultaneously on cattle. Conclusion on animal feeding behaviour can be drawn from this study in that cattle prefers maize leaves consumption than maize stalks due to low NDF and ADF content compared to maize stalks. This feeding behaviour exacerbates poor performance because if fed entirely on maize stalks, the intake and rumen degradability are both reduced.

The significantly low CP% content of maize stalks recorded in this study indicates that livestock diets must be supplemented with high protein fodder. It is recommended that L. leucocephala be utilized as a forage supplement due to its benefits in increasing rumen fermentable N. Some benefits include the promotion of rumen bacteria proliferation and optimal fermentation of roughages, increased digestibility, rumen outflow rate, food intake and better animal performance.

CHAPTER 9: GENERAL CONCLUSION

9.1. Participatory interventions in communal range management

The fact that communal rangelands in South Africa cover nearly 6 million hectares and are home to roughly 2.4 million rural households (Shackleton *et al.* 2001). This rationalises the need for participatory interventions in improving natural resources for the benefit of the poor. These rangelands are used by poor rural communities, not only for supporting livestock, but also for harvesting a wide range of natural resources (Twine 2003; Shackleton *et al.* 2001). Criticisms of the past State programme were that the traditional institutions regulating resource use and land access were undermined and the imposition of new leaders led to a total breakdown of regulations governing natural resource management (Allsopp *et al.* 2003). Historically, access to natural resources on communal land was controlled by chiefs and their head men. During the colonial and racial discrimination eras, these traditional authorities became bureaucratised by the prevailing Governments, and continued to serve as the institution responsible for controlling the utilisation of natural resources on communal lands (Twine 2003). Turner (2003) referenced a similar problem in Lesotho, whereby powers to manage local natural resources are controlled by the ministerial Governments.

Due to degradation of tribal power in rural communities and failures of outsiders to manage local resources, the National Department of Agriculture's LandCare programme was initiated through participatory approaches with the community and vested its power to the local *Inkosi* (traditional chief). The development of grazing systems in communal land was time consuming and difficult to implement as it requires much effort and resources with little success over a period of time (Tau & Everson 2005). Questions have been raised on the conventional approaches to land use planning with rural communities as it basically implies placing fixed grids (e.g. fences) on communities and resources. Sithole (2003) emphasised that conventional approaches have sought to put boundaries and limits to grazing landscapes. One can pose a question as to why after intense participatory planning with communities, they perceive that the only solution to problems in livestock management is to fence grazing camps. The community therefore required help to seek financial assistance on putting fences on their land.

The Okhombe grazing project initiated all the approaches of participatory planning, from visioning exercises to applying the SWOT model for effective involvement of the Inkosi, his councillors and the community in the grazing project. Through all sorts of consultation, the community decided on putting up the camp divisions. The decision by the community was not commercially driven as suggested, for instance by Allsop *et al.* (2003) that fenced camps is based on assumptions that the communities want to make a living from commercial farming. The decision to fence the land one can presume was influenced by many reasons, namely: the benefits of fenced camps were apparent in the betterment programme although they failed due to the top-down approach; escalating stock theft with an assumption that fences will control their cattle movement; and most importantly fences would reduce severe crop damage by cattle that resulted in a strain and a threat to social relationships within the area. The need to improve veld and animal production were also among the reasons for establishing fenced camps, but this was least prioritised by the community. The evidence of this was fence theft up in the mountain compared to no fence theft from the bottom fence separating the crop fields and grazing land which was safely guarded from theft due to its benefits. It is very difficult to plan for veld and animal improvements separately away from a holistic approach to resource management. There are a number of factors, for instance the reasons mentioned above, that enhance its successes and sustainability. The communities are not homogenous as such and different dwellers have different needs from natural resource management programmes.

Ainslie (1999) emphasised the need to identify, strengthen and work with legitimate local institutions when trying to improve livestock productivity and resource management. This approach was the key focus of this project, resulting in the establishment of an effective livestock committee that was respected by the community. Unanticipated from this project was that all stakeholders from the village were involved in planning, and were successfully involved in resolving social issues like fence theft, although the anticipated rotational resting plan was never fully established. The community failed to maintain the herders' fund, a core issue in implementing the grazing system in the area. Reasons for failure ranges from stock theft in the upland, the safety of their herds overnight and the power herders had on securing their stock. This was in relation to the fact that all non-milking cows from the ward were planned to be kraaled every night in the upland, protected by few herders. Turner (2003) explained in Lesotho, stock theft has become a national crisis and some upland pastures remain ungrazed due to the susceptibility of cattle to theft. The stock theft is among major priorities to be addressed when planning for the management of communal rangelands.

The Okhombe project still has the potential of becoming a successful pilot project in South Africa and future involvement needs to revisit its objectives. This should be in the light of improving social contributions from cattle with little focus on monetary contribution.

9.2 Socio-economic factors

Most issues constraining implementation of grazing management systems in communal areas are social, not technical in nature. The ecological survey done in the area showed the veld is heavily stocked with a poor veld condition. This study clearly showed that the ecological problems were understood by the community. However, this did not influence the community to destock since cattle are regarded as an investment. Overcoming socio-economic constraints in rural areas is therefore the core to a successful grazing management programme.

It is very important for outsiders to understand the social issues hindering the implementation of a grazing system and the links to economic issues around grazing management. For instance, institutional structures need to be defined and understood well, need to identify local super powers and decisions of the migrant workers must not be ignored in planning and implementation phases. Chapter 2 and Chapter 4 have dealt with the significant contributions that rural people place on cattle in Okhombe. It was apparent during the planning sessions that the proposed grazing system will have a great influence on multiple uses of stock. Allsop *et al.* (2003) found it erroneous for most extension officers to presume that livestock keepers should aim to earn a steady income from their livestock. A line needs to be drawn between the group that wants a steady income from livestock and groups that want to enhance the multiple usage of stock. It is from these needs that the two groups should try to work towards one goal of improving natural resource management but bearing in mind other goals. Twine (2003) mentioned poverty among factors that influence the community's behaviour to resource utilization. This raises awareness that grazing projects should have a poverty alleviation component from the planning to implementation phase.

9.3. Alternative fodder supply

Opportunities for sustainable intensification, in resource poor rural farming systems, are limited because of the inability of farmers to pay for external inputs (Trytsman & Mappledoram 2003). Poor animal condition was mentioned during participatory sessions with the community as a concern, more particularly during winter since Okhombe is located in the Sourveld region. Sourveld by definition does not sustain animal production throughout the year. This is the result of a substantial decrease in forage quality and acceptability towards the end of the growing season and during the dormant season (Hardy *et al.* 1999; Tainton 1999; Trytsman & Mappledoram (2003). In almost every rural area, cattle are fed entirely on low nutritional maize stover during cold winter months when grasses are dormant. It was recommended in Chapter 7 and 8 that planting of legumes may supply nutritional supplements for low nutrient, roughage diets.

Other authors like Trytsman & Mappledoram (2003) recommended further that intercropping with crops like cowpea and lablab could alleviate feed deficit during winter months. Multiple cropping in livestock systems as a means of intensification is recommended for sustainable rural development, since such planting can feed both humans and livestock. The relevancy of this to communal grazing management is that in addition to resource management within the rangeland, these projects could also expand to the household level whereby individuals can plant fodder trees and leguminous herbs such as cowpea to increase fodder production.

The participatory grazing management project in the Okhombe ward of the Amazizi Tribal Authority has been time consuming (over four years), requiring the development of ecological, technical, and social skills. The most significant failure has been to get all livestock owners to participate in the grazing system and in the payment of herders. The most significant successes yielded from participatory planning with the community include a sense of ownership by local institutions, development of capacity for interventions (e.g. innovative ways to address fence theft), reduction in stock theft, reduction of cattle damage to crops and improved capacity building in grazing management.

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Appendix 1

Agreement between the Okhombe Land Care Partners and the Okhombe community.

As part of the Okhombe LandCare project, the Okhombe community requested assistance on re-establishment of cattle grazing camps. Fencing of these camps is near completion, but has been halted due to theft of the fencing material. The community has been requested to replace this fencing material as the evidence suggests that the theft was from within the community.

It is however imperative to the project that the fencing is completed and that the community start to implement the rotational cattle management system.

To achieve this, the following agreement is reached:

The Partners will:

1) Pay for the fencing material to complete the sections of fencing not yet completed. This is the fencing that will divide the area into camps. 5300 m of fencing will be provided.
2) Pay for fencing to replace the stolen fencing. 1000 m will be provided.
   Note: the partners will not pay for labour to erect the fencing. The labour given by the community to erect the new fencing will be seen by the partners as the community's payment for the stolen fencing.
3) Help facilitate the start of the grazing system
4) Pay R 7875 as a start toward a herder's fund. This covers 9 herders for one month (R4500), ½ of the cost for 9 herders for the second month (R2250) and ¼ the cost of the herders for the third month (R1125).
5) Provide the herders with 3 cell phones so that they can report danger or theft to the rest of the community.

The Cattle management committee will.

1) Undertake organizing labour for erecting of the fence
2) Gather community support for the labourers erecting the fence
3) Ensure that the community adheres to the new grazing rules
4) Check to ensure that no fencing is stolen and report on stolen fencing if it happens (both to the police and tribal authority)
5) Appoint herders
6) Maintain a fund for paying the herders and collect cash from the community for paying of herders.

The Okhombe community will:

1) Ensure that the fence is not stolen or damaged
2) Be responsible for replacing damaged or stolen fencing unless it can be proven that the fencing was stolen or damaged as a criminal act not involving members of the community
3) Do all reasonable in their power to ensure that the fence is not stolen or damaged
4) Report any damage or theft of the fence to the cattle committee
5) Adhere to the cattle grazing plan as presented
6)

Agreement relating to provision of cell phones to cattle guards

The Okhombe land care partners will provide 3 cell phones to the cattle guards to aid in security.

The cattle guards will:

1) Take full responsibility for the safety of the cell phones
2) Prevent the cell phones being damaged or stolen
3) Ensure the cell phones are always in working order
4) Ensure the cell phone is always charged

5) Ensure the cell phones always have sufficient airtime for emergency calls
6) Pay for any non-emergency calls used on the phone
7) Be responsible for replacing phones that are damaged, lost or stolen if it is shown that there was negligence on the part of the guard

Signatures

Project Team	Date
…………………...	……………………….
Inkosi Miya	Date
…………………….	………………………..

Appendix 2:

Notes from the Grazing Management Meeting held at Okhombe Community Hall on the 15th September 2003.

Present: Mahlodi Tau (CSIR), Joshua Xaba (CSR), Mr. Mandla Xaba, Mr. Majonkosi Hlatswayo, Mr. Sipho Dlamini, Mr. Mdunyelwa Hlongwane, Mr. M. Miya, Mr. M. Sithole, Mr. Ndlovu and Mr. D Dladla.

Apologies: Mr. Ndaba

Agenda

1. Report Back (Livestock Committee)
2. Partners' Agreement
3. Herders' Duties
4. Cattle movement
5. Tribal Council/Subward meeting (Dates)

1. Report Back (Livestock Committee)

Fence: Okhombe Monitoring Group (OMG) member reported 8 fencing standards & 19 droppers were stolen in Ngubhela last week. The site were the materials were stolen will allow easy boundary crossing of cattle to other land because this has lowered the wire to the ground. The missing standards were reported after the meeting, therefore not discussed under the Report Back item. This is because the matter was not yet reported to the committee.

Community Meeting: The Livestock committee gathered the community on the 28th August 2003 to discuss about the agreement reached by Project Partners concerning the grazing project. The community agreed on free labour for replacing the vertical & the missing fence. Instead of having the entire community volunteer in putting up the fence, they decided to employ a score of people from each of the three subwards to lend a hand in erecting the fence. The number of people to be employed will depend on the length of the required fence. Figures were handed in to aid in employing the number of people required. The committee will collect R5.00/household from both the livestock & non-livestock owners to provide lunch for labours. The livestock sub-committee of each ward will be responsible for collecting money from each subward. The Ngubhela/Mpameni & Mahlabathini community would also contribute R5.00, as members from their subward will be employed in erecting the fence.

2. Partners' Agreement

Agreement on responsibilities of the committee, herders & the community in grazing management were read out & well translated in Zulu by Joshua. Responsibilities for each were welcomed & the committee appreciated the efforts/input done so far by Project partners in the grazing project and their service in implementing the plan. They requested two Zulu version be copied & handed out to the Tribal Council (TC) and the Livestock committee. Signing of the responsibilities by the TC & the Livestock committee were viewed crucial as it gives the TC more power in punishing individuals not adhering to the project's rules. Although the Liv. Committee didn't sign the paper, stating needs to present all the responsibilities to some key member of the committee like Chairperson Mr. Ndaba who sent an apology. Regarding opening herders' fund, they vowed will begin collecting money from the first month of the implementation stage & open a bank account with the notes collected.

3. Herders duties

General responsibilities:
Day-herders will mainly look after the fence, both non-milking & milking cows, particularly non-milking cows as they may cross to other Ward (Mnweni) & also check veld fires. Night herders will primarily look after the kraaled non-milking cows & patrol the fence.

Working Hours: Three appointed herders will start working from 6am-6pm, & six will go in from 6pm-6am. The committee guaranteed herders for the night shift would be healthy strong trustworthy men who will do their job perfectly. They proposed having stand-by herders in case others pull out or may be a need to change herders probably after every two months.

Kraaling: Hence the idea of having herders is part of harnessing soil erosion, all cattle particularly the non-milking cows will spend nights in the mountain. Cattle will be kraaled up for the night in specially marked site & guard by herders. The committee will undertake an inventory to identify potential sites (preferred sites are near dense forests, suitable for use as natural kraals). Milking cows may be kept in homestead kraals, but will not be compulsory as those who wish to leave their cows are allowed to keep them in camps. But wouldn't be the nightshifts' responsibilities if stolen because their duty is to look after the non-milking (easy to guard hence kraaled) cows.

Grazing camps: It is not herders' duty to accompany cattle from homesteads to the specified grazing camps but rather owners' responsibility to ensure his/her cattle are in the specified camp. Those not adhering, their cattle will be kept out by herders & reported to the TC.

Stolen fence/cattle: The committee stated not expecting any report on stolen cattle from both the daylight-herders & night herders. They stated might expect cutting of the fence at night because is difficult to cover the entire area especially after dusk but are not expecting ripping of the fence at daylight with herders in position. They still have to discuss punishment resulting from such act (e.g. replacing to the owner with another cow).

Herders' house: Old materials will be collected from the community to build house for the nightshift herders. The house is for use during wet/cold weather only not for sleeping. And it is their responsibility to ensure they have necessary clothes for both wet and cold weather hence will be paid. The committee will appreciate financial assistance from Project partners but have vowed not to put in an application for building material supply.

Cell phones: The committee to regularly check all cell phones to ensure are not misused & still operating in good condition. Herders will be required to buy airtime to replace the used one even if it means spending R5.00, because is essential to have enough money for calling the police, other herders & committee members for emergency. The committee prefers MTN phones because their airtime does not expire unlike other cellular network.

4. Rotational resting

It was confirmed that the system procedure is not yet changed since drawn up in 2001. Two camps adjacent to the Okhombe river will be under the same treatment (rest) & the remaining under utilisation for the coming season.

5. Tribal Council & Subward meeting

Mr. Hlatswayo was requested to set up dates for meetings at subward level (Enhlanokhombe, Sgodiphola & Oqolweni) as it deemed necessary to explain the agreements & their involvement in the grazing project. Mr. Hlatshwayo to hand in dates this coming Thursday to project team. Another date is for presenting the grazing plan, & responsibilities to the TA.

Appendix 3

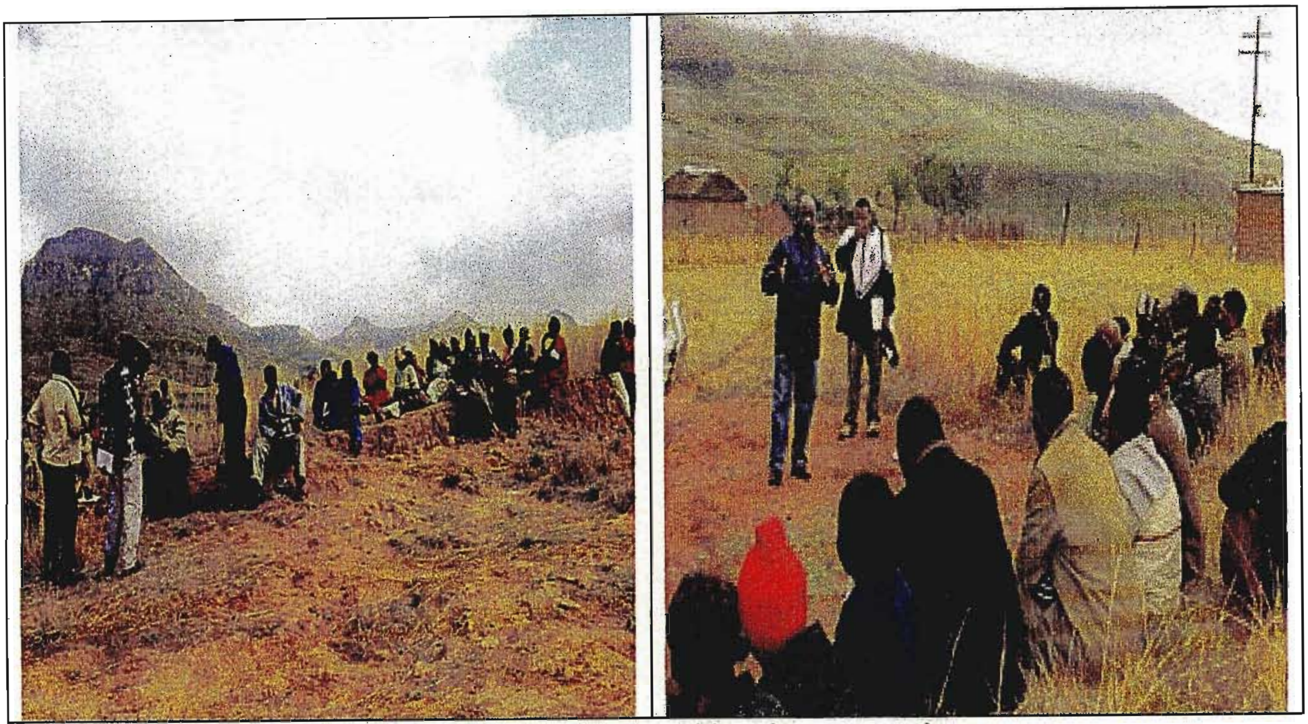

Plate 8: Participatory planning meetings with the Okhombe community.

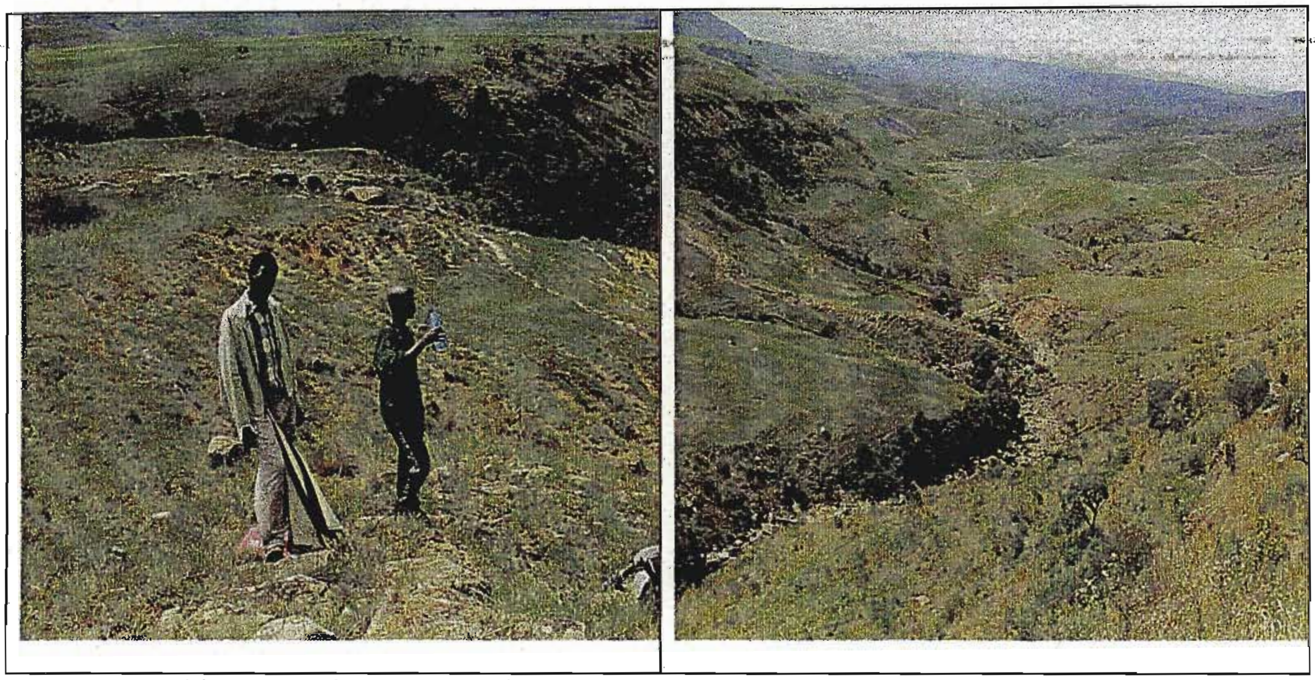

Plate 9: Marking upland boundary with a ward *Induna* (left) and Okhombe river (right), a natural boundary for two camps.

Appendix 4

Examples of statistical analysis from one-way ANOVA (Genstat statistical package).

******* Analysis of variance *****2003 data**

Variate: fodder_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Species	2	1419314.	709657.	18.37	<.001
Residual	15	579573.	38638.		
Total	17	1998887.			

******** Tables of means ********

Variate: fodder_kg_ha

Grand mean 1318.

species	acacia	leuc	mulb
	1140.	1715.	1101.

****** Standard errors of means ******

Table	species
rep.	6
d.f.	15
e.s.e.	80.2

****** Standard errors of differences of means ******

Table	species
rep.	6
d.f.	15
s.e.d.	113.5

****** Least significant differences of means (5% level) ******

Table	species
rep.	6
d.f.	15
l.s.d.	241.9

<u>*** Analysis of variance *****2003 data</u>**

Variate: fuelwood_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
species	2	314763.	157381.	1.02	0.383
Residual	15	2307641.	153843.		
Total	17	2622404.			

******** Tables of means ********

Variate: fuelwood_kg_ha

Grand mean 541.

species	acacia	leuc	mulb
	456.	439.	728.

***** Standard errors of means *****

Table	species
rep.	6
d.f.	15
e.s.e.	160.1

***** Standard errors of differences of means *****

Table	species
rep.	6
d.f.	15
s.e.d.	226.5

***** Least significant differences of means (5% level) *****

Table	species
rep.	6
d.f.	15
l.s.d.	482.7

Appendix 5

Examples of statistical analysis from one-way ANOVA (Genstat statistical package).

******* Analysis of variance *****2003 75 CM DATA**

Variate: Maize stalks_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
species	3	292727.	97576.	0.32	0.813
Residual	20	6150668.	307533.		
Total	23	6443395.			

******* *Tables of means* *******

Variate: stalks_kg_ha

Grand mean 1078.

species	acacia	leuc	mulb	no-trees
	1238.	1116.	947.	1011.

***** *Standard errors of means* *****

Table	species
rep.	6
d.f.	20
e.s.e.	226.4

***** *Standard errors of differences of means* *****

Table	species
rep.	6
d.f.	20
s.e.d.	320.2

*** *Least significant differences of means (5% level)* ***

Table	species
rep.	6
d.f.	20
l.s.d.	667.9

******* Analysis of variance *****2003 150CM DATA**

Variate: Maize stalks_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
species	3	179768.	59923.	0.45	0.721
Residual	20	2668766.	133438.		
Total	23	2848534.			

******* Tables of means *******

Variate: stalks_kg_ha

Grand mean 991.

species	acacia	leuc	mulb	control
	913.	937.	979.	1135.

*** *Standard errors of means* ***

Table	species
rep.	6
d.f.	20
e.s.e.	149.1

*** *Standard errors of differences of means* ***

Table	species
rep.	6
d.f.	20
s.e.d.	210.9

*** *Least significant differences of means (5% level)* ***

Table	species
rep.	6
d.f.	20
l.s.d.	439.9

******* Analysis of variance ***** 2003 225CM DATA**

Variate: Maize stalks_kg_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
species	3	1165900.	388633.	5.89	0.005
Residual	20	1319098.	65955.		
Total	23	2484998.			

***** *Tables of means* *****

Variate: stalks_kg_ha

Grand mean 925.

species	acacia	leuc	mulb	no-trees
	1259.	683.	780.	979.

*** *Standard errors of means* ***

Table	species
rep.	6
d.f.	20
e.s.e.	104.8

*** *Standard errors of differences of means* ***

Table	species
rep.	6
d.f.	20
s.e.d.	148.3

****** Least significant differences of means (5% level) ******

Table	species
rep.	6
d.f.	20
l.s.d.	309.3