Rangeland evaluation and perceptions of the pastoralists in the Borana zone of southern Ethiopia

by

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Submitted in partial fulfilment of the requirements for
the degree of

DOCTOR OF PHILOSOPHY

In the faculty of Natural and Agricultural Sciences
Department of Animal, Wildlife and Grassland Sciences
(Grassland Science)
University of the Free State
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March 2003

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DECLARATION

I declare the dissertation hereby submitted by me for the partial fulfillment of the requirement of the degree of Doctor of philosophy (Grassland Science) at the University of the Free State is my own independent work and has not been submitted by me at another university/faculty. I further cede copyright of the dissertation in favor of the University of the Free State.

Solomon Tefera Beyene

ACKNOWLEDGMENTS

First and foremost I honor and praise my Lord and I would like to say "Now to the king eternal, immortal, invisible, the only God, be honor and glory for ever and ever. Amen". 1 Timothy 1: 17.

I would like to acknowledge and offer sincere gratitude to my supervisors Prof. H A Snyman and G. N. Smit for giving their time, instructions, invaluable advice, assistance and for their active participation in the course of the study. Their criticism and appraisal of the thesis manuscript and their friendly approach during the course of the study is also appreciated.

I would like to appreciate and extend my sincere thanks to the staff members of the Grassland Sciences Discipline for their cooperation and enthusiastic support in one way or another during the course of the study.

I am indebted to thank the government of Ethiopia for the privilege given to me in the full sponsorship grant of my study.

I would like to thank the Oromia regional agricultural Bureau for timely cooperation in the selection of sites and provision of data from zonal Agricultural Bureau. I would like to give special thanks to mr Fekadu Ababate for his encouragement and moral support in the initiation of the research. I am deeply inspired by his willingness to help, advise and of all his extraordinary kindness.

Sincere appreciation is extended to dr Getachew Gebru for his invaluable input and friendship in the course of my study.

I am indebted to express sincere thanks to my colleagues and friends for their keen interest, valuable suggestions and prayer at the time of hardship and discouragement.

Finally, I would like to express my sincere gratitude to my father mr Tefera Beyene (Gashiye) and my mother mrs Bezunesh Beyessa (Bezuye) for their encouragement and constant love though out my life, which has contributed greatly to the realization of my dreams and vision. I would also like to express my deepest gratitude to my brothers and sisters, with special thanks to my younger brother Paulos Tefera (Mamush) for his cooperation and moral support in the course of my study.

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RANGELAND EVALUATION AND PERCEPTIONS OF THE PASTORALISTS IN THE BORANA ZONE OF SOUTHERN ETHIOPIA.

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ABSTRACT

The study was conducted in the Borana rangeland of southern Ethiopia. In the last few decades the Borana rangelands have been degraded while the pastoralists adhered to the traditional grazing strategies. The main aims with this study were to investigate the soil characteristics as well as aboveground plant communities and to assess the condition of the rangeland. In addition, the pastoralists' perceptions and cattle-rangeland management practices were evaluated.

The botanical composition of the grass layer, woody vegetation structure, soil and the rangeland condition were studied in four communal grazing areas (Did Yabello, Did Harra, Dubuluk and Melbana), three land use systems (communal land, government ranch and traditional grazing reserve) and along distance gradients from water source.

Species composition and basal cover of the grass layer was estimated using frequency of occurrence of plant species. Woody plant data were standardized to tree equivalent ha^{-1} (1 TE = 1 tree, 1.5 m high). Rangeland condition was assessed based on ecological condition index, weighted palatability composition of the grass layer, the structure of woody plants and soil compaction. Soil seed bank was studied under three land use systems and along a distance gradient from water source. Survey on cattle-rangeland management practice and pastoral perceptions was conducted on 40 individual households and 118 elders (7 per group).

Survey results of the pastoral households and elders indicated that the average household in the study area was 7 members. The percentages of male and female children who attended schools were 26 % and 9 % respectively. Livestock holding per household was estimated to be 14 cattle, 10 goats, 6 sheep and 2 camels. Cultivation is widespread in the study area. Major constraints in livestock production were in order of importance: drought, feed shortage, water scarcity, animal diseases, predators and communal land tenure. According to the pastoralists, contributing factors to rangeland degradation were in descending order: recurrent drought, human and livestock pressure, expansion of cultivation, ban on fire and development of water ponds.

A total of 49 grass species were identified in this study. The communal land had higher and lower percentages ($P<0.05$) of annual and perennial grasses, respectively, than the government ranch and the traditional grazing reserve. There were no marked differences ($P>0.05$) among the four communal grazing sites and the three different distances from water concerning both annuals and perennials. The occurrence of *Chrysopogon aucheri* was higher ($P<0.05$) on the government ranch (23 %) and traditional grazing reserve (27 %) than on the communal land (14 %). The frequency of *C. aucheri* did not vary between the communal grazing sites (average = 14 %) and along distance gradient from water (average = 12 %). *Leptothrium senegalensis* and *Chloris myriostachya* did not vary ($P<0.05$) between the land use systems (average = 4 % and 1 %, respectively) and along the distance gradient from water (average = 2 % for both species). The frequency of *Sporobulus nervosus* was highest ($P<0.05$) in the communal land (13 %), whereas the occurrence of *S. pyramidalis* did not differ markedly (average = 32 %) between the land use systems ($P>0.05$). Both species did not show prominent variations along the distance gradient from water (average = *S. nervosus*-14 % and *S. pyramidalis*-36 %). Grass basal cover was fairly low and similar in the land use systems, communal grazing sites and distance gradients from water.

A total of 54 woody plants were identified. Total density of woody plants was higher ($P<0.001$) on the communal land (1 083 TE ha^{-1}) or the government ranch (1 188 TE ha^{-1}) than on the traditional grazing reserve site. Within the communal grazing sites, the densities at Did Yabello (1 318 TE ha^{-1}), Did Harra (1 088 TE ha^{-1}) and Melbana (1 178 TE ha^{-1}) were higher ($P<0.05$) than on the fourth site, Dubuluk. Results from the distance gradient from water revealed that differences were not significant ($P>0.05$) between the near, middle and far sites (average = 1 150 TE ha^{-1}). Overall figure showed the advancement of woody encroachment in the semi-arid Borana rangelands. The most important invaders were *Commiphora africana, Grewia tembensis, Acacia drepanolobium* and *A. brevispica*.

Soil chemical analysis revealed low nutrient contents, which did not vary significantly ($P>0.05$) in all the study areas. Similarly, differences in pH, soil texture, soil bulk density and soil compaction were not significant.

Assessment of rangeland condition indicated that both ecological condition index (ECI) and weighted palatability composition (WPC) were highest on the government ranch (711 and 55 %, respectively). Along the distance gradient from water, differences in rangeland condition ($P>0.05$) were not significant (average: ECI = 533 and WPC = 29 %). Within the communal grazing sites, Dubuluk and Melbana had relatively higher ECI and WPC values (average: 602 and 36 %, respectively) than the other two sites (average = 520 and 25 %, respectively).

The soil seed bank study revealed that a total of 44 plant species were identified. Of these, 25 % were grasses and 75 % were non-grass plant species. As for the land use systems, seedling and floristic density of the graminoids were higher ($P<0.05$) on the traditional grazing reserve (798 seedling m^{-2} and 361 plants m^{-2}, respectively) than on the communal land and the government ranch. Along the distance gradient from water, the differences were not significant ($P>0.05$). Similarity between grass flora of seed bank and above ground plant community was low.

It can be concluded in this study that the deteriorating conditions of the Borana rangelands were revealed by changes in the structure and composition of the grass layer, woody vegetation, soil fertility and by the status of the soil seed bank. Bush encroachment is the critical problem. Therefore, workable control programs need to be devised immediately. It is also vital to develop a clear policy at national level on the use and management of the communal rangeland resource.

CHAPTER 1

INTRODUCTION

Ethiopian rangelands, located in the lowland regions, are home to a diverse array of pastoral people who depend to a high degree on livestock for their sustenance. These areas form the peripheral edge of the country surrounding the central highland massif. A small portion of the rangelands falls within the great rift valley that divides the west-central highlands from the north-eastern, eastern and southern lowlands (Coppock 1994). The altitude in the lowland regions is generally below 1 500 m elevation (a.s.l.), with a few exception of 1 700 m in the southeastern and southwestern rangelands (Kidane 1993).

The rangelands of Ethiopia are dominated by a relatively flat topography, harsh arid (64 %) to semi-arid (21 %) climate, having low, unreliable and erratic rainfall with high temperatures (Coppock 1994; Alemayehu Mengistu 1998). Such climatic conditions, together with the natural settings, favour pastoral livestock production rather than rain fed crop production (AACM 1984).

Pastoral area covers some 61 % of the total area of Ethiopia and is inhabited by 12 % of the total human population of Ethiopia (Getachew 2001). The majority of the pastoral communities belong to the Somali, Afar and Borana ethnic groups in the southeastern, north- eastern and southern rangelands, respectively. There are also smaller ethnic groups such as the Nuer, Kereyu, Hammer, Arbore and Dasssanech that live in the west, central and southern parts of the country (Hogg 1997; Melaku 2000). The survival of all these ethnic groups depends exclusively on livestock production though the degree of importance of the various livestock species varies from one ethnic group to another. For example, camel production for the Somali pastoralists is comparable to cattle production, whereas the Borana pastoralists rely more on cattle production, even though camel herding expanded in recent times.

The portion of the southern rangelands, hereafter referred to as the Borana rangeland (Plateau), covers approximately 95 000 km^2 (Tamene 1996). The human population including the Borana, Somali, Gabra as well as other minor communities is estimated to be over 0.41 million, of which 16 % live in the urban centers (CSA 1996). The Borana, the major ethnic group, with a population of around 0.33 million consists of 58 % pure pastoralists, 31 % predominantly pastoralists and 11 % crop farmers (Solomon Desta 2000).

Until a few decades ago the Borana rangeland was considered the best grazing land and with many detailed accounts of its hydrology, geology and sociology (Agrotec/crg/sedes 1974; Coppock 1994), it is one of the most studied regions in the pastoral east Africa. Communal ownership of land predominates in the Borana pastoral system. This furnishes the community members with equal rights but not in an open access grazing/browsing style. Local territorial units often adopt restrictive strategies constraining free access to the communal rangeland. Such indigenous land use, supported by strategic management, was reported to be appropriate to cope with rainfall variability, scarcity of grazing/browsing and water resources (Oba 1998). This allows the pastoralists to manage the scarce resources at higher level of productivity and in accordance with the ecological principles of sustained yield, which at the same time maintaining their characteristic way of life.

In the last few decades, the Borana rangelands have been degraded while still adhering to the traditional grazing strategies to a certain degree. In this case the rangeland degradation was considered as instances where the perennial grass cover had been substantially reduced, invasion of undesirable woody species took place and unpalatable forbs and soil erosion had increased (Assefa *et al.* 1986; Oba 1998). In the mid 1980s, about 19 % of the area was affected by erosion and about 40 % of the areas had a woody plant cover exceeding 40 % (Assefa *et al.* 1986). The major invading woody species included *Commiphora* spp, *Acacia brevispica, A. drepanolobium, A. seyal, A. bussei, A. nubica, A. nilotica, A. reficiens* and *A. mellifera* (Coppock 1994). A recent reconnaissance survey suggested that 10.5 % of the total landscapes of the Borana rangeland were in excellent condition and 40.4 % were reported to be in a moderate to poor condition (Oba 1998). The scant information available on the recent botanical composition of grasses indicated that the highly palatable species, namely; *Cenchrus ciliaris, Chrysopogon aucheri* and *Panicum coloratum* combined, made up 43 % of the total dry matter production of the herbaceous layer in both the encroached and non encroached vegetation (Ayana & Baars 2000). Discussions with Borana households and elders revealed that the overall utilization and depletion of their environment has resulted in low animal productivity and livestock loss, which subsequently has ended in unusual migration, starvation and poverty (Alemayehu Mengistu 1998).

Chronic overgrazing, drought and expansion of cultivation have been commonly cited as causes of rangeland deterioration (Coppock 1994). In particular, increase in the population of humans and livestock over centuries had elicited dynamic change to their environment with the effects will become more acute in the future (Coppock 1995). The mean annual grazing capacity during the period 1982 to 1990 was estimated at 0.83 ha Tropical Livestock Unit (TLU^{-1}), whereas the average stocking rate during the same period was estimated to be around 0.63 ha TLU^{-1} (Coppock 1994). Under livestock and human population growth, it may be expected that the stocking rate value may even show a further upward trend today than what it was in the past.

The degradation of the rangelands is an issue of concern for future animal production and survival of the Borana and other pastoral people of the country. There is no question that something has to be done to restore the sustainability of the ecosystem to ensure stable livestock production for the future. Until recently, the input of the government in terms of research and development activities in the pastoral areas of the country is far below what is required. There does not exist a pastoral policy and most development interventions in the past were top-down and unsustainable, which all together ended up in today's worsening situation of the pastoralists and in ecological crises of the rangelands.

Efforts to ameliorate the negative effects of the pastoralists on the rangeland ecosystem may initially focus on activities such as rangeland vegetation monitoring, bush control and grazing and rangeland rehabilitation. Unfortunately, these may not provide long term solutions in light of the pressure of human and livestock population growth. It was suggested that the ultimate development strategy for the future should be geared towards government policies and procedures. These programmes must facilitate diversification and security in the traditional economy; provide skills and choices for a segment of the society to pursue alternative lifestyles (Coppock 1995).

One of the most important issues raised concerning rangeland degradation is the question as to how its degree and extent can be measured and which aspects of the ecosystem need to be quantified and/or explained to assess the status, as well as the trend of the rangeland condition. Pratt & Gwynne (1977) defined rangeland condition as the state of health of the rangeland, which can be assessed on the basis of an area's vegetation composition, plant vigour, ground cover and soil status. This concept is used to denote the changes in vegetation composition, productivity and soil quality that occur when the rangelands are grazed by livestock (Wilson & Tupper 1982). The indices of these changes are dependent on the measurement of departure from a standard or reference site, which represents either the original or ideal for that land type (Wilson 1984).

The purpose of measuring the changes in vegetation condition and soil quality is based on a concern for long-term productivity and stability of rangelands. A good understanding of environmental pattern, quantification of the ecological changes and at the end determination of the vegetation condition and soil quality become increasingly important for effective management and rehabilitation of degraded rangelands (Holm *et al.* 1984; Trollope 1990; Hardy *et al.* 1999). In traditional communal pastoral areas such as the Borana, information acquired on the indigenous rangeland management practice, the pastoralists' attitudes and perceptions towards their environment and on the decision making processes can also have a paramount role in effective planning and application of the available management and rehabilitation options. In the Borana rangeland, there is lack of information on the recent pattern and distribution of grasses, woody vegetation and soil characteristics with respect to different land use systems and in relation to distances from water sources. Few studies were conducted on the assessment of the condition of the rangeland by taking the land use systems and distances from watering points into consideration. At least part of the failed efforts to prevent further deterioration can be ascribed to the lack of any general applicable method of estimating the condition of the rangeland relative to its potential under ideal management. Moreover, studies on the pastoralists' traditional use and management of rangeland resources as well as their perception towards environmental degradation are not exhaustive. In the past, such studies ranked the lowest order in terms of research priority in the pastoral areas of Ethiopia in general and that of the Borana in particular. Therefore, in this study, some recommendations on future planning are made, not only for survival of animals and people, but also for future sustainable use and management of the rangeland ecosystem. In addition, some priority areas for future research on the use, management and conservation of the biodiversity of the rangeland ecosystem are presented.

The main objectives of this study were therefore to investigate (i) cattle-rangeland management practices and perceptions of the pastoralists to rangeland degradation; (ii) the distribution and botanical composition of grasses in relation to land use and distance from water points; (iii) woody vegetation gradients around main water points and under different land use systems; (iv) the soil characteristics in relation to rangeland degradation, (vi) soil seed bank characteristics; and finally (vii) to assess the condition of the rangeland in relation to land use systems and distance from water points.

CHAPTER 2

LITERATURE REVIEW

2.1 PASTORALISM IN AFRICA: AN OVERVIEW

Pastoralism in Africa began as a result of a shift from hunting/collecting, which required some fairly fundamental changes in the social aspects of man and animal relationships (Smith 1992). Several authors have stressed that the nature of such hunting/collecting subsistence results in essentially egalitarian social organization (Lee 1969; Yellen 1984), which still exists in most pastoral societies in Africa.

The world's pastoralists population is estimated to be 30-40 million, of which Africa shares about 15-20 million (Sandford 1983). Almost all the pastoralists live in about 13-16 million km^2, or nearly half of the continent south of the Sahara, which is desert, semi- arid grasslands and savanna. In these areas cultivation is a high risk venture (Brown undated). In terms of the number of pastoralists, the most important countries in Africa are Sudan, Somali, Chad, Ethiopia, Mali, Niger, Mauritania and Kenya (Solomon Desta 1993).

Unlike many Agrarian societies, which combine cultivation and raising livestock, the pastoralists in Africa subsist almost wholly on the products of their livestock as well as on the sale of the livestock and/or their products (Helland 1980; Barbara undated). The rangelands have been traditionally used exclusively under a communal property regime. De Haan *et al.* (undated) described their economy as typically of the 'bust and boom' type and the abiotic factors such as the rainfall rather than livestock density determine long term primary production and vegetation cover (Mearns 1996).

2.1.1 Pastoralism in the Horn of Africa

The Horn of Africa contains the largest group of pastoralists in the world. Sudan has the highest percentage globally, Somali and Ethiopia rank third and fifth respectively and one third of Djibouti population is pastoralists (Mkutu 2002). The semi-arid and arid areas of Kenya, constituting 0.44 million km^2 of the landmass, which is equivalent to nearly 80 % of the total land area support 25 % of its population as well as half of the livestock (Mkutu 2002).

Anthropological research on pastoralism in the horn of Africa has a relatively long history. Herskovits (1926) studied the culture area paradigm and defined the 'cattle complex'. On the other hand, studies related to the major issues of ecology, pasture land systems and the dynamics of pastoral resource management only started during the 1960s.

The pastoral livelihood in the Horn of Africa has always been exposed to the vagaries of climate and harsh environment conditions. In recent years, the situation has further been exacerbated by a myriad of problems including competition for water and grazing in the context of decreased access to land, more explicit political and economical marginalisation, lack of appropriate responses to the deteriorating security situation, and the proliferation of weapons across the region (Mkutu 2002).

2.1.2 Pastoralism in Ethiopia

Ethiopia can be divided into highlands and lowlands. The highlands are characterized by typically higher annual rainfall, relatively low mean temperatures during the growing periods, variable climate, and contain (nearly) all the important areas for cereal cultivation as well as mixed crop livestock production enterprises (Westphal 1975; Jahnke 1982;). In contrast, the lowlands are home to a diverse array of pastoral people who depend mainly on extensive livestock production. Pratt & Gwynne (1977) defined such regions that support wildlife and domestic livestock operation on native vegetation as rangelands. These areas are further characterized by ecological variability, climatic unpredictability and low resilience.

Ethiopia's percentage share of the ruminant tropical livestock units and equines when calculated across 39 countries of tropical Africa were 17 and 60 %, respectively (Jahnke 1982). Alemayehu Mengistu (1994) estimated the livestock population of Ethiopia to be 30 million cattle, 23 million sheep, 18 million goats, 8.4 million equine and 1 million camels. The pastoral areas contributed 40 % of the cattle, 25 % of the sheep, 75 % of the goats and almost 100 % of the camels (Yacob 2000).

The pastoralists in Ethiopia are derived from 29 Nilotic and Cushitic ethnic groups. Common characteristics of this segment of the society is that they are sparsely populated, inhabit border lands often straddling across the inter ethnic and international frontiers, and they are mobile (Yacob, 2000). Within their social systems decentralized leadership that promotes flexibility in resource use is commonly emphasized (Jahnke 1982; Coppock *et al.* 1985).

The animal-based life style of most pastoralists, caused by uncertainties in rainfall and primary production, enable them to be mobile and opportunistic (Coppock 1994). The opportunistic nature is partly due to a decline in the total reliance on livestock ventures and this forced some of them to combine stock keeping with subsidiary economic activities like cultivation, commerce and wage employment.

The pastoral areas of Ethiopia have experienced various forms of land reform policies in the different state regimes. Prior to 1975 the pastoral land had been under direct state ownership, because they were conceived as 'no man's land'. This was clearly inacted in proclamation No. 70 of 1944, in the 1955 revised constitution of the country, and in the Ethiopia civil code of 1960. During 1975 land policy was reformed by a new government regime (The Derg) that came to power following the collapse of the previous regime. The later did not improve the land position of the pastoral communities. On the contrary, the power of the state expanded to a much greater extent than ever before, limiting the pastoralists by law, to usufructuary right. In the subsequent years, after the 1975 land act, large state farms emerged; best rangelands were enclosed for national parks and state forests. The post Derg regime provided for pastoralists in such a way that they could not be displaced without their wish. However, the loss of land and main water sources in favour of new concessions to private and state-sponsored investment has continued unabated. Until today, there does not exist a pastoral policy in Ethiopia. Major rangeland development programs in the past were driven by development paradigms that in turn promoted controlled grazing, infrastructure development, pastoral associations and integrated natural resource management (Samuel 2001). Moreover, most interventions were indeed top-down unsustainable and all together ended up in today's worsening situation of the pastoralists and in ecological crises of the rangelands on which they depend upon for their survival.

2.1.3 Views on pastoralism

It is common in the literature to describe and analyze contemporary societies in terms of variants of modern and traditional views. Modern societies are said to be rational in their social, political and economic affairs, whose individuals are assumed to be change oriented, consistently craving for "something better" and targeting maximum benefit in life. In contrast, pastoralists are characterized by "primitive pastoralism" who allegedly impede development and change (Boku 2000). They are perceived as ultra-conservative individuals, steeped in tradition, hemmed in by custom, lacking in motivation and incentive, captives of age-old methods, and lacking in ability to make decisions (Mathur 1989). Isbister (1993) opposed such views of having implications of stagnancy and unchanging.

Pastoral societies in east Africa in general and in Ethiopia in particular are the most misconceived section of the rural populations. Pastoralism is considered as a backward way of life and the people who depend on it are perceived as lawless and aimless ever wandering mass who move from place to place in search of feed and water. It was based on such views that intervention schemes in Ethiopia were drawn to pastoral habitats for the last decades to promote development. The schemes were designed and imposed, notably by the consecutive governments without the involvement of the people on the one hand and with no regard for their culture, economies and institutions on the other (Little 1985; Hogg 1987; Salih 1989; Spencer 1998). This, in fact, contradicts the 1986 declaration of the right to development by the General Assembly of the United Nations that defined it as "an inalienable human right by virtue of which every human person and all peoples are entitled to participate in, control and enjoy economic, social, cultural and political development in which all human rights and fundamental freedoms can be fully recognized" (General Assembly Resolution 41/128/ December 4, 1986).

2.2 THE BORANA OROMO

2.2.1 History

The Borana are a branch of the Oromo people, the largest ethnic group in Ethiopia, whose language belongs to the Cushitic subfamily common to most of the north eastern Africa (Asmarom 1973). Most of the Oromo people speak closely related dialects and share a similar cultural heritage. Asmarom (1973) regarded the Oromo as one of the most expansive Africa cultures on record. Coppock (1994) added that the spread over much of what is now Ethiopia and Kenya during the 1500s resulted from massive population growth combined with an aggressive, militaristic culture. About half of the present day Ethiopia falls under their dominance.

Some historians traced the whereabouts of the Borana Oromo to somewhere in the present day western Somali. Boku (2000) explained in his thesis the interviews of the leading experts in Boran Oromo history and culture that perceived the original place as 'Beyond the sea", where the 'sea' refers to the name by which the Borana know the

Indian ocean. Some researchers argued this perception of the elders and considered the 'sea' to be lake known as 'Abaya' which is located northwest of the Borana rangeland (e.g. Herbert 1965). Boku (2000) also reported the interview of another Borana elder explaining that the Boran established new sacred sites following the loss of several old shrines due to the expansion of Islam in the region many years ago.

Many scholarly perspectives support the historic displacement and land loss of the Borana by Somali and other neighboring ethnic groups. Particularly, there is evidence that the present Borana territory in the southern rangelands of Ethiopia has been somewhat reduced since 1910, mainly because of Somali encroachment from the east. Drought and/or overgrazing caused the Borana to move their cattle westward with the vacuum being filled by Somali herders of small ruminants and camels that were better suited to the induced habitat change (Asmarom 1973). Today pressure prevails on all sides of the Borana, with the Somalis continuing to expand in the east, and other small groups in the north, northeast and west (personal communication of local people).

2.2.2 Social, cultural and organizational features

In the Borana social system descent is recognized only through the male line and men and women descended from a common ancestor constitute a corporate group in that they share many collective rights and obligations (Coppock 1994). The social organization of Borana provides the framework for resource management at two broad levels of the traditional administrative structures. These two levels may be characterized as 'administrative from above', which is known as 'Gadda', and 'administrative from within' (Boku 2000). The two administrative systems share many similar attributes and ultimately are complementary in function. The Gadda, which is in charge of the entire Borana society ensures equitable and inalienable resource management and utilization in accordance with the societal laws (Personal communication). 'Administration within' is concerned with the individual clans by which each clan administers its own internal affairs.

The Borana achieve consensus on key community issues through open participatory assembly (Hogg 1990). Consensus and enforcement of social norms is achieved under the umbrella of the 'peace of the Borana', which refers to traditional values and laws. Participation at meeting can cut across many levels in the social hierarchy. Local assembly can deal with an issue at the household level or neighborhood level, with all rights reserved to come and express their views (Hogg 1990). If a problem cannot be solved at lower levels it is passed to a clan assembly or to Gadda officials (personal communication). The ultimate body of appeal, which is the assembly of the multitudes, occurs once every eight years in the Borana societies.

The Borana follow indigenous religious spiritual beliefs with a few exception of islamic and christianity in the urban areas and the vicinity. The indigenous belief stresses that God sent down their supreme spiritual leader who taught them how to sacrifice animals and instructed them in the peace of Borana (personal communication).

2.2.3 Human population growth

Helland (1980b) reviewed the Gadda system and rules on reproduction and noted the importance of population regulation for the Borana as an ecological adaptation because of their reliance on a finite resource base. The net rate of natural population increase in the Borana population in the 1972-73 was in order of 1.5 % to 1.8 % per annum (Agrotec/crg/sedes associates 1974). This means the population would double every 55 years, a very low growth rate for pastoralists such as the Borana (Meir 1987).

Demographic studies conducted in the 1980s prevailed net population growth rate of 2.5 % and this reduced the doubling time to 28 years (Coppock 1994). During 1994 human population in the Borana pastoral areas was 0.41 million (OBAD 1999), and this figure was raised to 0.5 million after two years (Alemayehu Reda 1998). There is no clear evidence whether all the surveys were carried out exactly on the same areas of sampling or not. The later two reports agreed that 91 % of the total population were living in the rural areas while the balance lives in the urban areas. Males accounted for 51 and females 49 %.

2.2.4 Borana in Ethiopia state structure

Borana society was incorporated into the Ethiopian state on the eve of the 20th century (1888-1896) by the forces of Menelik II (Boku 2000). The incorporation was part of the larger process of inventing a dependent colonial state in Africa by the international colonial powers (Holcomb & Sisai 1990, cited by Boku 2000). The current administrative system of Ethiopia divides the Borana zone into twelve districts namely; Galaana Abbaya, OddooShaakisoo, Boore, Hagarmaaram, Uraaga, Addola, Liben, Arero, Yaaballo, Taltallii, Dirree and Mooyyale. The first six districts constitute the northern part and are inhabited largely by ethnic groups outside the Borana (Boku 2000). The later six districts, located in the southern part, are predominantly lowland and pastoral.

2.2.5 Livestock production and marketing

Livestock production plays a major role in Ethiopia's economy and accounts for 30 % of the output value of the agricultural sector (GL-CRSP 1998). Livestock contributed about 15 % of the national Gross Domestic Product (GDP) during the mid 1980s and 1990s (IBRD 1987; Tegegne *et al.* 1999). In 1997/98, GDP at constant cost from agriculture and allied activities (crop, livestock, forestry and fishing) was 46.4 % of the national total (MEdaC 1999).

Livestock production is more important in the rangelands of Ethiopia, both in distribution and as a source of living. It is one of a few options available to millions of impoverished people who live in arid and semi-arid areas of the country. Livestock production in the lowlands provided subsistence employment and investment opportunities for around 5 million people living in some 24 major towns and cities within and adjacent to the lowland areas (Coppock 1994). Traditionally, rangeland livestock production is linked to the highland crop production farming system by providing draft animals and animal products for consumer markets.

Livestock production in Borana is predominantly cattle, but with a growing interest for camels and small ruminants. Solomon Desta (1999) explained such interest as components of an emerging strategy to achieve food security. Small ruminants are also very important for households to meet routine cash income needs, and besides, may help to avoid or at least minimize the need to sell cattle, which is considered as the most important means of wealth storage of Borana (Coppock 1992).

General aspects of cattle husbandry in the Borana were discussed by Coppock (1994) and some of the many aspects included the maintenance of a female dominated herd structure, dividing animals into satellite herds to conserve local resource, uncontrolled breeding, milking management of cows, intensive hand rearing of nursing calves and apportioning tasks according to gender and age.

2.2.5.1 Livestock population and trends

There is paucity of information on livestock resources, population and trend in Ethiopia in general and Borana in particular. The available information are from different sources, not comprehensive, nor continuous and with a lot of missing data. What has been done thus far in this regard was the description of the origin and type of the livestock species in the different parts of the country.

The estimates of Borana livestock population provided in the Agrotec/crg/sedes associates report (1974) indicated approximately 0.82 million heads of cattle, 0.02 million camels and 0.08 million sheep and goats prior to the drought of 1973-75. Alemayehu Reda (1998), Alemayehu Mengistu (1998) and OBAD (1999) reviewed the livestock population estimate of the year 1987/88 and 1994, respectively. The review of

Alemayehu Reda was based on SORDU'S vaccination campaign and socio economic survey census report.

Data on individual livestock holdings, trends and the status of restocking mechanisms are very relevant indicators in monitoring food security, and the overall livelihood of the Borana household economy. Results of interviews with 150 households from ten pastoral associations revealed that the average livestock holdings per household in 1990 was 43 % cattle, 24 % sheep, 19 % goats, 2.1 % camels and 1.3 % equines (Alemayehu Mengistu 1998). The number of livestock species owned per household during the years 1991/92 showed a dramatic decline when compared to the previous year. The same author noted the reduction for cattle (50 %), sheep (56 %), goats (51 %), camels (11 %), and equines (49). In fact, this dramatic change was attributed to the drought that prevailed during the 1991-92 year. This report also suggested that the average number of livestock decreased dramatically after the drought year (1994), except for the escalating number of camels. An increase in camel population may be due to a strategy by many Borana to diversify in response to woody plant encroachment in the rangelands that benefits browsing camels over cattle, and the contributions that camels make in terms of increased milk production for home consumption and sale during drought. The declining trend in livestock holding was supported by other researchers. According to Mulugeta (1990), the ratio of livestock holding per person varied from 14.2:1 for the wealthy, 7.3:1 for the middle class and 2.3:1-for the poor. Solomon Desta (1999) found the ratio to be 12.8:1, 6:1, and 2.5:1 for the wealthy, middle class and the poor, respectively and thus, there appeared to be a declining livestock to people ratio among the Borana, exhibiting a major drop in pastoral welfare and food security in less than 15 years.

2.2.5.2 Marketing of livestock and by products

There is a lack of time series data on livestock prices as well as on the performance and efficiency of the livestock marketing system in the Borana pastoral areas. In addition to milk and meat production for consumption, the survival of Borana depends on producing surplus animals and by-products for sale and the purchase of consumables, particularly grain, other goods and services. More than 90 % of Borana family's cash income has been assumed to be derived from livestock sales, mostly all from cattle (Cossins & Upton 1987; Solomon Desta 1999). Survey results on 150 households indicated that about 21 % of the respondents involved in milk production were found selling milk and about 10 % per day per household of milk produced is used for sale whereas the remaining 70 % and 20 % are used for daily consumption and butter making respectively (Alemayehu Mengistu 1998). The report also revealed that a major part of the income from livestock sales (70 %) is used for food and clothes purchase, 13 % for minor expenses, 10 % for ceremonial purposes and the rest (4 %) went to contributions that included tax.

The volume of livestock sold varies depending on season, availability of feed and water and price of food. The Borana herd owners seek to accumulate cattle as social and economic assets rather than to generate cash income (Coppock 1994). The primary reason for selling animal is to meet an acute need of money in general and this usually arises when milk production drops and food is needed. Therefore, herd owners always wait until a dry period to sell animals even though they realize that the terms of trade are less favourable compared to other times of the year.

As long as cash demands are modest, the top priority is to sell a sheep or goat. This is because they can substitute the sale of cattle and there are fewer regulations that constrain their sale. When cash demands are higher, then cattle are sold and their sale is in reverse order of their importance to herd generating capacity (Coppock 1994). Therefore, large animals tend to be sold as a priority because the price received is the highest and permits the purchase of the needed goods plus one or more replacement calves thereby attaining two objectives simultaneously.

Two kinds of livestock markets are distinguished in Borana. Internally, it consists of the sales of livestock to neighbouring farmers, traders and/or large home markets and externally it consists of unofficial, cross border trade with neighboring countries in the border area. For instance, in the mid 1980s unofficial annual livestock trade from Ethiopia to Djibouti, Kenya and Somali was estimated to be 550 00 cattle, 33 000 sheep and goats (Tegegne *et al.* 1999). More recent estimates put this number at approximately 260 000 cattle, 1 200 000 sheep and goats (Tegegne *et al.* 1999). Both kinds of the markets follow a three-tier system with primary, intermediate and terminal markets through which the marketable animals pass from the pastroalsits to large traders and/butchers via the small traders (Alemayehu Mengistu 1998).

The structure and performance of the Borana market system is reasonably good because of the ready access of primary markets and the presence of large number of buyers and sellers (Cossins & Upton 1988b). In addition, they stated that a major marketing constraint was the decline in the terms of trade of livestock for grain during drought, which reflects problems in national policies for food production and distribution rather than deficiencies in the local characteristics of the market.

2.2.5 3 Borana household economy

As discussed in the previous section, the Borana consider herding as the most valuable and honorable activity of their economy. They get their subsistence food either directly in the form of milk, its by-products, meat and blood or indirectly in the form of purchased cereals through the sale of animals and their by products (Helland 1980). In the last few years, the involvement of only a few Borana households in crop production was reported. (Cossins & Upton 1987; Holden 1989). This venture, however, has shown further expansion in recent years in response to drought and food insecurity (personal observation). In the past, cultivation was considered as an activity of distressed, poor pastoralists when they were ejected from pastoralist system because of livestock loss due to drought and/or diseases (Hogg 1986; Moris 1988).

The main interactions between crops and livestock in the Borana economy occur when oxen or camels are sometimes used to plough fields or when crop residues are fed to calves in dry seasons, and when small amounts of cash from sales of livestock products are used to purchase seeds.

The average gross income of an average Borana household in an average rainfall year during the early 1980s was about Ethiopian Birr (EB) 2000 (Coppock 1994). This calculation considered the values of marketed animals (EB 552), marketed milk (EB 71), consumed milk (EB 721), six new calves (EB 600) plus other useful animal products such as hides (EB 50) for a total grant of EB 1994. The mean cash income of Borana households in 1972 was EB 86 (Agrotec/crg/sedes associate 1974), which is only 14 % of the mean EB 623 for the 1983. This change may be due to changes in the prices of commodities as well as a previously lower need for market involvement. Except from trace amounts of income from sales of things like firewood, incense or handicrafts, virtually all of the income was from livestock, specifically from cattle and its products. Until today, the vast majority of the Borana operates largely pastoral rather than agro pastoral economy.

2.3 RESOURCE MANAGEMENT VERSUS VEGETATION DYNAMICS

2.3.1 Indigenous rangeland management: The debate

Traditional East African pastoralists have a rich knowledge of biodiversity that enabled them to distinguish less important invasive plant species from those that are valuable, but declining or becoming extinct. The management systems that they apply have made large inputs in the conservation of a wide variety of plants and the soil. This is because they have a direct and/or indirect interest in the plants and/or animals for their own survival. They have also gathered a wide range of products such as medicinal plants, gum and resins, which is an important part of the pastoral way of life.

Like many pastoralists elsewhere in east Africa, the Borana have managed the rangelands using their own experience and knowledge without any external support for many centuries. The indigenous rangeland management of the Borana is based on the interactions between plants, grazing animals and humans with abiotic components like rainfall and soil playing an important role (Ahmed & Menzel 1997). The essence of the pastoralists at large is to manipulate livestock number, species and their movement in accordance with the available forage and water resources. Overall, climate, notably low and erratic rainfall, has made their life somehow tenuous, but the pastoralists were able to maintain a precarious balance between themselves, the animals and their environment.

Several types of indigenous management techniques have been implemented by the Borana to maintain the ecological balance of the rangeland resources. Solomon Desta (2000) and Maryam (undated) stated that mobility is one of the important rangeland management tools available for drought survival and is one of the best adapted and effective means of obtaining what livestock need in an ever-variable environment. Encampments of the Borana typically change location once every five to eight years in search of better grazing (Donaldson 1986; Cossins & Upton 1987). They became highly mobile if need arises, especially during drought situations and move out of the core territory (Solomon Desta 2000).

In pastoral African context, including the Borana, mobility is not random but is regulated by socio-political controls and technical know how (Maryam undated). Being mobile to search for grazing and water requires as large an area as possible (Billé 1983). Herders indicate at times a need to move and the best direction to go. To do this, they have developed experience, for instance, of monitoring livestock faeces, milk yield, animal weight, and the numbers of cows in heat to evaluate the quantity and quality of forage available in the rangeland (Maliki 1984). Other than for grazing, water and drought, secondary factors that determine mobility patterns of the pastoralists were reported to be salt-licks, soil conditions, other environmental factors, prevalence of insects and diseases (Maryam undated).

Billé & Assefa (1983) noted the traditional importance of the hypothesized cycle of cattle patch-use and shifts on vegetation composition, in maintaining the long term, dynamic stability and diversity of the Borana ecosystem. But this would no longer function under increased human and livestock populations that continuously disrupted the cycle and finally end up in the use of sites before recovery has taken place (Coppock 1995).

The second management strategy of the Borana pastoralists is that of their organizational structure (Alemayehu Mengistu 1998). In order to maintain a sustainable use of the rangeland resources, the Borana have, over many centuries set up a wide territorial organization through which grazing and water management are governed (Hogg 1992). Accordingly, households are organized into encampments (Olla), which in turn are clustered to give localities (Arda). There are Ardas that are only meant for grazing and where nobody is allowed to settle. In other cases there are Ardas used for ritual purposes and others, which can never be cultivated (Solomon Desta 2000). The next territorial unit in the hierarchy over Arda is called Madda, an area around "permanently replenishing water points, the Wells". Hogg (1992) defined Madda as an area of grazing, which is demarcated in terms of access and customary use of particular wells. Thus, it is an important resource management unit in Borana in which herd owners who come from outside the Madda can be denied access.

Fire is another ancient and important tool of rangeland management employed by the Borana in control of undesirable plant species grown on the rangeland. Rotational burning was traditionally practiced by the Borana in the "forward grazing areas" (Oba 1998). Burning is believed by the Borana to remove moribund grass, renews grass growth and reduces tree sapling. At the same time post-fire grass growth is nutritionally superior to the unburned grass.

Undoubtedly, all the indigenous rangeland management practices of the pastoral Borana come to reality first, through their organizational and cooperation framework. This is to say that the Borana are egalitarian in ethos and decisions are based on consensus (Asmarom 1973; Hogg 1992; Coppock 1994). The whole pastoral systems in east Africa actually require a high degree of both if they are to function well. In other words this means that a society which stresses the community over the individual, and which stresses common but organized rights to resource, is more likely to succeed in the pastoral context (as it has happened for pastoral Borana over many centuries) than one which stresses individual rights (Cossins 1983).

Secondly, pastoral rangeland management is assisted by their indigenous geographical and ecological knowledge and abilities to classify basic grazing units (landscapes) in terms of grazing resource quality. According to Oba *et al.* (2000), Borana classified the landscape units into six major categories and several landscape patches. Oba (2001) noted over 54 landscape patches with 36 % that were named after landscape feature, 20 % after dominant plant species, 10.7 % after structures built by the people, 10.7 % by historical events and 0.4 % after dominant or common game species.

Among east African pastoralists, vegetation and soil types are good indicators of land use suitability of the landscapes and suitability of individual landscapes varies with season and the types of livestock (Oba 2001). For instance, the presence of perennial grasses and soils are suitability indicators to cattle grazing; camels and small stock suitability is based on soil types and browse availability. Landscapes suited for all livestock species have the right combinations of vegetation and soils (Oba 1998). Such indigenous knowledge of landscape suitability is developed from historical knowledge of landscape change (Oba 2001).

The identities of the landscapes under investigation have significance in terms of land use and location of grazing resources in time and space. Furthermore, landscape use is not haphazard but planned in accordance with an assessment of potential and suitability. Using factors such as grazing suitability, the pastoralists of east Africa allocate grazing to different landscapes during different seasons of the grazing cycles (Oba 2001).

2.3.1.1 Water resource management system

The water resource in the Borana rangeland is perhaps the most fundamental feature that has shaped the Borana society (Helland 1980; Cossins & Upton 1987; Bassi 1990 cited by Coppock 1994). Coppock (1994) cited Agrotec/crg/sedes associates (1974) who made a comprehensive survey indicating that the Borana rangelands were demarcated into two regions with different water-bearing properties namely: (1) a base complex formation dominant to the west with more favorable water shortage chractersitics, and (ii) stratigraphic sequence to the east.

2.3.1.1.1 Sources of Water

Three basic sources from which water is available in Boran have been identified (Helland 1977 cited by Boku 2000; Coppock 1994; Alemayehu Reda 1998; Alemayehu Mengistu 1998; Oba 1998). This is more or less similar to the traditional Borana classification, which categorises water sources into two broader typologies refering to surface waters and the subteranean water. In both cases the classification is based on the types of right regulating access, degree of seasonal perenneality (reliability), social and economical vitality, labor required for the development of the source, and watering of livestock (Boku 2000).

Occasional water source : This includes run-off resulting from the rain such as seasonal streams, rivers and water collected in natural depression, water in shallow or deep cut depressions of a big rocks, and a temporary oasis where water oozes up to the top soil (Boku 2000; Helland 1980).

Water ponds: These are the most important source of water after the wells in the Borana rangelands and are locally termed as Harra (Helland 1980; Hodgson 1990 cited by Coppock 1994) (Figure 2.1). In this case, the natural and the man made ponds have been identified (Alemayehu Reda 1998). According to Boku (2000), a person may select a flood catching site and scratch the ground for digging a pond. The labor for excavation and removal of soil or silt is contributed each year by village members who expect to make use of the pond (Hodgson 1990 cited in Coppock 1994). When the capacity improves, utilization extends to the nearby village or even beyond. There is no formal estimation of the number of ponds in the traditional system prior to or after the mechanized pond development programs started in 1950s (Tilaye Bekele 1987; personal communication of SORDU).

Machine dug water developments assumed that the low lands of Borana lacked surface water so that development would reduce pressure on the dry season rangelands by creating water points in the wet season grazing areas and hence increase more use of the wet season rangeland (Oba 1998). Accordingly, nearly 126 ponds with a total water holding capacity of 2 million m^3 ranging in size from 6000-10,000 m^3 were constructed from 1967 to 1997 (Oba 1998; Alemayehu Reda 1998).

Wells: These are most important source of water in the Borana rangeland (Figure 2.2). The comprehensive survey of Agrotec/crg/sedes associates (1974) cited by Coppock (1994) reported a total of 543 hand-dug wells in the Boran rangelands clustered in some 35-40 groups, broadly classified as either crater, shallow (Adadi), or deep (Tula) wells.

Crater wells can be the bottom of volcanic craters. Shallow wells consist of a wide shaft dug into alluvium and can be up to 10 m deep (Helland 1980; Cossins & Upton 1987). The shallow wells may be dug at any time. In contrast, Crater and deep wells are usually much deeper (up to 30 m deep) and require a massive excavation with shafts commonly sunk into rock. Helland (1980) cited Haberland (1963) who believed that the two wells had been dug by an unknown Megalithic culture (some 500 years ago).

Figure 2.1 Common type of water pond (Harro) in Borana communal grazing area: Harro Dambidikale.

There was a hypothesis that indicated that these wells had been dug by a group of people outside the Borana society but belonged to the same ethnic group (Helland 1980). Contrary to this, Asmarom (1973) has accepted the idea that Borana dug the wells themselves. It was reported that the deep wells in particular are impressive feats of engineering (Helland 1980b; Cossins 1983b; Donaldson 1983; Cossins & Upton 1987).

Water wells are the most reliable sources and the highest degree of access restriction is accordingly imposed on them. Besides, the largest labour was required to construct the wells and the largest amount of labour is required for watering the animals. The well clusters are not only central to the functioning of the Borana pastoral economy but are also important as social institution around which the Borana society is organized (Helland 1980b; Abunie 1991; Boku 2000). Every well belongs to the clan of the person, who initiated the digging ceremony, called the father of the well. The person who holds the property right of the well is not the caretaker. The caretaker is appointed by the clan. Being caretaker is an inherited title and responsibility for the well can be transferred to him if the father of the well is not present (Alemayehu Mengistu 1998). The well caretaker establishes watering rights for users by fixing water quota. He is kept under constant scrutiny by the clan elders to insure that he has accurately performed his obligations in accordance with the customary laws of the Borana (Alemayehu Mengistu 1998; Oba 1998).

Resource allocation for well maintenance varies with the type of wells. Deep wells are maintained by the resources of the clan and the shallow wells are maintained by resources contributed by users (Oba 1998). In sum, in either of the types; maintenance, construction and utilization of the wells are arduous jobs requiring clan cooperation in terms of labour, tools and consumable resources such as milk and animals needed to feed the workers (Baxter 1970; Asmarom 1973).

2.3.1.1.2 Water management

As a result of the fact that water is a crucial resource in the lowlands of Borana, the pastorlists have developed an elaborate water management culture compared to other pastoral communities of east Africa (Oba 1998). For them water is not only a resource but a tool for rangeland management. In other words, the far reaching knowledge of ecology they acquire over many centuries and the climatic situations had enabled the Borana pastoralists to develop their fine-tuned system based on the availability of water (Ahmed & Menzel 1997).

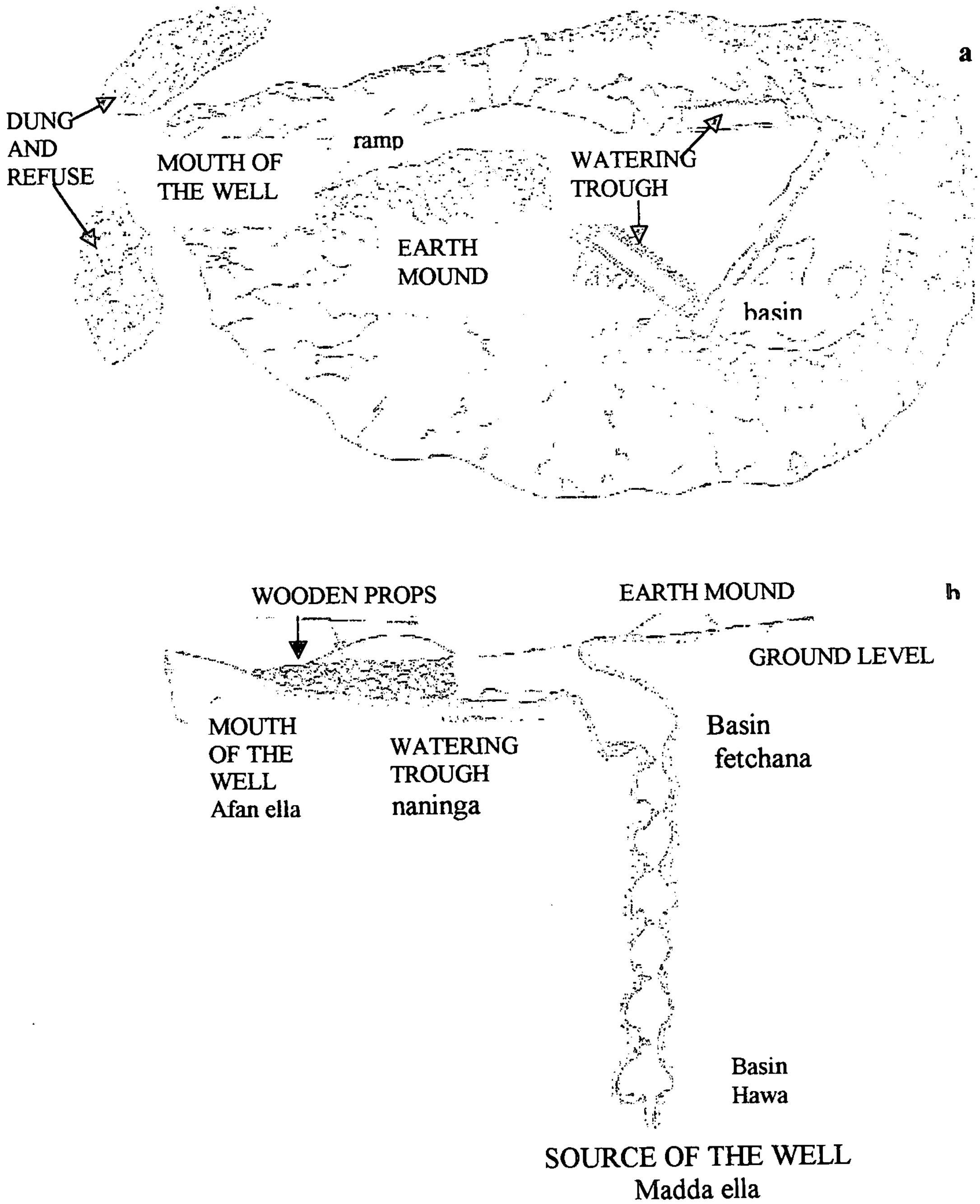


Figure 2.2 Schematic diagram of big wells on the Borana communal grazing areas: aerial view (a) and lateral view (b) (Source: Coppock 1994). The maximum depth of the well may be up to 40 m.

The Borana pastoralists have an efficient water use-system (Helland 1982 cited by Solomon Desta 1997, 2000). The rights for regulating the use of the different water sources vary depending upon the labour required to control and maintain them and the need to regulate the scarce resource so that sustainable pastoral production can be maintained. As long as water is available in either of the occasional sources, Borana tends to avoid utilization of pond water. Among the occasional sources, even Borana prefer to use the most occasional (Boku 2000). This may be because of the logic that the least permanent source is to be used before drying up through evaporation and percolation.

During the dry season herders move their animals to drink from wells and large ponds. If the dry season gets longer, or if it turns out to be a prolonged drought, then the herders will have no other choice than to keep concentrating animals near the wells, permanent ponds, and the few rivers (Solomon Desta 2000). Households, villages and regional society members (Madda members) will be busy meeting during the dry periods and drought to organize labour for well-watering and regular maintenance of wells.

The watering interval for all animals can increase during droughts; cattle may be watered once every four to five days during the critical droughts (Boku 2000; Solomon Desta 2000; Coppock 1994). Watering from wells requires cooperation of the well users. Water is drawn by a human chain that may vary from 15-20 (Asmarom 1973; Helland 1980). It is the organization of labour that contributes to social cohesion and effective utilization of particularly the deep wells.

2.3.1.2 Vegetation resource management

Most of the feed that the Borana livestock utilizes originate from rangeland. Therefore, the livestock may experience seasonal fluctuations in feed availability and quality. Eventually, most livestock maintained in the rangeland lose body weight and decrease in milk production throughout the dry season and during drought.

Unlike the water management system, which is based on village/clan arrangement, rangeland management is undertaken by spatial units within the framework of the Borana land tenure system. Communal ownership of land regardless of clan, village and social ranks distinguishes the Borana from other pastoral groups in Ethiopia such as the Somali and the Afar, among whom a specific clan or even individuals may demarcate a specific land territory (Boku 2000).

Land use in Borana is influenced by landscape types, water and rangeland vegetation resources. The strategy of ranging animals is flexible. Rangeland management is based on cumulative knowledge of the rangeland resources, assessment and distribution of rainfall (Oba 1998). That is why, among the Borana, communal land ownership furnishes community members with equal rights but not in an open access grazing/browsing style. Local territorial units often adopt restrictive strategies constraining access to the communal rangeland (Boku 2000). The strategies are adapted in order to utilize the pasture in an environmentally safe and economically viable way. Some of the restrictive strategies are discussed below:

***Restriction of settlement*:** In the normal dry season where water is inadequate, cattle are watered every third day. Watering frequency may extend up to four or even five days depending on the performance of the well. Villagers reserve the best grazing zones for communal grazing to be utilized on the days prior to watering. This zone of abundant and good quality grazing is known as 'grazing head' or locally 'Mataa tikaa'. The legal territorial units prohibit settlement at such community fodder bank (personal communication). Also the Borana recognize that livestock *en route* to and from the dry season watering wells would need some vegetation and thus, settlement between a village and its nearest perennial water wells is forbidden (Boku 2000).

***Grazing restriction by stock type*:** Dahi (1979) noted that management of the 'three with sweet milk'; cattle, camels and goats requires different strategies. Cattle and sheep need a bulk of perennial grasses while for camels and goats suitability is based on browse availability (Le Houérou 1980; Oba 1998; Boku 2000). Other than this, the Borana pastoralists traditionally perceived camel as incompatible with cattle for two reasons. Firstly, they say camels pollute the environment through continuously flowing urine and therefore cattle detest sites where camel herds have frequently browsed. Secondly, camels are said to destroy grass with flat hooves. As a result, camel owning families tend to keep their camels in places far from cattle grazing areas (personal communication of pastoralists). In recent times, however, camel pastoralism has been adopted on a much wide scale due to the ever declining reliance on cattle as the single most important economic resource (personal communication).

Calf grazing reserves: The reservation of part of the grazing land for later use is one of the rangeland management strategies that restrict open access. These are semi-private grazing resources allocated using traditional rules and regulations. In this case a portion of the communal rangeland, usually part of a hill or valley bottoms, is reserved for dry season grazing. Each grazing reserve area is governed by different rules and regulations (Bassi 1996 cited by Boku 2000; Oba 1998). The calf grazing reserve is a communal resource whose management is the responsibility of the collaborating village of each particular grazing area. Joint ownership of the fodder bank allows them to decide when to use and when to reserve. The grazing reserve is meant for latter grazing predominantly by drought vulnerable animals such as calves, weak and sick animals during the times when open grazing resource becomes depleted. The age of the calves that are allowed to use the fodder bank is limited to 1-2 years with no restriction on the number that individuals are allowed to graze (Oba 1998). Other categories of healthy livestock are excluded.

Establishment of calf grazing reserves in the settled areas is an adaptive response to declining grazing resources (Oba 1998; Boku 2000). Boku (2000) also reported that one of the strategies for managing communal fodder banks included the avoidance of fragmentation of the communal property. If, however, the villages are spatially scattered, each will be allowed to establish its own reserve (personal communication and observation). Alternatively, an option exists for small villages to join a neighboring larger village or a new village to join an old village. The Borana believe that proliferation of grazing reserve would cause land fragmentation and thereby exposing other types of livestock to grass /browse scarcity and obstruct mobility. Thus, the community seems to prefer restriction of using grazing areas that are big enough to support all the adjacent villages to fragmented fodder banks (Boku 2000).

Another issue worth mentioning about calf grazing reserves is that they used to be only a temporary space in the past. Currently, however, some reserve sites have become permanent (pastoral communication and observation). The permanent reserve came to exist because of the introduction of big ponds through the government rangeland development programs and due to an ever expansion of farm activities.

***Seasonal grazing*:** Another rangeland management strategy is the arbitrary partitioning of grazing/browsing in to the wet and the dry season areas (Coppock 1994; Oba 1998; Boku 2000). During the wet seasons, herds migrate to remote sites inaccessible for grazing during the dry season due to water scarcity. A greater portion of the landscape falls into the wet season grazing lands (Agrotec/crg/sedes associates 1974). The wet season rangelands are used while rainwater is obtainable. The use of the wet season grazing lands is located surrounding the well complexes. Such areas tend to be overstocked when human and livestock populations converge from the dry season grazing rangelands. Oba (1998) also noticed that some of the rangelands of the dry season grazing areas have maintained a fairly good rangeland condition despite several centuries of use. Apart from these two, the Borana have grazing reserves that can be used during prolonged drought year. The pastoralists gain access to the waterless rangelands in the drought periods and grazing of such reserves is made by altering the water regimes of cattle from normal two or three to four or five days (Oba & Lusigi 1987; Oba 1994).

In general, division of rangelands into wet season, dry season and drought year grazing areas provides a good opportunity for rest, growth and recovery of the rangeland before the next grazing. This strategy may avoid or minimize rangeland degradation. Recently, however, sedentarization has become much more pronounced than ever before, which has resulted in the Borana to be less strict in adopting these flexible strategies, especially in the agro pastoral areas (communication of agricultural office).

2.3.1.3 Borana herd management

The most important herd management techniques in the Borana society include diversification, splitting and calf management. Pastoralists always try to maintain a diverse portfolio of livestock designed: (1) to meet their immediate sustenance and economic needs and, (2) to fit into the environment.

African rangelands in general and that of the Borana in particular are characterized by edaphic grasslands, and pure shrub thickets can be mixed with open canopy savannas and wooded *Acacias*. On the fringes of ecosystems, the ecotones can be sharper or gradual; in both cases resulting in very special and diverse flora (Maryam undated). In such ecosystems, one may find that raising cattle only, as is common on modern ranches, requires much more capital as well as a higher demand for labor for bush clearing and other management aspects in order to maintain the grassland. This is in marked contrast to the traditional herd management of the pastoral Borana who accepted and responded to the diversity of the ecosystem by having a herd of mixed species including cattle/sheep to rely largely on grasses and camel/goat on browse (Le Houérou 1980; Coppock 1994; Oba 1998; Boku 2000). Each type of animals fulfills a specific objective of the pastoral family. Large animals (cattle/camel) are raised not so much for their meat as for their milk, but also they are the bank account and security deposits of the pastoralists.

Herd splitting is the practice of dividing livestock into separate herds depending upon their age, sex, type and productivity. African pastoralists frequently separate large ruminants from small ones; milking, pregnant animals and their young from main or dry herds (Maryam undated). Likewise, the Borana generally split the herds into two groups, commonly known as the "Forra" and the "Warra" herds (Solomon Desta 2000). The "Forra" herd is basically the dry herd and thus, consists of bulls, immatures older than 2 years and dry cows. The "Warra" herd constitutes the milking cows, calves and immatures younger than two-year of age (Coppock 1994). Splitting of mainly cattle as less mobile "Warra" group or far ranging "Forra" herd depends on the conditions of the resource base, availability of labour and according to the sex, age, class of animals and whether or not cows are in milk.

As described by Donaldson (1986), the primary purpose of the warra-forra system is to distribute animals away from the home area during times of restricted availability of forage (and sometimes water). "Forra" herds are managed by older boys and young men whereas the "Warra" herds are kept by relatively younger boys and old age groups who are not capable of moving long distance (Cossins & Upton 1987). The "Warra" herds are kept within closer grazing orbits whose distance varies depending on whether the day is used for grazing or grazing and watering. In contrast, the "Forra" herds move longer distances outside the radii of proximate areas (Coppock 1994). The composition and size of "Warra" and "Forra" herds is dynamic across seasons, depending on average rainfall. Coppock (1994) reported that years of high rainfall may be characterized by "Warra" herds of larger size and a more heterogeneous composition, while the inverse holds true for "Forra" herds. Both the "Warra" and the "Forra" herds may be watered once every two to four days during the dry periods and this is considered as a management adaptation to minimize labour required to raise water from the deep wells and maximize the size of grazing orbits (Nicholson 1987).

Herd diversity and splitting can result in increased niche specialization, in reduced competition among the livestock for the same vegetation and in a dispersion of grazing pressure as each type of livestock is taken to the area which suits it best. Therefore, both techniques can help to maintain the long term productivity of rangeland to ensure sustainable production at a comparatively low cost, and in some cases to improve the degraded rangeland.

The calf management strategy of the Borana pastoral society was initially described by Donaldson (1986). Accordingly, he reported that during the first 7-12 months of its life, the calf's diet consists of milk from restricted suckling and a combination of grazed and cut and carry forage. The amount of milk a calf receives varies with season, milking class of the dam (high, average or low) and human demand for milk. In general, milk intake for calves will be the highest during the wet seasons for those born to high producing dams owned by wealthier families that put less demand on the milk supply (Coppock 1994).

2.3.1.4 The 'tragedy of the commons'

Debate and controversy regarding pastoralism and the associated common use of land resources dated a long time a go. In fact, the debate about the rationale of communal land use gets stronger these days. In most African countries, the official views and the classical rangeland theory have portrayed traditional, communal rangeland management as an unproductive and unsustainable form of land use, invariably leading to irreversible rangeland degradation (Peters 1987; Abel 1993; Shackleton 1993; Okoth-Ogendo 1998).

According to Lamprey (1983) cited by Fratkin *et al.* (1994), pastoralists are the sole catalyser to the destruction of their own habitat because the pastoralists are so selfish that they keep accumulating excess animals on the commons. A detailed view on the same ideas was put forward in the theory of 'the tragedy of the commons' (Hardin 1968). According to this theory, the individual pastoralists seek to maximize returns from the communally held resources by keeping as large a herd as possible, without caring for their ecology and undoubtedly this results in growth rates in the livestock population beyond the capacity of natural resources. Lane (1998) provided further elaboration on the tenets of the 'tragedy of the commons' as follows:

> "*The tragedy of the commons theory argues that indigenous communal land tenure systems are incapable of efficient land use as herders with the means and desire to expand their livestock holding will ultimately destroy the range through overgrazing. As each individual has unrestricted access to the common and is motivated by a wish to maximize his herd, so tragedy is inevitable. The logic that lies behind this is that for each animal a herder adds to his herd on a common, the extra consumption of resources will provide a direct benefit to him alone but the cost of that increased consumption will be shared by all. As the benefit enjoyed by the individual exceeds the shared cost, the herder is encouraged to continue increasing his herd size even if it results in the destruction of the range and a general loss for all.*"

The tragedy of the commons model considers the pastoralists as egocentric and environmentally destructive. This theory also suggested that the change from the commons to individual owned property is the only measure to curb overgrazing and the alleged resultant ecological degradation that would inevitably lead to desertification. Such assumptions, as Manger (1996) noted, have reduced the interest of important aid agencies to work in the semi-arid and arid pastoral regions of east Africa. Lane & Moorehead (1995) assessed the overall implications of the advocated privatization of pastoral lands suggested in 'the tragedy of the commons'. They concluded that such land reforms always provide little protection to pastoralists from land alienation. The reforms limit strategies for herd movement and efficient use of resources. They also indicated more vividly that the reforms tend to marginalize the poorer sections in the pastoralists.

In contrast, for many parts of Africa, assessment of the traditional pastoral system and associated opportunistic approach to land management have highlighted the compatibility of the system with the prevailing uncertainty of the physical, social and economic climate under which they operate (Abel & Blaikie 1989; Behnke & Scoones 1993; Ellis *et al.* 1995; Dahlberg & Blaikie 1999; Sullivan 1999).

According to Abdel Ghaffar (1976), pastoralism is an appropriate and efficient adaptation to the arid and semi-arid environments of Africa. Pastoralists deploy elaborate, ecological knowledge and herding strategies in their management and utilization of the available meager resources. Challenging the conception of pastoralism as an inherently crisis-ridden production system, it was contended that the crisis experienced by contemporary African pastoralism is caused, first and foremost, by externally imposed factors and inputs (Manger 1996). Cossins (1983) elaborated his supportive idea on the pastoral use of lands as follows:

> *"The communal use of land is another pastoral strategy, and it makes sense considering the availability and unreliability of rainfall in African rangelands. In any one year rainfall may vary within a pastoral system by as much as 200 % from the mean, as it may between years. As there also appears to be no cyclical effect involved (Billé 1983) so that a planned rotational system is not feasible, it pays pastoralists to have access to as large an area as possible in common. Individual or group ownership of specific areas of land precludes this strategy, and just so long as a pastoralist continues to have his life at risk rather than his livelihood, and maintains his bankable reserves as livestock, subdivision of land will be counter to the ability of a pastoralist to survive."*

Many scholars emphasize the status of herd mobility not only as a mechanism to deal with resource scarcity, but also as a wise practice through which the alleged ecological jeopardy is avoided. In line with this, Fratkin (1998) noted that herd mobility should be encouraged and practiced, notably by recognizing common property rights.

While the debate is still raging, it is evident that among pastoral groups in several African countries, common property regimes are changing gradually into individualized ownership. In South Darfar of the Sudan, pastoralists' access to land was being obstructed by the individual promoters of spontaneous enclosures on the communal rangelands (Behnke 1985). The process of land dispossession has been taking place over several decades among the Maasai of Kenya and Tanzania (Galaty 1992; 1994). Among the Somali clans in eastern Ethiopia, communal grazing lands have been turned into privatized enclosures (Takele *et al.* 1994). The Afar pastoralists in northeastern Ethiopia have lived for decades under pressure exerted by ill-designed development approaches that led to the displacement of the people from their land (Ali 1992).

Like other pastoral groups in the country, the Borana are also experiencing changes in their resource tenure from communal to individualized holdings with exclusive access whereby communal grazing lands are reduced. Other processes contributing to the serious reduction of communal grazing lands, however, are bush encroachment, state and private ranching and administrative boundary delineation (Boku 2000).

2.3.2 Rangeland condition and vegetation dynamics of Borana rangelands

The term rangeland condition has been defined as the state of health on the rangeland in terms of its ecological status, resistance to soil erosion and its potential for producing forage to sustain long term optimum livestock production (Pratt & Gwynne 1977; Trollope *et al.* 1990).

Soil loss due to erosion may be regarded as an absolute measure of the health of grazing land since it is irreversible, except over extremely long period of time, and results in a reduction in productivity and affects future land use options (Wilson *et al.* 1984, Snyman 1999). Vegetation change is usually used to quantify rangeland condition because it is a more sensitive indicator of ecosystem change, and is easier to measure than is the soil (Teague & Danckwerts 1989 cited by Hardy *et al.* 1999).

The use of vegetation as a primary indicator of the state of health of rangelands is based on the assumption that vegetation is a reliable mirror of its ecological environment (Mouat & Johnson 1981). The vegetation indicators usually considered as indicative of rangeland degradation were described as a low grass cover, preponderance of grasses of low palatability, change from a species composition where perennials predominate to one dominated by annuals, particularly forbs and increase in woody vegetation density (Stoddart *et al.* 1975). Other indicators of decreased rangeland condition are decreased soil water availability, and livestock condition or productivity which may, however, lag behind a deterioration in vegetation or soil condition (ILCA 1990).

Savannas cover approximately 40 % of Africa and is the main source of feed for grazing and browsing animals (Grunow *et al.* 1980). Changes in the composition and productivity of open savannas have been described earlier from many semi-arid and arid regions of the world (Buffington & Herbel 1965; Blackburn & Tueller 1970; Madany & West 1983; Van Vegten 1983; Hacker 1984; Tolsma *et al.* 1987; Acocks 1988; Archer *et al.* 1988). In east Africa, unfavourable and long-term changes in the composition and productivity of rangeland vegetation have far-reaching implications for pastoral economies.

Climate and soil characteristics are the primary determinants of species composition and structure of vegetation communities in semi-arid and arid areas (O'Connor 1985; Scholes & Walker 1993). Secondary determinants that may modify this basic pattern include grazing and fire (Noy-Meir 1982; Teague & Smit 1992; Scholes & Walker 1993).

Overgrazing is considered as the most important cause of rangeland degradation (Danckwerts & Tainton 1996). When the potential of rangeland is overestimated, the resultant overgrazing will cause a decrease of the palatable perennial plants in favour of less palatable undesirable vegetation. Such changes will also influence the hydrological status (Snyman & Fouché 1991, 1993), stability (Snyman 1998), quality (Potgieter 1991 cited by Van der Westhuizen *et al.* 1999), productivity (Kirkman & Moore 1995; O'Connor & Bredenkamp 1997; Snyman 1997) and utilization potential of rangelands.

Chronic overgrazing, drought and inappropriate cultivation have been most commonly cited as causes of deterioration of rangeland condition in east Africa (Coppock 1994; Mäckel 1994; Herlocker *et al.* 1995; Herlocker 1999). It is difficult to generalize about the causes of change in rangeland condition because of site specific interactions among ecological features and human use (IPAL 1984; Sinclair & Fryxell 1985; Homewood & Rogers 1987).

The Borana rangeland accounts for 7.6 % to 12.3 % of the total land area of Ethiopia (Tamene 1990). A few decades ago, this rangeland was considered as the finest grasslands in east Africa (Agrotec/crg/sedes associates 1974). However, since the last decade the rangeland condition and trends in the lowlands of Borana have been reported to deteriorate (Oba 1998).

Rangeland degradation was described as instances where the perennial grass cover had been substantially reduced combined with the invasion of undesirable woody species and unpalatable forbs and with increased soil erosion that occurred as sheets or gullies (Assefa *et al.* 1986; Oba 1998). According to Oba (1998), of the total landscapes of the Borana rangelands, only 10.5 % (this includes the ranches and grazing reserves) were in excellent condition and 40.4 % were either in poor or moderate to poor condition. Even in those rangelands, which received good to excellent condition ratings, 58.6 % experienced a downward trend and less than 4 % showed an upward trends. Pratt (1987) & Hacker (1990) reported that 43 % of Borana rangelands is in a poor to very poor condition with the government ranches having a markedly higher grass cover than areas outside. The pastoral survey results of Alemayehu Mengistu (1998) showed that the majority of the households that were interviewed rated the rangeland as having a good plant growth and species composition, while 25 % reported the existence of overgrazing, 12 % indicated that the rangeland had been invaded by bush, and the remaining 25 %

reported areas with a mix of good plant growth and bush encroachment. Ayana & Baars (2000) reported that the Borana rangelands were not overgrazed or deteriorated. They also stressed, however, that most of the rangelands are in a state of transition towards deterioration.

A high incidence of soil erosion as well as the presence of young woody plants was reported in the Borana rangelands (Assefa *et al.* 1986; Hacker 1990). In the mid 1980s, about 19 % of the Borana rangeland was affected by erosion, and about 40 % of the area had a woody cover exceeding 40 % (Ayana & Baars 2000). Soil erosion appeared to be greatest on slopes comprising of red soil where grass cover was reduced by grazing (Hacker 1990). In contrast, Oba (1998) argued that soil erosion was not a problem in Borana rangeland, while it was a growing threat in the croplands. He also calculated that approximately 26 % of the Borana rangelands were either severely or moderately degraded and 74.1 % showed no evidence of erosion or only light erosion.

Various causes for rangeland degradation in Borana were suggested. It was speculated that increased livestock pressure had occurred over many years and extensive rangeland degradation was inflicted due to grazing during rainy season with effects magnified on shallow soils (IBRD 1987). Supporting this, Coppcok (1995) concluded that both human and livestock population over centuries had elicited dynamic change to their environment with their effects expected to become more acute in the future.

Another evidences emphasized that ecological deterioration in the Borana rangelands did not result from historical use, instead it was associated with the water development activities that eventually led to a deterioration of the pattern of traditional grazing systems (Oba 1998; Ayana & Baars 2000). Unlike the traditional wells where livestock numbers were controlled by amounts of water and human labour, the high yielding water ponds and bore holes attracted a greater livestock population, which is much higher than what the rangelands can support (Oba 1998). Furthermore, the government's ban on fire as a traditional tool of rangeland management was believed to result in a rapid decline and downward trend in rangeland condition (Ayana & Baars 2000).

2.3.2.1 Bush encroachment

Imbalances in rangeland ecology can manifest in various forms and one of the most conspicuous imbalances is the problem of bush encroachment. Bush encroachment is defined as the ecological process in which a grass-dominated community changes into one dominated by woody species (Strang 1974 cited by Tolsma *et al.* 1987).

Rangeland degradation in the form of bush encroachment remains one of the major structural problems handicapping optimal animal production (Bester & Reed 1997). It is an example of an agricultural problem that is also a biodiversity problem (Ward 2000). However, Mesghena (2002) citing Krestin (undated) who reported that woody plants are an integral part of the ecosystem that can be contained in the natural state of savannas.

The savannas of the world are defined as having a continuos well developed layer of graminoid and forbs and an open discontinuous layer of shrubs or trees (Huntley 1982; Walker & Gillison 1982; Bourliere & Hadley 1983; Knoop & Walker 1985). These are species with a range of life characteristic and different abilities to respond to environmental influences (Noble & Slatyer 1980; Silva & Ataroff 1985). Increasing density of woody plants in tropical and temperate grassland savannas has been regarded as a well-known ecological phenomena (Scott 1967; Donaldson & Kelk 1970; Archer *et al.* 1988; McPherson 1997).

The ecological succession in the Borana rangeland indicates that the potential of grassland is threatened by bush encroachment in many areas. According to Oba (1998), bush encroachment in Borana grassland started after 1952 and the situation worsened in recent decades. Aerial surveys of Cossins & Upton (1988b) revealed an estimate of over 40% canopy cover in the eastern and central areas of the Borana rangelands. Oba (1998) reported that 82.8 % of the landscapes in Borana lowland were threatened by a combination of bush encroachment, unpalatable forbs and shrubs, with only 17.2 % of the area that were free from either bush encroachment or invasion by unpalatable forbs. Oba (1998) also stressed that bush encroachment was in climax stages in 24.1 % of the landscapes. Other investigators also addressed the prevalence of bush encroachment in Borana rangelands (UNDP/RRC 1984; Coppock 1994). Interviews of household members and elders indicated that the Borana society also witnessed the increasing population of woody vegetation as well as unpalatable and poisonous plants in the rangelands (Alemayehu Mengistu 1998).

The reasons for an increase in density of woody plants in any savanna types are diverse and complex. In most situations the determinants of savanna system have been modified by man, either directly or indirectly (Smit *et al.* 1999). A widely accepted assumption is that the historical range expansion and density of many woody species has been facilitated by the introduction of domestic livestock and the subsequent overgrazing of herbaceous plants (Norton-Griffiths 1979; Walker *et al.* 1981; Cumming 1982; Sabiiti & Wein 1988; á Tchie & Gakahu 1989; Belsky *et al.* 1989; Msafiri & Pieper 1989).

While livestock pressure can be directly linked to soil erosion along trekking routes and high-elevation slopes, mechanistic ways that link cattle to woody plant encroachment are less clear (Coppock 1994). In Borana rangelands, the tendency for woody plants to proliferate under grazing perturbation was greatest in the upper semi-arid and sub-humid zones (Tamene 1990). In addition, woody plant encroachment could also be facilitated if grazing modifies the competitive relations among grasses and woody seedlings for soil water and nutrients, an interaction which may be more pronounced on fine-textured rather than sandy soils (Walker *et al.* 1981; Knoop & Walker 1985; Walker 1985;). Most of the soils in the Borana rangelands were reported to be fine-textured (Kamara & Haque 1988).

Climate change was also considered to be a factor to facilitate the expansion of woody plants in savannas (Brown & Archer 1989). Pratt (1987) noted that given the favourable rainfall in a region, natural succession may lead to a dominance of woody plants in some communities regardless of grazing. The dynamics of savannas was seen inextricably linked to their characteristically marked year to year variability of rainfall and consequent disequilibrium behaviour.

Expansion of woody plants in savannas was also associated with the exclusion of occasional fire as a rangeland management tool. In Borana rangelands the most important factor that has probably facilitated bush encroachment may be the national policy banning burning of grazing land since the 1970s. Prior to this the Borana society burned the rangeland to improve forage quality and control woody plants and ticks (Coppock 1990). This policy constraint was also noted by several investigators (Billé 1985; Pratt 1987; Hacker 1990). However, there was some evidence which proved extensive woody plant encroachment predated the ban of burning (Agrotec/crg/sedes associates 1974; Billé *et al.* 1983).

Hatton & Smart (1984) noted that under natural condition, elephants prevented the persistence of woody populations through their feeding activities. Once elephants were excluded, however, an increase in Acacias occurred. Pratt (1987) hypothesized that overall increase in woody plants appeared to be due to a gradual thickening of existing stands as a result of seedling recruitment rather than expansion of plants into new sites. The restriction of movement of herbivores, poor grazing management practice, development of water points and recurrent drought are all determinants, which exacerbate the invasion of woody plants in savanna grasslands (Alemayehu Mengistu 1998; Smit *et al.* 1999).

Several studies demonstrated the suppression effects of bush encroachment on the herbaceous layer of savannas. The increase in tree density in the temperate and tropical savannas was thought to reduce herbaceous plant production through competition for light, water and nutrients (Walter 1971; Walker & Noy-Meir 1982; McMurtrie & Wolf 1983; Stuart-Hill & Tainton 1989; Smit 1999). In some case there was evidence that an increase in woody plants abundance with a resultant reduction in herbaceous production rendered an environment less suitable to grazers such as cattle and possibly more suitable for browsers such as goats and camels (Coppock 1994). In addition, Richter (1991) cited by Meyer (1998) and Mesghena (2002) reported that bush encroachment accentuates the effect of drought and often gives rise to pseudo-drought that eventually would result in a shortage of fodder during dry or even normal years.

Some reports addressed the role of woody plants in facilitating the recovery of the herbaceous layer. In addition, trees and shrubs contribute significantly to bio-diversity, structural complexity and spatial heterogeneity in tropical savannas (Parker & Muller 1982; Vetaas 1992; Belsky & Canham 1994). If nutrient depletion in topsoil plays a role in the decline of herbaceous productivity under heavy grazing on the Boran plateau, there is evidence that woody plants could have beneficial effects on the recovery of herbaceous vegetation by improving soil fertility. Firstly, since woody seedlings can grow deep roots quickly (Gates & Brown 1988; Solomon Kebede 1989; Tamene 1990) they could establish and tolerate nutrient-depleted topsoils to a higher degree than shallow-rooted grasses. Secondly, woody plants have been shown to play a potentially significant role in nutrient turnover and the replacement of soil nutrients in semi-arid savannas (Coppock 1994). Dreyfus & Dommergues (1981) highlighted the potential of nitrogen fixation by native woody legumes in improving soil fertility when colonizing new sites.

Pratt (1987) concluded that marked woody encroachment may not necessarily mean that the rangeland is in bad condition because patches of high quality perennial grasses may remain in heavy grazing sites that could respond to adequate rainfall. It is also important to note that the interaction between woody and herbaceous layer can be positive, neutral or negative and that soil texture (Walker 1985) and soil fertility (Coppock 1994) play an important role in this regard.

Regarding positive grass-tree interactions, a number of studies have documented the effect of isolated trees on the improvement of the productivity of the associated grass layer (Stuart-Hill *et al.* 1987; Belsky *et al.* 1989, 1993; Frost & McDougald 1989; Weltzin & Coughenour 1990). Important grass species, such as *Panicum maximum* grow preferentially underneath tree canopies and, therefore, bush control measures should not simply imply a complete removal of woody plants (Smit & Swart 1994). However, such favourable herbaceous production under or near tree crowns is more common in the tropics and sub-tropics and in plant communities with a low tree density, high rainfall and moderate fertility (Knoop & Walker 1985; McClaran & Bartolome 1989 cited by Belsky 1994; Burrows *et al.* 1990; Belsky *et al.* 1993).

In contrast, trees occurring in communities with a high density, low rainfall, or extremely nutrient poor soils displayed the more expected pattern of reduced understorey productivity (Burrows *et al.* 1988), and tree removal increased herbaceous productivity (Walker *et al.* 1986; Pieper 1990).

2.3.3 Theory of equilibrium versus non -equilibrium

There is little doubt that herders of sub-Saharan Africa are exposed to high levels of climatic, economic and political risks, even when compared to other risk prone populations on the continent. This is especially true for the rangeland of northern Kenya, southern Somali, and southern Ethiopia where herders inhabit areas of widespread insecurity and conflict, climatic instability, destructive livestock diseases and unreliable markets and infrastructure.

There has been recent debates concerning the degree to which climate, pastoralists and their livestock cause apparent degradation in semi-arid and arid sub-Saharan rangeland resources. In line with this, the mainstream views fall into two broad bodies of work. One conventional notion dictates that heavy grazing by livestock, commonly exacerbated by inappropriate development such as proliferation of watering points, or extensive veterinary campaign in the absence of stimuli for animal offtake, has served to cause erosion and detrimental changes in vegetation, reducing system productivity and sustainability over the long term (Lamprey 1983). Another view is that changes in vegetation are commonly driven by medium and long-term rainfall trends and that the livestock play a relatively inferior role in vegetation change and are also victimized by vagaries of rainfall (Horowitz & Little 1987; Ellis & Swift 1988).

Implicit in the first theory is the assumption that livestock populations are tightly coupled to the vegetation. These systems are regarded as 'equilibrium' in the sense that heavy grazing of livestock can affect a negative trend in forage production, which eventually results in reduced animal performance and numbers. Animal performance equates to primary production and thus internal interactions are important (Coppock 1994).

The equilibrium theory proposes that high livestock mortality in semi-arid regions during drought is influenced by density dependent factors. It is presumed that increased forage production during above average rainfall years results in increased livestock densities, while decline in forage production results in livestock loss and reduced density. This implies that a relationship exists between rangeland productivity and livestock density. The theory reasons that changes in rangeland productivity are predictable and advocates the importance of manipulating livestock density in response to changes in forage production. Hence concepts such as carrying capacity were developed for managing such systems (Coppock 1994; Oba 1998). The failure in manipulating the livestock density may result in overstocking followed by degradation. It is presumed that overstocking reduces forage production, causing the disappearance of palatable grass species and an increase in unpalatable forbs and bush encroachment. Perennial grass stands with more predictable productivity represents equilibrium systems (Oba 1998).

Coppock *et al.* (1987) concluded that the Borana system appeared to be equilibrial in light of cattle population. Coppock (1995) characterized the Borana pastoral system in a way that (i) the pastoral population became increasingly confined to a fixed territory, (ii) the number of cattle per people gradually increased as a result of health interventions and/or water development, (iii) degradation of vegetation and soil became more pervasive, (iv) the production system is more susceptible to even modest fluctuation in annual rainfall and, (v) there is increased migration of young males outside the system to other sector of the national economy, who then provide cash income remittances which help to subsidize those who remain in the pastoral system.

The equilibrial system in the Borana rangeland is fundamentally defined by a more favourable rainfall regime (*i.e.* 600 mm/year) in which frequency of drought is low enough (*i.e.* once in 10-20 years) and epidemic diseases are apparently under control (Coppock 1994). Under these situations, there is a high probability that cattle can reach population levels that ultimately make them susceptible to modest fluctuations in rainfall in dry years, resulting in competition for forage. Although many cattle emigrated during the drought years, the persistence of perennial grass cover sets the stage for longer periods of grazing interaction and density dependent effects during drought, even at low stocking rate (Donaldson 1986; Cossins & Upton 1988a).

The greatest effects of cattle in mediating compositional changes in vegetation occur during the high density phase of the cattle population in average rainfall years (Coppock 1995). Many scholars contended that the equilibrial thought to the Borana rangelands did not take into account socio-political factors that contributed to the ongoing crises over resource use. Coppock (1994), however, suggested that the Borana became density dependent following loss of land and increased human and livestock population densities. Arguing this, Oba (1998) asserted that the weather in Borana is unpredictable and hence the reduction of Borana rangelands has not changed this unpredictability of weather as well as its influence on the primary productivity rather, the problem was confounded by loss of external grazing reserves, weakening coping strategies and increasing pressure on vegetation. Apart from this, given a highly variable rainfall distribution, calculation of long term carrying capacity and correlating rangeland degradation to population density without considering internal pressure and loss of the land to external conflicts may not benefit rangeland development plans. In addition, human and livestock population are unreliable for making predications of the carrying capacity.

Several investigators reported elsewhere that precipitation, the main weather element showing both spatial and temporal variation, has to account for variation in production of semi-arid areas at global (Lauenroth 1979), regional (Rutherford 1980; Le Houerou *et al.* 1988; Sala *et al.* 1988), landscape (Briggs & Knapp 1995) and individual (Dye & Spear 1982; Lauenroth & Sala 1992) site level.

The alternative non-equilibrial theory assumes that livestock are never able to reach densities at which they fundamentally affect the vegetation. The arid (and semi- arid) rangelands are influenced by stochastic events. Plant production, cover and species composition are more affected by annual rainfall or other external events than livestock and vegetation. Rainfall is highly unreliable both in space and time, making predictions to match livestock numbers with rangeland productivity impossible.

Indeed, high temporal and spatial variation in rainfall is characteristics of mostly arid areas (Sharon 1972, 1981; Evenari *et al.* 1982), which results in arid grazing ecosystem that are non-equilibrial, and event driven system (O'Connor 1985; Venter *et al.* 1989; Milchunas *et al.* 1989; Behnke & Abel 1996). In other words, this may imply many arid ecosystems have a " bust and boom" type of pastoral economy with a 'boom' when the rainfall is plentiful and herds grow, and a 'bust' when drought occurs and animals die. Concepts such as carrying capacity are less relevant for management of these ecosystems because stocking rates have little influence on vegetation performance from year to year (Coppock 1994; Oba 1998).

Recent advances in the "ecology of disequilbrium" are relevant to the understanding of the complex relationships between politics, human agency, and savanna habitat. Empirical findings from this body of work challenged the orthodox assumption of the influence of the pastoralists and their livestock on the environment. Climate data collected over several years revealed that most of the grassland zones of Africa are inherently unstable and, therefore, attempts to adjust conditions to some notion of 'stability' violate natural order and in themselves are destabilizing (Behnke *et al.* 1993). These findings confront the "carrying capacity" concept for its failure to recognize the variability and patchness of the savanna ecologies (Scoones 1989) and for its requirement of quantifying a process as dynamic as the feeding habit of different animal species (Bartels *et al.* 1991; de Leeuw & Tothill 1995). Moreover, dry savanna regions are intrinsically resilient compared with more stable ecosystems (Abel & Blaikie 1990) because they must deal with such climate perturbations and instability.

Unlike what most literature portray, dry arid savannas are not inherently fragile ecologies, although as with any ecosystem they can be made fragile through inappropriate development and land use practices. The latter would include settlement projects that encourage excessive population densities, inappropriate development interventions and cultivation in zones better suited to extensive livestock systems.

Because of the high variability of climate and unpredictable drought events in dry savanna ecosystems, many of the concepts developed in the temperate zones fail to explain the dynamics of these highly variable ecologies. Many of the primary indicators including the carrying capacity and "climax" vegetation stages, which have been used to measure the productivity of different ecosystems, are of limited use in these dynamic ecosystems (Little 1994).

The very arid pastoral system in east Africa that shows typical non-equilibrial characteristics is that of the northwest Kenya in south Turkana (Ellis & Swift 1988). Drought may occur at a high frequency, which commonly disrupts growth and survival of slow maturing larger species such as cattle and camels (Coppock 1994). The low annual rainfall in south Turkana (350 mm) has resulted in an annual community of grasses produced from seed in a 'boom or bust' mode depending, almost exclusively on annual rainfall (Coppock 1994).

Annuals have several important features that would contribute to the severity of drought impacts and the resilience of an arid ecosystem. Even a two year drought can result in virtually no standing biomass, annuals persist in the seed banks, and standing biomass is gradually lost either by weathering or grazing (Coppock 1995). This means that drought in pastoral areas of arid ecosystems can have a devastating impact on cattle, irrespective of their pre-drought densities. During years of average rainfall, herbaceous productivity depends on variation in the seed bank. Coppock (1985) reported that the annual grasses mature and set seed within 6 weeks provided that they receive sufficient rainfall.

The analysis of the arid and semi-arid systems into the two broad spectrum is supported by other theoretical frame works. Noy-Meir (1973) noted that systems having less that 400 mm of annual rainfall are under abiotic control in relation to water, and non-equilibrial dynamics system should prevail in these instances (Ellis & Swift 1988). The semi-arid Borana system, however, falls more within the realm of at least periodic biotic regulation with the frequent occurrence of equilbrial dynamics among primary production and consumers (Norton-Griffiths 1979; Cumming 1982; Walker 1985). It is also generally agreed that where pastoralists are able to maintain their activities on a large spatial scale by migrating to areas where key resource can be exploited, negative effects of grazing on plant diversity do not develop (Sinclair & Fryxell 1985; Ellis & Swift; 1988; Behnke & Abel 1996). More over, even where pastoralists are forced to settle in a small area, abiotic variables such as precipitation may be of such an overriding importance that the negative effects of grazing cannot be detected (O'Connor 1985; Archer *et al.* 1989; Tapson 1993; Scoones 1995; Ward *et al.* 1998).

2.4 DROUGHT AND MITIGATION TACTICS

2.4.1 Definition

Six major drought episodes have been recorded on the African continent in the last three decades and with it significant effects on the livelihood of the pastoralists as well as on their responses to cope (Zinash 2000). Drought occurs when the normal pattern of rainfall is disrupted and the wet season extends into the normal dry season. Drought is said to be such a gradual process that the beginning and the end of it may not be clearly demarcated.

Different opinions have been presented to define drought. Pratt *et al.* (1997) suggested it can be considered a drought when rainfall is below the long term average or when rainfall during two or more successive years falls 75 % below average. Coppock (1994) defined drought as "when two or more consecutive dry years occur in which the length of the growing period is less than 75 % of the mean, i.e. a drought is driven by several consecutive rainy seasons of deficient rainfall with detrimental effects on the production system". The Society of Range Management (1974) highlighted drought as prolonged dry weather, generally when precipitation is less than three-quarters of the average rainfall. With respect to agriculture, drought is the origin of stress that causes plants to wilt or die, resulting in lower production. This is attributed not only to rainfall amount and distribution but also is a function of other influential factors such as temperature, soil characteristics and management of the land (Zinash 2000).

Tolumin (1995) illustrated the three phases of the drought cycle in the arid and semi-arid pastoral areas. The first phase is characterized by an imbalance between livestock numbers and available forage. As the drought hits harder, the grain prices rise and livestock prices decline. The second phase at the bottom of the drought cycle, is featured by a continuous fall in the number of livestock because of sales and deaths despite the leveling off and gradual improvement of fodder availability due to the onset of rainfall. The third phase is the recovery period from previous drought.

2.4.2 Drought and the consequence

Oba (1998) identified two types of drought in Borana pastoral areas. Localized drought is a common feature of some lowland areas that are typically characterized by recurrent rainfall failure or poor rainfall distribution. When rainfall becomes insufficient periodically as a whole, it results in regional drought. In either of these, the effects of drought on livestock are mediated by several associated factors.

When drought occurs, the resultant shortage of soil water may reduce overall plant growth and vigour. The effect may be worse for the grasses than for the shrubs and trees. This gives, therefore, opportunity for bush encroachment and undesirable plants to invade the rangelands. High temperatures during drought may accelerate stem development and the maturation process in plants leading to increased cell wall content and lignification; which both decrease herbage digestibility and intake. Alemayehu Mengistu (1998) noted that drought in pastoral areas also results in the concentration of livestock around a limited number of water points, which eventually lead to severe overgrazing around these water points.

The overall indirect impact of drought on livestock diseases out break was reported by many researchers. According to Alemayehu Mengistu (1998), most of the effects of drought, namely; feed shortage, rangeland deterioration, and water shortage are strongly associated with livestock diseases. Since drought aggravates starvation and nutritional deficiencies, excessive movement and high concentration of livestock around water points can influence the prevalence and distribution of diseases. For instance, nutritional deficiencies due to low energy and inadequate protein, vitamins and minerals in the forage may predispose almost all livestock into loss of resistance, making the animals vulnerable to different kinds of diseases. Moreover, excessive movement of livestock and their concentration around a limited number of water points create favorable conditions to transmit bacterial diseases and internal parasites to those with already weakened immunity (Alemayehu Mengistu 1998).

The significant loss of cattle, their productivity and the apparent greater susceptibility of cows and immatures to starvation during drought has been reported for the pastoral systems in east Africa. Compared to the dry season in an average rainfall year, the net production impact of the 1983-84 drought on Borana households was a 92 % reduction in milk offtake for human consumption due to a 90 % reduction in the number of cows in milk and a 65 % reduction in offtake per lactating cows (Donaldson 1986). During the same drought years, approximately 60 % of the pre-drought inventory of cattle was lost due to mortality, and from the sales of males and other followers to purchase grain (Coppock 1994). During the 1991-92 drought, an average Borana individual households had lost about 79 % of cattle, 95 % camel, 83 % equines and 60 % sheep and goat. During the 1980s drought, Rodgers & Homewood (1986) found a net 52 % loss of cattle among the Massai in semi-arid Tanzania with a 75 % loss of lactating cows and a 20 % decline in calving rate. In the semi-arid Baringo of Kenya, Homewood & Lewis (1987) revealed regionally variable loss of cattle, sheep and goats during the first nine months of the drought that averaged 50 % overall for each species.

Calves were reported to be highly vulnerable to drought because of restricted milk supply and immobility. Milk cows, next to calves, are second in vulnerability owing to the energy demands of lactation and because they are kept near encampment where forage is commonly depleted (Coppock 1992b). Small ruminants appeared to have survived better than cattle during the 1983-84 drought in Borana, and this in part was probably because of their lower absolute nutritional requirements and mixed feeding habits that include drought resistant browse species (Coppock 1994). In contrast, relatively more small ruminants than cattle and camels reportedly died of starvation, and this was attributed to their reduced mobility in this patchy, arid environment (Coppock

1994). Fratkin & Roth (1990) noted that camel keepers tended to lose fewer stock than keepers of cattle and small ruminants among the Ariaal of arid Kenya.

The mitigation of the effects of drought on pastoral populations in sub-Saharan Africa has received much attention in the literature. With few exceptions (e.g. McCabe & Ellis 1987), the commonly held view is that traditional pastoral societies are increasingly unable to cope with drought, as indicated by large losses of capital, widening poverty and frequent famine. Traditional pastoral systems are thus thought to be in the process of gradual destruction through the combined effects of internal and external forces as exacerbated by drought.

One of the first management response to deficient rainfall by the Borana pastoralists is the dispersal of cattle from home based "Warra" herds to satellite "Forra" herds as an attempt to expand grazing the area in relation to a decline in net production (Donaldson 1986; Cossins & Upton 1988a). Herd segregation and reliance on the fallback regions or drought reserves are common traditional responses to drought elsewhere in African pastoral systems (Homewood & Lewis 1987; Grandin *et al.* 1989; Coppock 1994 citing McCabe 1987). Coppock (1994) citing Moris (1988) noted the reduction in traditional fodder reserve areas owing to population growth and land alienation and the threat this poses to pastoral drought endurance and the subsequent recovery. The use of the fodder reserve areas for settlement and unregulated grazing by the Borana is potentially dangerous as cattle herd crashes could occur if fodder reserve areas are not reclaimed. High population growth rates among neighbouring people along with the proliferation of weapons, suggest that the use of external fodder reserve regions will be constrained in the future (Coppock 1994). This loss of fodder reserve areas may constitute the most immediate threat to growth and sustainability of the Borana pastoral system.

At the household level, Donaldson (1986), Coppock (1988), Cossins & Upton (1988a) and Webb *et al.* (1992) observed that internal adjustment by the Borana in response to restricted resources included; (i) youths were dispersed for "Forra" herding, which decreased food demand at encampments; (ii) young children were given priority to receive milk, while older youths and adults consumed more grain, meat, blood and other commodities; (iii) more income was allocated to the purchase of food, along with attempts made to diversify income-earning activities, intensify social networking and increase efforts to collect bush food and consume other unusual food items; (iv) older adults voluntarily received restricted food rations; and (v) some individuals emigrate to famine relief camps (Coppock 1994). The subsidy of milk dominated diet of pastoralists with non-pastoral grain and an increased use of such ancillary pastoral food as blood, meat and native plant material during drought, is well known (Ellis *et al.* 1986; Sperling 1989). Besides, the need for pastorlaists to seek employment or engage in other unusual economic activities during drought is also common (Campbell 1984; Hay 1986; Mortimore 1987).

Gifting and social networking among pastoralists is frequent and regarded as a social tactic to ameliorate risks. At the Borana household level, families of different wealth ranks depend on each other's resources for survival. One type of networking is that of mutual and involves reciprocal relationship among the households. This type of networking is exclusive to women and such a household reciprocal relationship involves minor food items and services. The sustenance of the relationship depends on continuos exchange of goods and services. When this fails for one or another reason, the relationship becomes dormant. Another type of networking is cattle sharing. Under this system, impoverished community members are able to request help from the wealthy in the form of cattle, sheep and goats. The support is especially important after periods of drought, when the redistribution of surviving animals can provide hard-hit families with a basis for re-establishing their herds (IRIN 2002). Personal communication of the Borana pastoralists, however, revealed that these robust social networking systems are weakening due to a decline in the traditional Borana social system and widespread poverty.

Human response to drought can be characterized as a hierarchy of adjustment over time. Corbett (1988) proposed a framework for subsistence farmers, which consists of three major stages. In the first stage known as 'the insurance', households first attempt to buffer themselves by selling small ruminants or other 'less essential' and more readily replaceable animals; reducing food demand; collecting wild foods; conducting inter-household transfers of assets and loans; increasing production of 'petty commodities' for sale; migrating in search of employment; and selling personal possessions. During the second 'crisis stage', households begin to dispose of productive assets, which may include larger, more durable livestock such as cattle; sell agricultural tools; seeking credit; and initiate further reductions in food demand. The Borana appeared to sell cattle mostly when they have an acute need for money. Their ultimate goal is not income generation but animal accumulation for status (Coppock 1994). They themselves try to endure periods of stress so they do not have to make a "withdrawal" from their pool of herd capital. Those households with marketable animals restrict food intake and undergo other severe hardship during drought (Webb *et al.* 1992). When given no other income generating option and when the drought situation is exacerbated, the Borana reportedly prefer to sell mature male cattle because the gross income received allows them to purchase food plus replacement calves; and thus attain two goals, namely; commodity procurement and herd building. The third stage is the distress migration stage where people embark on mass migrations in search of food. This is a stage during which numerous people also dies.

Poor pastoralists entered the crisis stage considerably sooner than the middle class or wealthy, simply because of a lower number and diversity of livestock (Coppock 1994). Coppock (1994) also hypothesized that on average pastoral families in Borana probably spent most drought periods in the insurance stage, with the crisis stage encountered only when households were forced to sell prime cattle or camels, commonly during the second drought year. There has not been a distress migration stage in Borana for the last drought periods (Webb *et al.* 1992).

2.5 OVERVIEW OF RANGELAND CONDITION ASSESSMENT TECHNIQUES IN OPEN AND SHRUBBY/WOODY GRASSLANDS

2.5.1 Methods of plant survey

Rangelands in Ethiopia are at the point of becoming seriously degraded, and this implies that rehabilitation is the overwhelming agricultural priority in these areas. In order to achieve success with rangeland rehabilitation, assessing the extent of the degradation is a prerequisite so that the data obtained from it can be used to plan and execute the management options at hand. In fact, the methods for assessment should preferably not be time consuming, inexpensive, reliable and easy to use by researcher and development workers alike.

Vegetation composition can be estimated on the basis of frequency of occurrence, density, dry weight (biomass) and basal cover. The frequency sampling method records the species present and absent in each quadrate. Large area can be surveyed very quickly, especially if the attention is focused on a few key indicator species (Tothill 1978). This method can be used to estimate the composition of tree, shrubs and /or herbaceous species. It can be useful in the study of vegetation patterns because it reflects the distribution of vegetation species within an area. The density method can be suitable when individual species are clearly distinguishable as in woodland, and it may, therefore, be appropriate to estimate woody species composition.

In the beginning, subjective method was used by field workers and experts to estimate plant density and composition with considerable personal bias in the method, which resulted in misleading interpretations. This was done in such a way that the operator looked over an area perpendicularly and then estimated the amount of area that is bare, covered by herbs, or by woody plants (ILCA 1990).

2.5.1.1 Point methods

Of the many techniques devised, the so called 'Point methods' developed by Levy (1934) cited by Tidmarsh & Havenga (1955) appeared in many respects to hold the most promise. The point method was a logical outcome of thriving for a quadrat that became smaller and smaller until it was only a point (Olang Undated). In its simplest form, the step point method is employed to count the number of different plant species in contact with the point of the foot when walking along a transect (ILCA 1990). With this method, the observer made a mark on his shoe, which served as the descending point and then he walks backward (to avoid bias in placing the foot) recording the percentage species composition using the nearest plant to the point of the foot (Mentis 1981). The point position is examined at every predetermined number of paces. This method is simple and a rapid means of making a preliminary assessment of composition (frequency and is best suited to areas with low growing herbaceous vegetation (ILCA 1990). A more sophisticated modification of the step point is the wheel point apparatus (Figure 2.3) developed by Tidmarsh & Havenga (1955).

The wheel point apparatus with a single aluminum wheel (Von Broemsen 1965 cited by Foran *et al.* 1978) and with points 1 mm in diameter and 3.05 m apart, was first adopted because of its ease of use. Strikes on rooted, living basal material were recorded by species to provide an estimate of basal cover, and in the absence of a strike the species of the nearest plant to the point was recorded to provide more comprehensive floristic records, which could be used (with the strike data) in the estimation of species composition.

Mentis (1981) noted that the step-point method yielded the same results as the wheel point method and hence it could be concluded that the former may be applied, with a saving in equipment and manpower. However, the step-point method provides no estimate of basal cover, which in any case is worth measuring by the standard wheel point method (Mentis *et al.* 1980). Moreover, in broken terrain or bushy situation, use of the wheel point apparatus may facilitate a more even spread of points over the same plot than would the step-point method (Mentis 1981).

Figure 2.3 The wheel point apparatus used in the Borana communal grazing areas.

Species composition alone is not enough for predicting rangeland condition and all what is required is a relationship between species composition score and herbage forage production. In the False Thornveld and Natal Sourveld of South Africa, a strong relationship was found between herbage yield and rangeland composition score (Danckwerts & Barnard 1981; Mentis & Tainton 1984). In contrast, Stuart-Hill (undated) reported that no such relationship was established in the arid Valley Bushveld and marginal karoo of South Africa. Stuart-Hill (undated) also noted that forbs, which are often ruderal in habit, can at the time of the survey mask the real rangeland condition and consequently sites with a high population of forbs, besides to good cover of desirable plants, may be underscored. A similar misleading interpretation could have been made on the difference between rangeland composition score before and after rangeland treatments. For instance, it was found that the percentage of *Themeda triandra* of the grassland was 13.7 % and this increased to 50.8 % after tillage during the experimental period, which Stuart-Hill (1984) cited by Stuart-Hill (undated) attributed to the death of some of the other grass species, and not to an improvement in rangeland conditions. Such cases would be misinterpreted if species composition was used as the only comparative measure. Similarly, Stuart-Hill (undated) suggested that an increase in percentage of *Themeda triandra* after fire may not necessarily mean that this species has increased in absolute terms; rather it may be that some of other species less adapted to fire than *Themeda triandra* may have died.

2.5.1.2 Plot (quadrate) method

The quadrat method is not commonly used for rangeland condition assessment and is employed more for yield and grazing capacity estimation. The quadrate method involves establishing sample plots (quadrate) of vegetation whose size and shape will depend on the type of vegetation being sampled, the density of the vegetation encountered, as well as the type of survey being undertaken. Rangeland scientists often use a large sample of small quadrate (e.g. 50 cm x 50 cm), because it is easier to absorb information quickly from small units. However, when the vegetation is sparse (as is the case in the arid and semi-arid rangelands), large quadrates should be used to ensure adequate sampling (e.g. IPAL 1983).

Nest quadrates are usually used for mixtures of trees, shrubs and herbaceous vegetation. A nested unit might include a 1000 m^2 quadrate for the estimation of tree composition, several 200 m^2 shrub quadrates and further randomly sited herbaceous units enclosed within the larger area (IPAL 1983).

The measurement of biomass or dry matter of herbaceous and foliar material from smaller shrubs may help to establish relationships between species composition and biomass production; biomass production and soil type or rainfall (ILCA 1990). The conventional method in this case involves cutting, sorting and weighing the different species in each quadrate by hand, which is time consuming and requires considerable skills; particularly in multi-species rangelands. An alternative to the conventional method is the dry weight rank method (t'Mannetje & Haydock 1963; Jones & Hargreaves 1979). This method involves the selection of the first, second and third heaviest species (on the basis of biomass) within each quadrate, each of which is then assigned weighting based on standard multipliers. The dry weight rank methods were applied over a range of pasture types in Australia, the United States and Zimbabwe (Jones & Tothill 1985).

2.5.1.3 Disc pasture meter

Bransby & Tainton (1977) described the operation of disc pasture meter in South Africa and suggested that it could be used as a useful tool in pasture research. The instrument was subsequently used by Bransby (1978), Bransby & Tainton (1979), and Trollope (1978).

The disc pasture meter consists of three basic parts (Figure 2. 4): A central aluminium rod 180 cm long with an external diameter of 22 mm; a 120 cm long aluminium sleeve (with an external diameter of 27 mm) that slides freely on the central rod and has a strong steel base-plate attached to the lower end; an alumimium disc1.5 mm thick and 45.8 cm in diameter which is attached to the base plate of the sleeve by four small bolts. Small weights may also be attached to the base-plate with these bolts so that the sleeve together with the base plate and disc has a mass of 1.5 kg. The central rod is marked at 1 cm intervals in an upward direction starting at the top end of the sleeve when the under surface of the disc is flush with the lower end of the rod.

To operate the disc meter the central rod is held perpendicular to the ground surface while the sleeve with the attached disc is released onto the sward from a position where the upper end is level with the upper end of the rod. This means that the disc itself is being released from a standard height of 60 cm above ground level. Settling height of the disc is then read off the road from the position corresponding with the upper end of the sleeve. This method of operation is suitable for dense swards that are relatively resistant to compression by the disc. For swards that are more sensitive to compression the sleeve with the attached disc should be gently placed on the sward surface (with the rod held perpendicular) and allowed to settle until constant height is reached or alternatively, for a maximum settling time of 15 seconds. When operating on uneven ground care should be taken that the lower end of the rod is not placed in a hole or on top of a mound or tuft of grass (Bransby & Tainton 1977).

The commonly used techniques to estimate yield of the densely tufted grass swards found in the False Thornbush grasslands of South Africa were clipped quadrates and mown strips (Danckwerts & Trollope 1980). The disc pasture meter compared favourably with these methods of yield determination and its attractiveness lies in the rapidity with which estimates can be made and the none destructive nature of sampling (Danckwerts & Trollope 1980). Moreover, the single stem disc meter was reported to be simple to construct, inexpensive, durable and easy to handle (Bransby & Tainton 1977). It was also found that linear regression relationships between meter reading and pasture dry matter yield were fairly good and these may be affected by a number of factors implying that the instrument need to be calibrated for a specific set of conditions in which it is to be used (Bransby & Tainton 1977).

2.5.1.4 Point centered quarter method

This method was developed by the Wisconsin plant ecology laboratory in the United States (Mueller-Dombois & Ellenberg 1974). It was primarily developed for measuring the tree layer of the plant community. The technique is based on the idea that the number of trees per unit area can be calculated from the average distance between trees. Sampling points are randomly located along a line transect and from each point four quarters are established (NRC 1962). The distance from the plant nearest to the point in each quarter is then measured. The mean distance is used to calculate the mean area occupied by each tree (ILCA 1990).

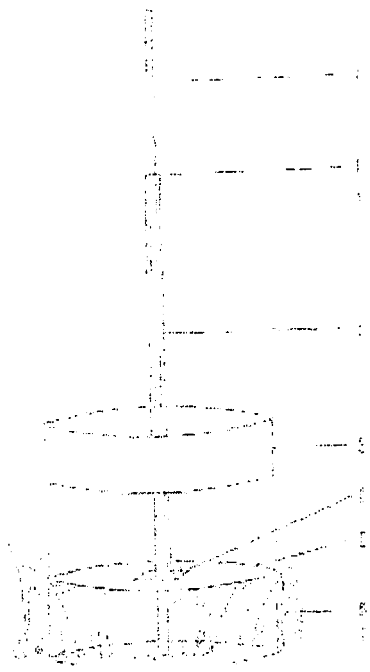


Figure 2.4 Illustration of a single stem disc meter and sampling cylinder (Bransby & Tainton 1977).

While developing this method, the basis for argument was that it is easier to estimate the number of individuals using mean distance rather than the standard way of counting all plants appearing in the quadrate or plot. It also saves time because it is easier to measure the distance rather than plot boundaries and the accuracy increases with increasing number of sampling points (ILCA 1990). The limitations found in this method include: an individual must be located in each quarter, an individual must not be measured twice, and the method overestimates regularly spaced individuals by 100 % and underestimates clumped vegetation by 50 % (Mueller-Dombois & Ellenberg 1979; Olang & Peden 1982).

2.5.1.5 Landsat imagery

Because of the vast rangeland areas that have very little development in terms of roads and communication, the landsat imagery interpretation method is quite suitable. The method is actually a modified version of the area sampling frame method (Wigton & Borman 1978).

Enhanced imagery of a false colour at a scale of 1: 250 000 is preferred because contrast is increased between different colours (Olang undated). The method is used in stages (Olang 1983). The first stage is visual interpretation of landsat imagery into different strata. Stratification is done on an overlay that is later transferred onto a topographic survey map of the same scale as the landsat imagery. Using artificially constructed and natural features like roads and rivers, each stratum is further subdivided into primary sampling units (PSU).

All PSUs' having the same colour tone are given the same number for random selection of sampling units (SU). The number of SU units selected for sampling depends on the time and money available for work. A topographical map is used for orientation purposes and for navigating the site. The same sites can be revisited if another sampling is necessary. It has been found that different plant communities can register different tones either because of different plant densities or composition (Olang 1983).

The second stage involves the location of a sampling site within a sampling unit that has been randomly selected and is a critical phase in the whole sampling methodology. The site should be located in a representative area, for instance, at least 500 m a way from a road and away from any watering point (Olang undated).

Using the overlay and topographic survey map the researcher can drive or walk to one of the sampling units. Once within the unit, the researcher should decide on which direction to move and for how many meters. Next, the starting point for the transect line should be fixed for monitoring purposes, and the sampling site should be permanently fixed.

2.5.2 RANGELAND CONDITION ASSESSMENT TECHNIQUES

Rangeland deterioration leading to reduced animal production and accelerated soil erosion has for long been an important problem in many rangelands. In the rangelands where livestock industries are based on grazing/browsing of natural grasslands and shrubs, the pressure of livestock and the incidence of other management practices such as fire often lead to modification of the vegetation and also to loss of productivity and soil stability. At least part of the problem facing efforts to prevent continued deterioration has been the lack of any generally applicable quantitative and objective method of assessing the condition of the rangeland relative to its potential (Foran *et al.* 1978).

An assessment of the condition of plant communities constitutes a convenient means of comparing them, as well as of providing a way to quantify and observe spatial and temporal changes within a particular community or vegetation type (Hardy *et al.* 1999). As a result of this, Tainton (1988) & Smith (1989) regarded assessment of rangeland condition as the most important cornerstone of any management system.

Rangeland condition has been defined in a number of different ways but usually 'condition' is an index for the current 'state of health' (Stuart-Hill & Hobson 1991), meaning that what the vegetation should be like under normal climate and the current management practice (Short & Woolfolk 1956; Tueller & Blackburn 1974; Tainton 1981). Range condition assessment is, therefore, a form of vegetation inventory and essentially it is evaluated in terms of expressions such as 'excellent', 'good', 'fair', and 'poor' (Stuart-Hill & Hobson 1991).

The objective of rangeland condition assessment is to provide information for management and planning (e.g. setting sustainable stocking rates, soil hazard evaluation, etc) which are geared towards maintaining highly productive and palatable plant species in order to maximize optimum financial return in the short term (e.g. commercial ranches). In the long term, a set of assessment data provides information for management decision of how to maintain the stability of the rangeland so that its potential can fulfill the needs and aspiration of the future generation in a sustainable way (Danckwerts undated).

Certain species respond differently to the same grazing impact as a result of, for example, differences in soils (Bosch & Van Rensburg 1987; Van Rensburg & Bosch 1990). Hence, meaningful results can be obtained when vegetation assessment is made within a specific ecological zone where spatial variation in the abiotic environment (such as soil, temperature, rainfall) is kept to a minimum and where the grassland, is therefore, relatively homogenous.

Although different condition assessment techniques vary in their approach, there are at least some common objectives in that most of the methods attempt to provide a means of monitoring trends with time, and they will aim to provide a basis for determining grazing capacity (Heard *et al.* 1986). According to these authors, the ideal condition to achieve these objectives is, however, the use of a single common method of rangeland condition assessment, which is relatively simple and can be applied widely. Moreover, Foran *et al.* (1978) suggested a technique to be used by non-pasture specialists and in particular those, which are not time consuming, but which provides relatively accurate estimates of rangeland condition.

Friedel (1991) pointed out that although rangeland condition assessment is the most important concept of rangeland management, serious debates are still being held about this concept. According to Jordaan *et al.* (1997), there may be confusion as to which factors are of particular importance for meaningful rangeland condition assessment.

Furthermore, the authors found that a disagreement may arise regarding how these factors should be collected or determined, whilst the interpretation of results can vary from one researcher to another depending on the person's original objective. Aside from the obvious difficulty of defining 'normal' climate, 'optimum' management and 'health' range, Stuart-Hill & Hobson (1991) agreed that the different states that the vegetation can assume are not equal, and for a specific objectives, some conditions are more desirable than others.

Although condition assessment methods use proportional species composition data as a basis, the manner in which data are used to derive a condition index varies according to the objectives of each method (Hurt & Bosch 1991). Certain techniques indicate abundance of all species, while others use only species, which are significant indicators of grazing conditions. Some methods use the forage value of species, while others use the ecological indicator status of certain species. Procedures, therefore, differ considerably in their objectivity (e.g. the classification of species into ecological groups, the derivation and allocation of weightings to the forage value of species) as well as in their objectives for indexing rangeland condition (e.g. the determination of available forage, monitoring rangeland trend) (Hurt & Bosch 1991).

2.5.2.1 Subjective method

The subjective method is an assessment technique, which is so simple that it can be used by extension workers and researchers without complexion. The technique is based on a complete survey of the vegetation and soil surface condition (Van Zyl 1986). Questions regarding botanical composition, vegetation cover, vigour, soil surface condition as well as insects and rodents damage are answered. The answer to each question is scaled from 1-10 while weights are also allocated to each question. The score from each question is multiplied by the applicable weight after which all the scores are added up to obtain an average index score (Van Zyl 1986). The indexes are either used for monitoring purposes or to read grazing capacity from a rainfall table (Jordaan *et al.* 1997).

With subjective methods, a higher rangeland condition index may be given to medium condition rangelands than to good rangelands (Jordaan *et al.* 1997). This, therefore, may imply that if this technique is used in the long-term, the rangeland in the medium condition would always carry more stock than good rangelands. Eventually such judgement could lead to the vegetation becoming ecologically unstable, the habitat degenerating and in the end the rangeland may move into a lower ecological status. Jordaan *et al.* (1997) recommended that this technique, because it can be carried out quickly, should be possibly used for short-term decision making.

2.5.2.2 Methods based on agronomic principles

Humphrey (1949, 1962) first expressed the view that maximum forage production for the type of livestock being grazed should be the sole criteria used to estimate the condition of rangelands. This implies that a site in excellent ecological condition may not necessarily be the most productive from a grazing point of view. Similarly, fields in a poor ecological condition could rate well according to this system.

Agronomic approach has been used widely in the United States and was introduced into Africa with the principles being used to determine grazing capacity in the highveld grasslands of South Africa (Edwards & Coetsee 1971). One of the agronomic methods exlusively developed in South Africa is the weighted palatability composition method (Barnes *et al.* 1984). This approach correlates the livestock potential of a site with its immediate forage production potential. Likewise species are allocated palatability ratings according to their forage production potential. The three palatability classes described for the purpose of categorizing grassland species were: Highly palatable (class I), Intermediate (class II), and unpalatable (Class III) (Barnes *et al.* 1985, 1987; Rethman & Kotze 1986).

Multipliers, *i.e.* weighting of 3, 2, and 1 for classes I, II and III respectively, are used to derive a palatability composition rating (PC) for each sample site. It is calculated as the sum of the relative abundance of each species and its weighting, and is expressed as a percentage of the maximum PC (Viz. 300) to produce a scale ranging from 33.3 (all species in class III) to 100 (all species in class I). These PC values are converted to weighted palatability composition (WPC) values by means of the following formula (Barnes *et al.* 1984):

WPC = (PC – 33.3) X 100 /66.7.

Another agronomic approach used in South Africa is based on the calculation of a rangeland condition index, which can be compared with that of the benchmark (Dekker & Oosthuizen 1988; Danckwerts undated). The principle in this method is that the species are divided into a decreaser, increaser groups as well as an invader group (Jordaan *et al.* 1997). Forage factors representing their agronomic values are allocated to each species. The frequency of species is then multiplied by the forage factor in order to calculate a score for each species. These scores are added up to obtain a score for each group, where after the marks for the groups are added to obtain a final total (Danckwerts undated, Dekker & Oosthuizen 1988). The total score is then compared with that of the benchmark (expressed as percentage), thereby obtaining a range index for the specific site. Barnes *et al.* (1984) pointed out that the agronomic approach apparently provides satisfactory estimates of the relative value of different species in terms of the grazing capacity. In addition, it gives a clear illustration of the crucial importance of rangeland composition in relation to the grazing capacity. The authors also stressed that on a research project level, this approach appears to be generally applicable as a means of increasing objectivity in evaluating grassland species in relation to animal production, and in establishing relations between composition and grazing capacity.

Jordaan *et al.* (1997) argued that the methods based on agronomic principles do not lend themselves to the calculation of rangeland condition indices, nor to determining grazing capacity, especially if the long-term stability of the rangeland is a priority. Moreover, the authors noted the sensibility of the technique in the fact that certain palatable species are associated with poor rangelands as for instance in the case of the occurrence of relatively pioneer species, like *Cynodon dactylon (L) pers*.

2.5.2.3 Benchmark method

The use of benchmarks was initially introduced in South Africa in the grasslands of KwaZulu Natal (Foran 1976; Foran *et al.* 1978) and was then refined by Tainton & Booysen (1978) and Tainton *et al.* (1980). Since the basis of rangeland assessment is to compare a site with rangeland, which is in excellent condition (in terms of defined management objectives) in the same ecological zone, the first requirement of the method is to define the nature of such an excellent rangeland unit (Hardy *et al.* 1999).

The identification of the benchmark is subjective. It is apparent that the criteria for the identification of a benchmark has a large influence on the ratings or indices of change assigned to measurement areas, particularly when benchmark is used repeatedly in a regional survey of rangeland condition (Wilson 1984). The identification of a benchmark involves the selection of sites, which are productive and stable and which would support long-term animal production, while conserving the water and soil resources (Hardy *et al.* 1999). Similarly, a benchmark is an example of vegetation that is considered to provide the highest possible sustained profit from animal production for the veld type under consideration (Danckwerts undated).

Benchmarks are chosen on the basis that there is an original or climax vegetation that is best and hence the standard of reference for each type of land or rangeland unit (Dyksterhuis 1949; Laycock 1975 cited by Wilson 1984). Danckwerts (undated) stated that a benchmark will not necessarily represent the climax vegetation for an area, and it is in fact usually some form of sub-climax chosen under a practical management system. If such conditions are not satisfactory, idealized theoretical reference standards may be used (Lendon & Lamacraft 1976).

The benchmark method has an advantage of providing an indication of the overall direction of change that has taken place at the sample site in terms of whether it has been well managed, under grazed or overgrazed. Furthermore, if repeated at intervals, it is able to provide an indication of the change and direction of changes taking place in response to current management practices (Danckwerts undated).

In contrast, there are some critiques that invalidate the use of reference areas (benchmarks) from which departure or differences are measured as an indication of rangeland condition. Austin (1981) asserted that vegetation communities must be viewed as dynamic entities with both temporal and spatial heterogeneity in which both quantity and composition fluctuated in response to continuos and recurrent disturbances of climate, fire, drought, grazing, insect attack etc. (Noble & Slatyer 1980). In some cases vegetation may appear to be relatively stable for long periods, but the occurrence of infrequent events such as severe drought or wet periods may have predetermined the vegetation composition during these stable periods (Westboy 1980). Another criticism lies on the fact that benchmarks are often favoured parts of land in terms of soil depth and moisture availability and thus the use of such artificial standards is likely to contribute to the low incidence of the 'excellent' category in surveys condition (Wilson 1984). When benchmarks of the so called original or ungrazed/unburned areas are used, Wilson (1984) continued to argue, it is likely to be wooded in the savanna woodlands where as a herbaceous dominance is desirable for maximum grazing productivity. Foran *et al.* (1978) also confirmed from KwaZulu Natal of South Africa where ungrazed grasslands are regarded as inferior to those that are moderately grazed.

2.5.2.4 Ecological index method (EIM)

Vorster (1982) described this method for assessing the condition of Karroid vegetation in South Africa. Tainton (1982) also suggested several adaptations of this approach for use in the South African grassland vegetation. The basis of this method is a rangeland composition score based on a division of species into groups, which are judged to have ecological affinity. These groups are commonly termed 'decreasers', 'increasers' and, in some cases, 'invaders'. The basis of the ecological index method is the quantitative climax methods (QCM) of Dyksterhuis (1949). The QCM had been developed in an area of climax rangeland, where degeneration implied only a regression towards the pioneer stage. (Foran *et al.* 1978) concluded that in the fire grazing sub-climax grassland, however, regression could also result from the progression of plant succession towards the climatic scrub forest vegetation, a community, which is considerably less useful for livestock production than the fire-grazing sub-climax. For this reason, the increaser category used by Dyksterhuis (1949) was expanded to include those species which increase in abundance when grazing or fire is infrequent and those species which increase when the range is over utilized (Foran *et al.* 1978; Jordaan *et al.* 1997). According to Dyksterhuis (1949); Foran *et al.* (1978) and Barnes *et al.* (1984), these groups have been differentiated in a somewhat arbitrary manner, partly on the basis of their estimated position in seres (climax and sub climax herbaceous species being regarded as the most desirable), and partly on the known or supposed reaction of the species to injudicious range management practices and other disturbances such as drought and fire.

Anon (1981) cited by Vorster (1982) gave the detailed definition of the ecological groups as follows:

Decreasers: Species which are dominant in range in excellent condition and which decrease with under or over utilization. Most of the so called climax grasses falls under this group.

Increasers II (a): Species rare in veld in excellent condition, but increases when the rangeland is moderately overgrazed over the long-term. These groups usually increase when decreasers decrease. The sub-climax/dis-climax grasses belong to this group. Rangeland dominant by these species may agro-ecologically be classified as being in a good to fair condition

Increasers II (b): Species rare in range in excellent condition but increase as the range is heavily overgrazed over the long term. The increasing of this group is at the expense of the decreasers and increasers II (a). Species of this category will include perennial pioneer grasses and moderately hardy less palatable small bushes and taller shrubs. Dominance of plants in a rangeland generally is a sign of an agro-ecologically fair to poor conditions.

Increasers II (c): Species rare in veld in excellent condition, and increase when the veld is excessively overgrazed over the long term. This group increases when all the species mentioned above show a decreasing trend. The species in this category include mainly rain-dependent annual grass species, ephermals, hardy unpalatable bushes and taller shrubs as well as acknowledged poisonous plants. The rangeland if dominated by such species, is agro-ecologically poor to very poor condition.

Invaders: May be described as plants which are foreign to a given plant community or which increase aggressively in the plant community to which they belong. Rangeland which has a dominance of this group of plant is agro-ecologically in a very poor condition.

When needed, the ecological index method based primarily on the botanical composition of the vegetation requires modification to suit the particular circumstances in which it is being used (Riney & Dunbar 1956; McLean & Marchand 1968; Bhimaya & Ahuja 1969 cited by Foran 1978; Launchbaugh 1969; Tueller & Blackburn 1979). For instance, ratings may be drawn up for soil erosion, forage yield, litter cover, vigour of decreaser species, and bush encroachment so that the scores derived from these ratings could logically be deducted from the initial score based on plant composition to provide a more realistic assessment of range condition (Foran *et al.* 1978).

Vorster (1982) argued that soil erosion is irrelevant as an indicator of rangeland condition assessment. The chance for visual observation of soil erosion was found to be minimum on the shallow and rock soils (Vorster 1980 cited by Vorster 1982). In addition, Roberts *et al.* (1976) viewed that soil erosion is too advanced a symptom to be used in practical condition assessment for management decision making purposes. With regard to litter, although a good correlation was found, difficulties arose in coupling quantitative norms to each range condition class (Vorster 1980 cited by Vorster 1982). Moreover, the amount of litter varies with soil type, soil depth, drainage, slope, exposure, botanical composition, season, degree of utilization and climate (Sampson 1952). This, therefore, may imply that litter can be omitted as an indicator in veld assessment.

Vorster (1982) and Jordaan *et al.* (1997) concluded that the ecological index method is a sensitive and excellent technique to couple grazing capacity norms to each condition class. The methods also meet the requirements for successful rangeland condition assessments as set out by Humphrey (1962) in terms of its accuracy, speed of evaluation of extensive areas, minimum decisions required, objectivity and ecological basis. Vorster (1982) and Hurt & Bosch (1991) pointed out that the EIM, however, uses all species to calculate the rangeland condition index. In other words, species that do not react to grazing are also used. Furthermore, this technique divides species into increaser and decreaser groups on a subjective basis (Jordaan *et al.* 1997).

2.5.2.5 Key species method

Mentis (1983) called for the objective assessment of rangeland condition and suggested that only species, which respond sensitively to the grazing gradient should be used to index range condition. The key species methods developed from this suggestion recognizes that not all species encountered in rangeland show the typical decreaser/increaser response to utilization intensity (Hardy *et al.* 1999). Heard *et al.* (1986) applied this method with considerable success in the highland sour veld and tall rangeland of South Africa (Acocks 1988). Willis & Trollope (1987) also adopted a key species approach in the eastern Cape Döhne sourveld and False thornveld of South Africa.

The key species were identified in order of importance in terms of the extent to which they affect rangeland condition score, but a prerequisite was that the list of key species should be long enough to contain one species from each major species category (Danckwerts undated). Analysis of sample sites using the key species technique is identical to that of EIM, except where a species encountered is not a key species, it is recorded as 'other species'. Also the calculation of range condition score is done in the same manner, but scoring is conducted using only key species both in the benchmark and for sample site.

The key species approach may have the definite advantage in that the operator needs to be able to identify only a handful of species. Identification and listing of all species may be considered both practicable and desirable when conducting surveys for research purposes. However, it would be meaningful to identify those species of significant importance for farm planning purposes. Apart from this, it may be unrealistic to expect field workers, commercial ranch farmers and even researchers to identify all species that occur at a given sample site, particularly after grazing or during drought (Danckwerts undated).

Limitation on the use of the key species method happens when a decreaser species other than those identified as a key species occur in some abundance (>10%). A further limitation of this approach prevails relatively commonly when an increaser species other than the key species is present in some abundance at the sample site (Danckwerts undated).

2.5.2.6 Weighted key species

Heard *et al.* (1986) modified the key species methods to deduce rangeland condition indexes from weighted species occurrence. Hurt & Hardy (1989) and Hurt *et al.* (1993) adopted this weighted key species method to include eight species for the highland sourveld of South Africa. Species weights are based on the positioning of the key species on the grazing gradient (Jordaan *et al.* 1997; Hardy *et al.* 1999). The range condition index is calculated as the sum of products of the proportions of the key species and their associated weightings. The position of the benchmark along the grazing gradient can be calculated in a similar fashion (Hardy *et al.* 1999). Since all the key species react to the grazing impact, the final score is thus an exact indication of the sites position on the grazing gradient (Hurt & Bosch 1991). Weighted key species, however, is sufficiently sensitive to monitor range condition trends (Jordaan *et al.* 1997).

2.5.2.7 The use of degradation gradients (DGT)

Mentis (1983) & Stuart-Hill *et al.* (1986) proposed an approach whereby vegetation condition could be quantified along an ordination axis, which represented rangeland degradation. This means the position of a particular sample of vegetation is quantified along a degradation gradient, i.e. a model describing long-term vegetation and habitat changes from under utilized to severely over utilized (Hardy *et al.* 1999).

The degradation gradient technique was developed in the climatic climax grasslands using multivariate procedures (Bosch 1989; Bosch *et al.* 1989; Bosch & Gauch 1991; Bosch & Kellner 1991). This represents a suite of sample sites in deteriorating ecological conditions along a grazing gradient and was constructed for certain relatively homogenous grazing areas (Jordaan *et al.* 1997). Within such ecological units, data on species composition and soil condition are collected from rangeland in various 'stages of degradation'. Such data are obtained from long-term grazing trials, from obvious variation in the pastoral impact of vegetation, such as one given by fence line contrasts, and by sampling at various distances from well established points of animal concentration such as watering points (Hardy *et al.* 1999).

Gradients are described in terms of floristic composition and soil factors, and are subdivided into five categories viz. under utilized, undergrazed (lightly utilized), moderately degraded, moderately to severely degraded and severely degraded (Hardy *et al.* 1999). These gradients are then used as a basis for objective and quantitative condition assessments of new sites by incorporating the new sites into the old ordinations (Bosch & Gauch 1991) thereby providing an index of its condition

The degradation gradient technique, as with the key species approach uses only those species, which are significant indicator of grazing conditions (Jordaan *et al.* 1997; Hardy *et al.* 1999). Ecological interpretation of any rangeland is possible with this method because the researcher acquires knowledge regarding species reactions to grazing, grass community dynamics as well as the relationship between vegetation and habitat degeneration during the construction of the gradient (Hurt & Bosch 1991). Bosch (1989), Bosch & Kellner (1991) emphasized that the use of gradients in the assessment of rangeland condition helps to identify domains of attraction. Domain identification has important implications as it determines whether the degradation trend is reversible by means of normal rangeland management practice, or whether the physical reclamation methods need to be applied to restore the productivity of the land (Bosch & Kellner 1991).

Though the degradation gradient method can be described as one if the most accurate methods for calculating rangeland condition (Hurt & Bosch 1991), several limitations exist in using this approach. Hurt & Bosch (1991) pointed out that relatively large sets of data are required to construct gradients. Moreover, Jordaan *et al.* (1997) considered the degradation gradient technique as time consuming and cost ineffective technique. The use of ordination procedures to elucidate species trends along degradation gradients has a possible deficiency in that the model represents different land types that could explain the low r^2 (regression) values of most species (Van der Westhuizen *et al.* 1991). It is also difficult to satisfy description of gradients for every land type if there is very little botanical difference between land types. Moreover, the multivariate techniques on which this method is based are complicated and only possible with a computer.

2.5.3 Estimation of rangeland condition, grazing capacity and browsing capacity: Application in woody savannas

Rangeland condition assessment in woody savannas is dependent on the condition of both the herbaceous layer and the shrub-tree community. In savanna grasslands where woody component can prevail to varying degrees, overgrazing is regarded as one of those factors to induce the proliferation of these components. In such situations, assessment techniques, therefore, must be concerned with the herbaceous layer as well as determining the density of woody plants (from counts in transect).

A simple approach suggested earlier to describe the woody vegetation (Tainton *et al.* 1980) was the classification of the woody plants into the same categories as the grass species, counting them, and presenting the density into 3 categories (Coppice growth, seedling < 2m and trees > 2m).

In the semi-arid savanna of South Africa, a model to predict grazing capacity from grass composition score was developed and tree density was incorporated as one factor. Trees were described according to different effects they have on the herbaceous layer of the grasslands. For one reason, woody plants reduced the grazing capacity in accordance with their competitiveness and negative influence on the sward productivity (Danckwerts 1981 cited by Stuart-Hill & Hobson 1991; Aucamp *et al.* 1983). Teague *et al.* (1981) introduced a refinement on using tree density where the height of the trees was measured and converted into an index of tree competitiveness known as 'a tree equivalent'. At the same time the role of trees as browsing forage was recognized (Aucamp & Barnard 1980 cited in Stuart-Hill & Hobson 1991) and each tree was then considered in terms of 'a browse unit'; the number depending on the height of tree, the height of its canopy and its palatability. While determining grazing capacity, the same model was employed but tree equivalent was used instead of tree density to correct grazier stocking rate (Stuart-Hill & Hobson 1991) to account for the competitiveness effect of trees. Browser carrying capacity was determined from the number of browse unit (Teague 1987).

Another attempt was made to improve the accuracy of measuring aerial woody phytomass by using canopy volume (derived from various formulas). The later was found to be more closely correlated with phytomass than tree height, tree equivalent or browse units (Teague 1987; Smit 1989). Hobson & De Ridder (1991) found, however, that these attributes had poor repeatability between operators and advised tree height to be used, provided that a curvilinear relationship between height and competitiveness be adapted. 'Browse' on the other hand was best measured using a volumetric measurement called 'partial special volume' (Stuart-Hill & Hobson 1991).

Smit (1989) developed a model, known as BECVOL model (Biomass estimate from canopy volume), by taking into account the ecological implications of woody plants in savannas with respect to (i) competition with herbaceous vegetation for soil, water and nutrients; (ii) food for browsers, and (iii) creation of sub-habitats suitable for desirable grass species. This is a model to quantitatively describe woody plant communities and can be generally applied and is meaningful in terms of both plant and animal production.

The BECVOL-model provides estimates of the actual leaf volume and leaf mass of individual woody plants, from which evapotranspiration Tree Equivalent (ETTE) and Browse Tree Equivalent (BTE) are derived. These values are also calculated per hectare. This is done for individual species as well as for the total population. In addition, total leaf dry matter per hectare (DM ha^{-1}), stratified estimates of the leaf DM ha^{-1} below 1.5, 2.0 m and 5.0 m, respectively, are also calculated by the BECVOL-model. The height of 1.5 m represents the mean browsing height of the boer goats (Aucamp 1976) and Impala

(*Aepyceros melampus*) (Dayton 1978), while 2.0 m and 5.0 m represent the mean browsing heights of the Kudu (*Tragelaphus strepciseros)* (Wentzel 1990) and giraffe (*Giraffa camelopardalis*) (Skinner & Smithers 1990), respectively. These browse units are mean heights and not maximum browsing heights.

The BECVOL estimates are based on relations between the spatial canopy volume (calculated from various dimension measurements of the trees) and the tree's true leaf volume and true leaf mass. In addition, the model also calculates simple tree density data (plants ha^{-1}) on a species basis and CSI values (canopy sub-habitat-index) (Smit 1996). This model incorporates considerable an amount of mathematical calculations, some of which are difficult and time consuming if attempted without the aid of computerized computation (e.g. calculations of partial canopy volumes). These calculations are therefore suited for inclusion in a computer model since it will free the user from laborious calculations and provide fast and consistently accurate calculations (Smit 1996).

CHAPTER 3

STUDY AREA AND GENERAL PROCEDURE

3.1 STUDY AREA

3.1.1 Location

The study was conducted in the Borana rangeland (plateau) located in the southern part of Ethiopia (Figure 3.1). The landscape is gently undulating across an elevation of 1 000 to 1 600 m, except for a few mountain ranges, scattered volcanic cones and craters (Coppock 1994). Latitude ranges between 4° 3′ N and 5° 00′ N, where as longitude ranges between 37° 38′ E and 38° 23′ E.

3.1.2 Climate

The Borana plateau is dominated by a semi-arid climate. The average annual rainfall for the period 1980 to 2000 in the Borana lowland areas ranged from 111.2 mm (Moyale) to 858 mm (Arero) (Figure 3.2). The average annual rainfall for the study area for the period 1980-2000 ranged from 390 mm (Dubuluk) to 468 mm (Yabello). The rainfall occurrence in general is bimodal with 59 % of the total rainfall that occurred from March to May and 27 % from September to November (Coppock 1994). Droughts are common with intervals of 5 – 20 years. The mean annual temperatures vary from 15 - 24 °C and shows little seasonal variation (Figure 3.3). The temperature decreases by 1 °C for every increase in elevation (JEPSS 1983; Coppock 1994).

3.1.3 Vegetation

The Borana plateau is dominated by savanna vegetation containing a mixture of herbaceous annual, perennial and woody vegetation.

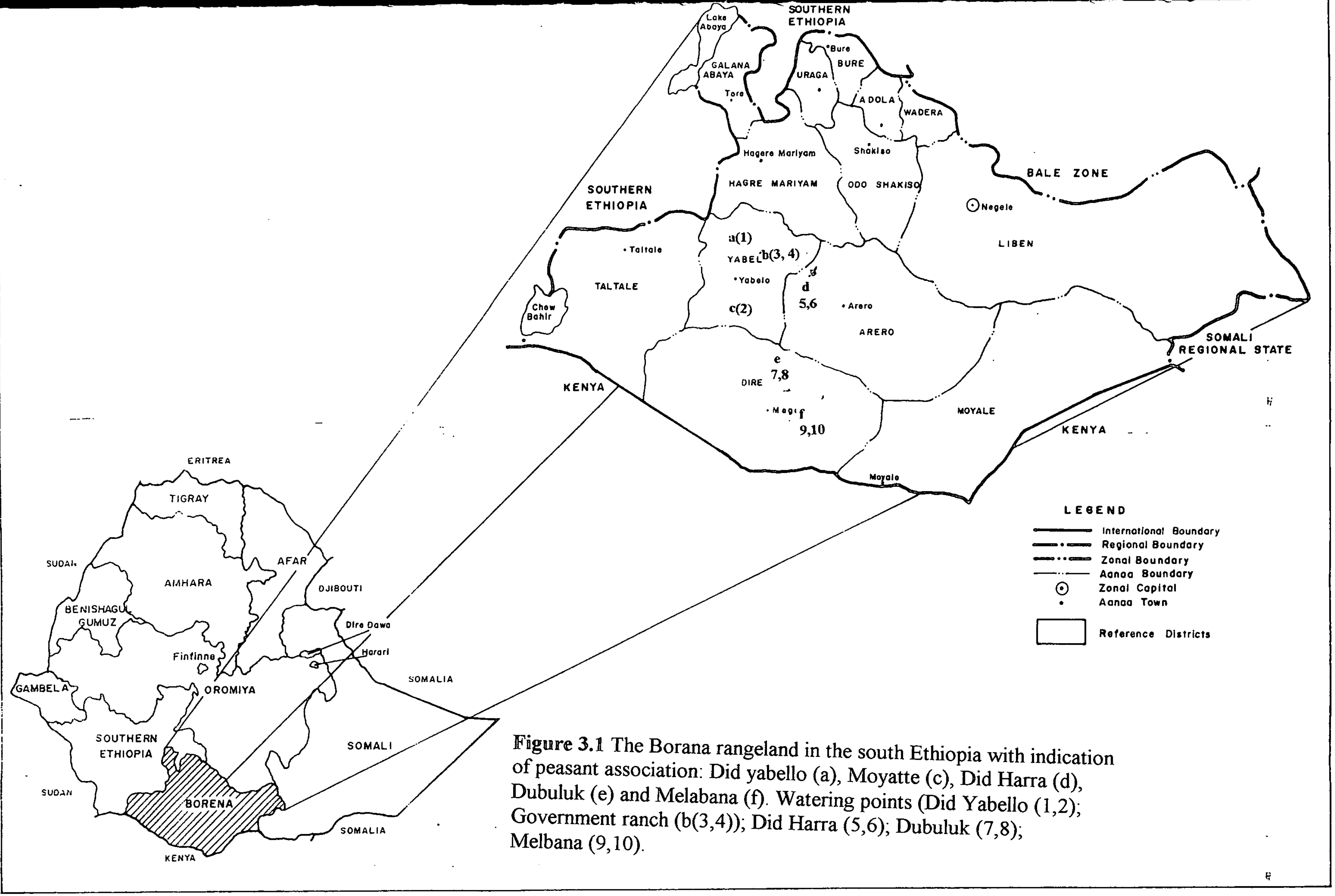


Figure 3.1 The Borana rangeland in the south Ethiopia with indication of peasant association: Did yabello (a), Moyatte (c), Did Harra (d), Dubuluk (e) and Melabana (f). Watering points (Did Yabello (1,2); Government ranch (b(3,4)); Did Harra (5,6); Dubuluk (7,8); Melbana (9,10).

Four major vegetation types were described (Agrotec/crg/sedes associates 1974): (i) evergreen and semi-ever green bushland and thickets, (ii) rangeland dominated by *Acacia* and *Commiphora,* (iii) rangeland dominated by shrubby *Acacia, Commiphora* and allied genera, and (iv) dwarf shrub grassland or shrub grassland. The dominant herbaceous plants were perennials rather than annuals (Ayana & Baars 2000). Previous studies indicated that variation in the pattern of the vegetation is due to a water gradient (UNDP/RRC 1984), ecological zonation and grazing intensity (Corra 1993).

3.1.4 Geology and soil

There is scant information available on the geology and the soil types of the Borana Plateau. However, the meager studies on an area of 15 475 km^2 suggested that the geology is dominated by 40 % quaternary deposits, 38 % basement complex formations, and 20 % volcanics (Coppock 1994). The same source also reported the occurrence of vertisols in valley bottoms while upland soil is widely distributed.

3.2 GENERAL PROCEDURE

3.2.1 Selection of study sites

The study on vegetation dynamics, soil and rangeland condition was made on four communal grazing areas, one government ranch (Did Tyura ranch) and four traditional grazing reserves (kallos) selected in the four communal grazing areas. A total of eight water points from the communal grazing areas and two from the government ranch were selected (Figure 3.1). The four traditional grazing reserves were located regardless of the distance from the water source. There are no private ranches in the study area. A few available ones are owned by the state and Did Tyura is the only government ranch that is conveniently located for the purpose of this study. This ranch has been serving as a center for genetic conservation of the Borana cattle breed. The selected sites had similar soil (red type), landscape, altitude (1550 to 1700 m) and climate, but the four communal grazing sites differed in the intensity and historical pastoral use. In addition, proximity to road and aspects of social security were considered in the selection of the sites. These criteria were also used for the selection of the water points. Besides, water holding capacity and age were also considered. Water ponds (wells) with either a small capacity or with a very recent establishment (<10 years old) were excluded.

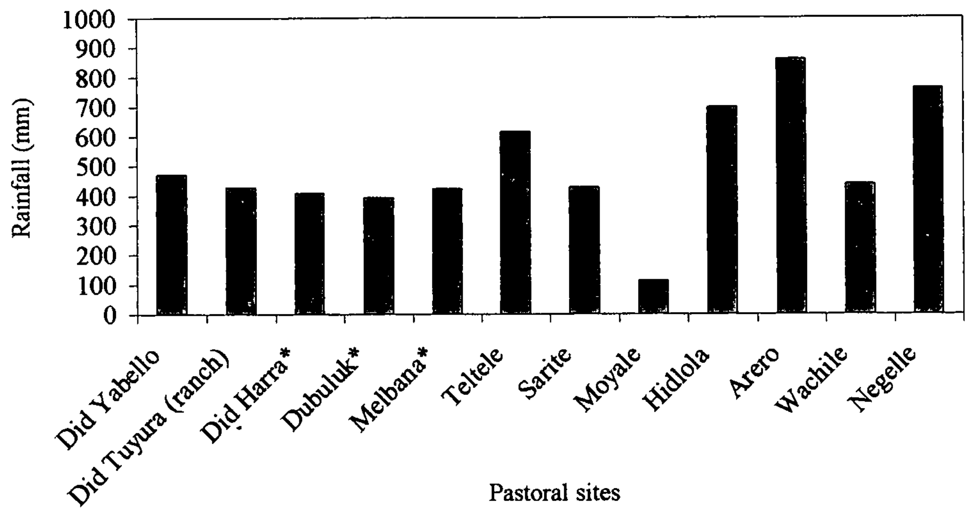


Figure 3.2 Annual rainfall (mm) (January to December) for 12 grazing sites in the Borana pastoral areas for the period of 1980-2000.
(* denotes the data is not complete for the mentioned period).

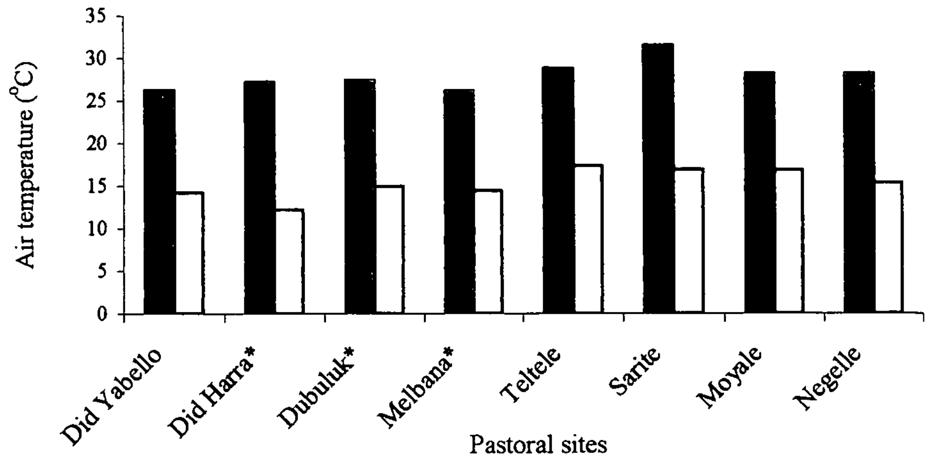


Figure 3.3 Air temperature for the period 1980- 2000 for eight grazing sites of the Borana pastoral areas. (* denotes data for some of the years are missing).

Temperature: ■ Max □ Min

3.2.1.1 Transects, sub-transects and plots

Due to similar vegetation patterns around the watering points, only one transect was established in each selected watering point. The length of the transect ranged from 3 to 12 km. Areas disturbed by crop cultivation were avoided. Each transect was divided into three sub-transects to cover three relative distances (near, middle and far) from the water sources. The same distance length of the near, middle and far sub-transects was not taken to all the selected watering points because this was not possible, first due to the fact that the area coverage of the grazing land around the different watering points are not the same, and secondly, mountains, gorges and rivers found around the watering points precluded the allocation of similar lengths for each distance sub-transect. Thus, the distance from the watering points to the end point of the near and middle sub-transects varied from 1 to 4 km and from 1.5 to 8 km, respectively. Approximately in the middle of each sub-transect and in each traditional grazing reserve a plot of 20 m x 50 m (1000 m^2) was marked. These plots were used as the main zone for the vegetation and soil surveys. Altitude was measured in each plot and near to each watering points by using an altimeter.

3.2.2 Selection of villages

The study on the pastoralists perceptions and cattle rangeland management practices was conducted on forty households. The government administrative institution considers the communal grazing area(s) selected in this study as peasant association(s). A total of 20 villages were identified from the five grazing areas (peasant associations) from which households and elders were selected for the study of the cattle-range management practices and the perceptions of pastoralists towards rangeland degradation (Table 3.1).

The villages were selected randomly, but restrictions on the selection were imposed based on the current experience of households, the proximity to roads and aspects of social security. Staff members from the zonal Ministry of Agriculture and the non-governmental organization offices participated in the selection procedure because of their access to detailed information and knowledge of the villages under each peasant association.

Table 3.1 Selected peasant associations and respective villages included for the household survey.

Name of Peasant associations	Name of villages
Did Yabello	Roba Boru
	Dabassa Jaldessa
	Nura Tuke
	Kalicha Bagajo
Did Harra	Guyo Kayu
	Dulacha Halake
	Guyo Jateni
	Cahau hallo
Moyatee	Tadicha Waryo
	Waryo Jilo
	Huka Lemma
	Dida Dhagaagaln
Dubuluk	Jilo Boru
	Barchi Akobo
	Dabassa Waryo
	Boru Waryo
Melbana	Dida Boru
	Dida Waryo
	Liben Gofu
	Jarso Agali

Two interviewers who know the local language of the pastoralists (Afaan Oromoo) were recruited. They were given training before commencing with the actual interviews. The training provided a general understanding of pastoral rangeland and included a detailed explanation of important issues concerning the respective areas and contents of the questions. After the training, they worked in one peasant association, where after they held discussions on the responses in order to develop experience and gain practical exposure.

CHAPTER 4

CATTLE-RANGELAND MANGEMENT PRACTICES AND PERCEPTIONS OF PASTORALISTS TOWARDS RANGELAND DEGRADATION

4.1 INTRODUCTION

The Borana lowland was the center of a once widespread nomadic culture carried out by the people of the Borana tribes, a stable and peaceful society (ESAP 2000). Pastoralism among the Borana constitutes an age-old tradition that historically proved capable of adaptation to a region characterized by frequent and often dramatic climatic vulnerability. In recent decades, however, pastoralism in the traditional Borana lifestyle has come under enormous pressure, which undermined its vitality to maintain the households of a large sector of pastoralists (Boku 2000). The people are suffering considerable erosion of their lifestyles, as encountered in other parts of Africa, through long-term land degradation, increased livestock and human population as well as increased competition with outsider people requiring areas for cultivation (Behnke *et al.* 1993; Scoones 1995).

In spite of the many problems the pastoralists encountered, they continue to be themselves the experts in using, living in and surviving in such a harsh environment under often unpredictable weather conditions. Therefore, while attempting to deal with their problems, it is vital that any pastoral development planning and intervention should first focus on a thorough understanding of the pastoralists' goals and strategies.

In Borana, most pastoral interventions and development activities have been unsuccessful, partly, because of the ignorance of the pastoralists participation in providing information, undermining their traditional livestock and rangeland management practices, their perceptions on the rangeland, as well as limiting their involvement in decision making and development planning processes.

In view of this background a survey was conducted with the following objectives:

(i) to describe the current livestock holdings of the Borana pastoralists,
(ii) to assess the livestock-rangeland management practices,
(iii) to identify current constraints to livestock production, and
(iv) assess current perceptions of the pastoralists towards rangeland degradation.

4.2 PROCEDURE

4.2.1 Selection of peasant associations and villages

This survey was conducted during October-December 2001. The first step in the survey process was to identify five peasant associations. Accordingly, the target associations comprised those grazing areas where the vegetation and soil survey were conducted. Four villages within each peasant association were selected for this study. The process and criteria for the selection of the villages were already discussed in section 3. 2. 2.

4.2.2 Selection of households and ethnic elders

A total of 40 households were identified (Appendix 1), with 2-3 households in each village. The selection of the households was random. Out of 18 villages, a total of 128 ethnic elders were selected (average 7 per village). The selected elders were long-term residents. The reason for this choice of participants was to get reliable information from them concerning perceived changes in the ecology. In order to ensure that most of the information gathered was reliable, the selected elderly people were those who had spent their whole lives in the area and who depended totally on pastoralism for their livelihood.

4.2.3 Data collection and analysis

In this study, data on the characteristics and performance of individual livestock holdings were obtained by a combination of formal discussions and structured interviews of individual households (for the layout of the questionnaires see Appendix 2). The target interviewees in this case included both male and female parents. Other young members of the family were encouraged to participate when necessary. The data collected in this part were related to livestock inventory, management and production, health and disease situations, major constraints to livestock production and other related topics.

Opinions of the pastoralists on the rangeland condition and trends were gathered from group discussions with elders (Figure 4.1) in each selected village. The group discussion was conducted in an open-ended fashion with sufficient time to gather details from the group respondents. Where appropriate, information was also obtained from formal discussions and interviews of individual respondents. Questions were asked regarding perceptions on rangeland deterioration, long-term vegetation change, its causes and characteristics and other related issues. To supplement what was obtained from both interviews, additional information was gathered from secondary sources.

Data were analyzed using the SPSS statistical software program (SPSS 1996). For ranked data, statistical analysis of Friedman's Chi-square test (Steel & Torrie 1980) was used. When the analysis of Friedman's test revealed the existence of significant variation, a set of sign tests were performed for multiple comparison of means. For the rest of the data, mean, standard deviation and percentages were derived to present results for different categories.

4.3 RESULTS

4.3.1 Family size and educational background

A Borana household is defined as a man, his wife, their children and those who are food dependent on the household's livestock and other resources. Such households may include other kin or non-kin members (Tilahun 1984; Hogg 1992).

Figure 4.1 Group photograph with Borana elders in one of the villages after a discussion (Did Harra - Dambidikale).

The average household size of a family for the five peasant associations in the study area was 7.23, ranging from 5.39 (Melbana) to 8.62 (Did Yabello) (Table 4.1). Males (<10-50 years of age) accounted for 48.3 % of the total household (range: 34.9 %- Moyate to 49.2 %- Did Yabello). The proportion of females (<10-50 years of age) was on average

52.2 % per household, with a range of 48.35 % (Did Yabello) to 56.7 % (Melbana). Considering the age distribution (both males and females) it was as follows: less than 15 years of age (59 %), 15-50 years (29 %) and above 50 years (12 %) (Table 4.1).

In this study, as far as educational status was concerned, the percentage of male students who attended elementary school was 21.8 %, while that of junior/senior secondary and higher institution were 4.2 % and 0 %, respectively. Regarding female students, the figure was 9.3 % for elementary school and 0 % for both secondary schools and higher institutions.

4.3.2 Major farm activities

The majority of the Borana pastoralists in the five peasant associations relied on both livestock and crop activities, whereas only a few pastoralists depend on only livestock production (Figure 4.2).

4.3.2.1 Livestock holding and trends

Of the total households, 100 % were involved on rearing cattle, 89.8 % reared goats, 64.1 % and 46.2 % reared sheep and camel, respectively (Table 4.2).

4.3.2.1.1 Livestock holdings

The average livestock holding per household in the five peasant associations during the study period was estimated to be 14 cattle, 10 goats, 6 sheep and 2 camels. Of the total cattle holdings, cows made up 40 %, calves 40 % and young and mature animals 20 % (Table 4.3). There were differences in the average individual holdings among the five peasant associations. In terms of total livestock holdings, Did Yabello and Dubuluk had the greatest number, where as Moyate had the lowest. In Did Yabello, the greatest holding was accounted by a larger proportion of goats.

Table 4.1 Age distribution and mean household size of Borana households in the five peasant associations (respondents, n = 40). Standard deviation (SD) is indicated in the brackets.

Male (age in years)	**Did Yabello**	**Did Harra**	**Moyatee**	**Dubuluk**	**Melbana**
<10	1.86 (0.64)	1.12 (0.99)	1.50 (0.93	0.63 (0.74)	0.88 (0.99)
10-14	1.00 (0.76)	0.63 (1.06)	0.86 (0.83)	0.75 (1.04)	0.25 (0.46)
>14-50	1.38 (1.50)	0.88 (0.64)	1.13 (0.83)	1.13 (0.99)	0.88 (0.99)
Sub total	**4.24**	**2.63**	**3.49**	**2.51**	**2.01**
Female					
<10	2.25 (0.87)	1.38 (1.41)	1.75 (1.17)	1.37 (0.92)	1.25 (1.39)
10-14	0.38 (0.74)	0.88 (0.99)	0.88 (1.13)	0.63 (0.92)	0.63 (0.74)
>14-50	1.25 (0.89)	1.38 (0.74)	0.75 (0.71)	0.63 (0.74)	0.75 (0.89)
Sub total	**3.88**	**3.64**	**3.38**	**2.63**	**2.63**
>50 (male/female)	0.50 (0.76)	0.63 (1.06)	1.00 (1.07)	1.13 (1.25)	0.75 (0.89
Total family size/HH[1]	**8.62**	**8.02**	**7.87**	**6.27**	**5.39**

[1] = household

Table 4.2 Types of livestock kept by pastoralists in five pastoral associations (respondents, n = 40).

Livestock species	**Respondent (%)**
Cattle	10.3
Cattle and goats	15.4
Cattle, sheep and goats	28.2
Cattle, goats and camel	10.3
All species	35.9

Considering the cattle, Dubuluk and Melbana had the greatest holdings where as Moyate had the lowest (Table 4.3). Elders' response to the ranking of the previous years (15-20 years ago) population of livestock species (Table 4.4) indicated the descending order of cattle, goats, camels and sheep. With regard to the population of individual species (Table 4.5), cattle, sheep and goats showed a declining trend, whereas camel was speculated to show an increasing (55.6 %) trend.

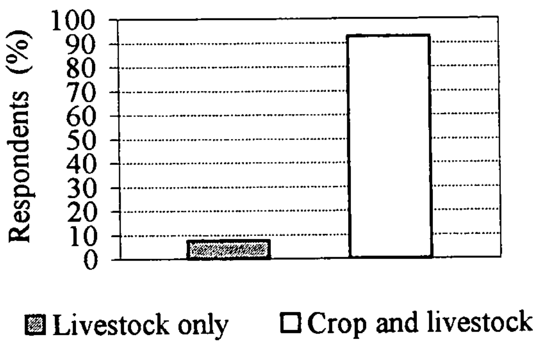


Figure 4.2 Major farm activities in five peasant associations of Borana pastoral areas (respondents, n = 40).

4.3.2.2 Crop production

At least six types of crops were identified to be cultivated in the survey areas. The importance of these crops differed between households. However, most household respondents grew maize and haricot bean (Table 4.6). Wheat and sorghum were indicated to be important crops next to maize and haricot bean. Other crops rarely grown in these areas include barely and teff. Data on average area cultivated per household in the five peasant associations (Table 4.7) indicated that it was the largest in Did Yabello and the lowest in Did Harra.

4.3.2.3 Labor distribution

Important labour sharing activities of households in crop production identified in the five peasant associations were weeding, ploughing, harvesting and protection of the farm from birds and animals.

Table 4.3 Mean livestock holdings in five peasant associations of Borana pastoral areas (respondents, n = 40). Standard deviation (SD) is indicated in the brackets. See figure 4.1.

Livestock	**Peasant associations**				
Cattle	**Did Yabello**	**Did Harra**	**Moyatee**	**Dubuluk**	**Melbana**
Calve (< 1 year)	4.25 (4.03)	4.00 (3.12)	3.13 (3.31)	9.38 (11.72)	7.25 (13.53)
Young stock (1-3 years)	0.25 (0.71)	1.13 (1.64)	0.13 (0.35)	1.25 (2.19)	0.88 (2.47)
Cows	5.25 (4.20)	6.63 (5.95)	3.63 (2.19)	9.50 (10.38)	8.38 (13.15)
Mature male	1.25 (1.04)	0.88 (0.99)	1.75 (1.49)	2.38 (3.29)	0.88 (0.99)
Sub total	**11 (8.49)**	**12.63 (8.60)**	**8.63 (4.90)**	**21.25 (23.49)**	**17.38 (26.88)**
Camel					
Calves (<1 years)	0.75 (1.49)	0.25 (0.71)	0.63 (1.06)	0.13 (0.35)	0.38 (1.06)
Young stock (1-3 years)	0.75 (1.17)	0.50 (1.07)	0.25 (0.71)	0.50 (0.93)	0.50 (1.41)
Milked	1.13 (2.10)	1.13 (1.64)	0.63 (1.41)	1.13 (1.64)	0.38 (1.06)
Mature male	0.25 (0.46)	0.25 (0.71)	0.25 (0.46)	0.13 (0.35)	0.25 (0.71)
Sub total	**2.88**	**2.38 (3.42)**	**1.75 (2.87)**	**1.88 (2.75)**	**1.38 (3.50)**
Sheep	5.88 (5.44)	4.00 (3.16)	4.00 (5.71)	1.50 (2.27)	0.75 (2.12)
Goat	15.88 (13.05)	7.13 (5.03)	9.13 (5.38)	9.13 (8.93)	9.00 (12.32)
Sub total	**21.76**	**11.13**	**13.13**	**10.63**	**9.75**
Total	**35.64**	**26.14**	**23.51**	**33.76**	**28.51**

In this survey, it was found that weeding and protection involves both males and females between the age of 10 - > 50 years (Table 4.8). Ploughing and harvesting are the duties of both males and females in the age group of >10-50 years.

The most important labour sharing activities of households in livestock production include the tending of small ruminants and calves, herding resident and far ranging cattle and camels (mature animals), watering animals from deep wells, gathering and feeding supplements to resident animals and constructing corrals and fences. Herding of small ruminants and calves are the major activities of younger children and females (Table 4.9). Herding mature animals near the encampments and on a far-ranging basis are mostly accomplished by both sexes from 14-50 years of age.

Table 4.4 Abundance of individual livestock species population (mean rank) in the previous years (15-20 years ago) as ranked by household respondents in the five peasant associations[1] (respondents, n = 40).

Number	Mean rank[2]	Attribute
1	1.57[a]	Cattle
2	1.71[b]	Goat
3	3.43[c]	Camel
4	3.57[d]	Sheep
5	4.71[c]	Equine

[1] = Attributes were listed and ranked from most important (1) to least important (5);
[2] = Entries are accompanied by the same letter were not ranked differently (P>0.05) according to Friednman's test (Steel & Torrie 1980).

Table 4.5 Perceptions of household respondents in the trends of individual livestock population in 15-20 years period (respondents, n = 40).

Species	Respondents (%)	
	Increase	Decrease
Cattle		100
Sheep	5.4	84.6
Goat		100
Camel	55.6	44.4
Total population		100

Older girls (in their late teens) are involved in these activities when there is shortage of labour supply in the household. Watering animals from deep wells, gathering and feeding supplements to resident animals are the responsibilities of many young men and women (Table 4.9).

Table 4.6 Major types of crops produced in five pastoral associations of the Boran pastoral areas (respondents, n = 40).

Crop types	Respondent (%)
Maize	95.00
Boloke	90.00
Sorghum	25.00
Barley	20.00
Wheat	37.50
Teff	22.50

Table 4.7 Area of land (ha) cultivated for crop production purposes in the selected households of the survey areas (respondents, n = 40).

	Peasant association				
Households	**Did Yabello**	**Did Harra**	**Moyate**	**Dubuluk**	**Melbana**
1	1	1	1	2	0
2	1	0.5	1.5	0.5	1
3	3	1	1.5	0	1
4	2	1.7	1	2	1
5	1	0	1.5	0	2
6	2	0		1	1
7	3	0	2	3	1
8	5	0	2	1.5	1
Average	**2.25**	**0.525**	**1.5**	**1.25**	**1**
SD	**1.38873**	**0.647523**	**0.408248**	**1.069045**	**0.534522**

Table 4.8 Major crop activities and labour sharing of households in five peasant associations (respondents, n = 40).

	Respondent (%)				
	No task	**Weeding**	**Protection**	**Ploughing**	**Harvesting**
Male (years)					
< 10	58.60	41.40			
10-14				84.20	15.80
>14-50		100.00	83.90	100.00	71.00
>50		43.80	25.00		
Female (years					
<10	18.70	32.30	50.00		
10-14		53.30	31.60		100.00
>15-50		82.10	33.30		100.00
>50		41.70	18.20		

4.3.3 Cattle-rangeland management practice

4.3.3.1 Relative importance of livestock

Pastoralists in the five peasant associations have a special regard for cattle and keep cattle for various purposes. As ranked by the respondents, the first priority of keeping cattle is for milk production, which is the main food in their diet (Table 4.10). The contribution of cattle for provision of income from sales was ranked second.

Table 4.9 Major livestock activities and labour distribution of household in the five peasant associations (respondents, n = 40).

	Respondent (%)			
Person (years)	**Shepherd young Stock/small ruminants animals**	**Water animals**	**Gather and feeding supplements**	**Shepherd Mature**
Male (age)				
< 10	100.00			
10-14	63.60	50.00	52.20	73.90
>14-50	77.40	96.80	80.60	90.30
>50	23.50	37.50	31.30	
Female (age)				
<10	100.00			
10-14	75.00	73.30	40.00	62.50
>15-50	22.20	75.90	82.80	24.10
>50	8.30	16.70	54.50	

The third importance of rearing cattle is the provision of meat supply for consumption. Other than these contributions cattle are also reared for animal draft power, breeding and prestige.

The three most important purposes of keeping sheep in order of importance are slaughter for meat, income generation and prestige (Table 4.10). Goats are reared for various purposes (Table 4.11). These include in order of importance: milk, meat, income generation, prestige and breeding. Open discussion with the respondents indicated that few years ago goats were primarily kept for occasional slaughter for meat and prestige purposes, but recently the role of keeping goats for their milk has shown an increase trend in importance.

Table 4.10 Relative importance (mean rank) of the purposes for rearing cattle and sheep as ranked by the respondents in the five peasant associations[1] (respondents, n = 40).

	Cattle	
Number	**Mean rank[2]**	**Attribute**
1	1.16[a]	Milk
2	2.53[b]	Income generation (sales)
3	3.37[c]	Meat (slaughter)
4	4.00[cd]	Plough
5	4.21[d]	breeding
6	5.74[e]	Prestige
	Sheep	
Number	**Mean rank[2]**	**Attribute**
1	1.22 [a]	Meat (slaughter)
2	1.88[a]	Income generation (sale)
3	2.92[a]	Prestige

[1] = Attributes were listed and ranked from most important (1) to least important (6) for cattle and from most important (1) to least important (3) for sheep;
[2]= Entries accompanied by the same letter were not ranked differently (P>0.05) according to Friednman's test (Steel & Torrie 1980).

Camels are also kept for different purposes (Table 4.11). According to informal discussions made with the respondents, previously the pastoralists only kept a few camels for the sole purpose of transportation. In this survey, camel milk, as a substitute for cattle milk was ranked as the primary reason of rearing camel, followed by transportation, income generation, meat source and lastly, prestige. Other than these, the role of camels to provide draft power has emerged in the more recent times.

4.3.3.2 Livestock and rangeland management

Nearly 92 % of the respondents in the five peasant associations indicated that herds were primarily grouped in terms of species and age for the sake of convenience during herding. Generally, it was discussed that overall livestock herding falls into two categories. These included the home based and satellite herding. Home based herding involves the herding of 'Warra' herds, which constitutes milking cows, calves and immatures < 2 years old, small ruminants and equines. These herds graze close to the encampments. Satellite herding constitutes herding of "Forra" herds, namely; bulls, immatures > 2 years old (both cattle and camel), and dry cows. For most of the year the satellite herds move further away from villages in search of grazing and browsing.

Table 4.11 Relative importance (mean rank) of the purposes for rearing goats and camels as ranked by the respondents in the five peasant associations[1] (respondents, n = 40).

	Goat	
Number	**Mean rank[2]**	**Attribute**
1	1.04^{a}	Milk
2	2.49^{b}	Meat (slaughter)
3	2.69^{b}	Income generation (sales)
4	3.93^{c}	Prestige
5	4.85^{d}	breeding
	Camel	
Number	**Mean rank**	**Attribute**
1	1.39^{a}	Milk
2	2.11^{a}	Transportation
3	3.28^{b}	Income generation (sales)
4	3.72^{cb}	Meat (slaughter)
5	4.50^{c}	Prestige

[1] = Attributes were listed and ranked from most important (1) to least important (5);
[2] = Entries accompanied by the same letter were not ranked differently (P>0.05) according to Friednman's test (Steel & Torrie 1980).

Pastoralists in the five peasant associations revealed that it is a common experience to have a strong fluctuation of livestock feed, both in terms of availability and quality, with the critical period of shortage during the dry season (December to February). The respondents also mentioned that there could be similar problems during the short rainy season (September to November). The strategies to alleviate feed shortage during these months included mobility and feeding supplements (particularly homestead herds).

In fact, supplementary feeding cannot be associated at all times with a feed shortage. Be it in the presence or absence of feed shortage, it is a common practice to supplement those animals that are close to the encampments. The common feed supplement types used in the study areas are presented in Table 4.12.

The respondents in the five peasant associations also stressed that mobility is not only a strategy to minimize the associated risk of grazing/browsing shortage but is also one option of rangeland management. Apart from this, all the pastoralists interviewed indicated that burning was one of the most effective traditional practices of rangeland management. This practice has no longer been a tool since 1974/75. The pastoralists expressed their views on the reasons why burning was not used any more. Ninety five percent of the respondents agreed that the government's ban on burning is still in place. The remaining argued that the ban was lifted some years ago but this is not yet official and because of the fear that they may get penalized by the local administration, they have refrained from burning the rangelands.

Bush clearing was and continues to be practiced in the study areas. As mechanical bush clearing is an arduous job, and too labour intensive to cover large areas, it is commonly done on small traditional grazing reserves and enclosures. Visual observation witnessed that there has been bush-cleared rangelands in some parts of the study areas. Eighty three percent of the respondents noted that bush clearing activities was supported and coordinated by non-government organizations.

Interviews regarding the efficiency of the use of the available rangeland indicated that 54 % of the household was of the opinion that the available rangeland was not utilized to its maximum potential. The reasons for this were ranked to be inaccessibility (too far) and lack of infrastructures (e.g. roads), hilly and mountainous topography, fear of wild animals and unavailability of water.

4.3.3.3 Major constraints in livestock production

The major constraints of livestock production in the Borana rangelands are presented in Table 4.13. Pastoralists in the five peasant associations ranked recurrent drought as the primary constraint. According to the pastoralists, recurrent drought has aggravated other problems, such as feed and water shortage, disease prevalence and consequently, causing livestock loss, food insecurity, starvation and poverty. Feed and water resource scarcity in the rangeland were ranked the second and third, respectively, as the major constraints of livestock production. It was also stressed, in order, that animal diseases and predators and communal land ownership constrained livestock production, but not to such a great extent.

Table 4.12 Types of livestock feed supplements used by the Borana and feeding priority in the five peasant associations (respondents, n = 40).

		Feeding priority	
Feed supplement	**Respondents (%)**	**Animal type**	**Respondents (%)**
Salt	2.6	Milked cows/mature animals	2.6
Grass hay	2.6	Young stocks/calves	76.9
Leaves and branches	2.6	All	20.5
Salt & hay	5.3		
Salt, grass hay, leaves, branches & maize straw	26.6		
Grass hay, leaves, branches & maize straw	2.6		
Salt, grass & maize straw	5.3		
Salt, grass, leaves and branches	36.8		
Salt, grass hay, leaves, branches & food residue	2.6		
Grass, leaves and branches	7.9		
Salt and food residue	2.6		
Salt, grass and food residue	2.6		

4.3.4 Perceptions of pastoralists to rangeland deterioration

Interviews with pastoral elders indicated that all the respondents in the five peasant associations considered the rangeland condition to have declined over time. It was emphasized that the rate of decline was very fast in the recent few years (15-20 years period). All the respondents noted a decline in the abundance of highly palatable grass species, an increase in woody vegetation and bare ground. According to the respondents, these are the most important indicators of rangeland condition. Some of the respondents illustrated this situation by recalling the past, mentioning that the Borana rangeland was an open dense grassland and that horse riding over a long distance was once practiced as a traditional race of the herdsmen.

Table 4.13 Attributing constraint factors (mean rank) to livestock production as ranked by Borana elders in the five peasant association[1] (respondents, n = 128).

Number	Mean rank[2]	Attribute
1	1.90[a]	Recurrent drought
2	2.25[b]	Grazing and feed shortage
3	2.92[b]	Water scarcity
4	4.30[c]	Animal diseases
5	4.79[c]	Predators
6	4.84[c]	Communal land tenure

[1] = Attributes were listed and ranked from most important (1) to least important (6);
[2] = Entries accompanied by the same letter were not ranked differently (P>0.05) according to Friednman's test (Steel & Torrie 1980).

4.3.4.1 Attributing factors to rangeland deterioration

In this survey, rangeland deterioration is used synonymous with rangeland degradation. The term degradation is used to explain losses in the rangelands productivity, particularly, through bush encroachment, a decline in the grass productivity and soil erosion (Cossins & Upton 1988b).

Interviewed elders in the survey areas revealed that rangeland degradation has taken place in many semi-arid areas of the Borana. The main reasons suggested by the elders are presented in Table 4.14. All the respondents in the five peasant associations firstly ranked recurrent and prolonged drought as main contributing factor. The second and third ranks were given to increased livestock population and the use of grazing land for cultivation, respectively. The ban on the use of fire and development of water ponds were also emphasized as the fourth and fifth attributes that cause rangeland deterioration, respectively.

Table 4.14 Attributing factors (mean rank) to rangeland deterioration as ranked by Borana elders in the five peasant association[1] (respondents, n = 128).

Number	Mean rank[2]	Attribute
1	1.33^a	Recurrent drought
2	2.56^b	Increased human and livestock population
3	2.78^b	Increased use of land for cultivation
4	3.72^b	Ban of fire
5	4.61^c	Development of water ponds

[1] = Attributes were listed and ranked from most important (1) to least important (5);
[2] = Entries accompanied by the same letter were not ranked differently (P>0.05) according to Friednman's test (Steel & Torrie 1980).

4.3.4.2 Bush encroachment

Interviews of group elders in the five peasant associations indicated that there is a perceived problem of woody encroachment in the semi-arid Borana rangeland. Woody plant species considered by the respondents as the main encroachers are *Acacia brevispica*, *Commiphora africana*, *A. drepanolobium*, *A. tortilis* and *Euclea shimperi* (Figure 4.3). Some of the respondents remorsefully reported an increase in the populations of *A. brevispica* and *A. drepanolobium* as well as other non-woody, less palatable, unpalatable and poisonous plant species in some of the rangelands. Some of the plants were reported to be even fatal to the animals upon foraging. The two livestock species most detrimentally affected by bush encroachment are cattle and sheep (Figure

4.4). All elder group respondents suggested that increased woody vegetation reduces grass cover. In addition, some of the noxious woody plants are thorny and thicket forming so that grasses produced beneath their canopies are out of reach of livestock. The respondents' understandings of the factors that contribute to the invasion process of woody plants indicated that the ban of traditional burning by the government and recurrent drought were primarily emphasized (Table 4.15). Other causes, mentioned by the elders were overgrazing, expansion of cultivation and development of water ponds.

Table 4.15 Attributing factors (mean rank) to bush encroachment as ranked by Borana elders in the five peasant association[1] (respondents, n = 128).

Number	Mean rank[2]	Attribute
1	1.72[a]	Ban of fire
2	1.92[a]	Recurrent drought
3	3.22[b]	Increased human and livestock population
4	4.06[b]	Increased use of land for cultivation
5	4.06[b]	Development of water ponds

[1] = Attributes were listed and ranked from most important (1) to least important (5);
[2] = Entries accompanied by the same letter were not ranked differently (P>0.05) according to Friednman's test (Steel & Torrie 1980).

4.3.4.3 Forecasting the future and opinions about improvements

While forecasting the future prospects of what the rangeland condition will be, 50 % of the respondents in the five peasant associations noted that it is difficult to determine. Forty percent of the respondents agreed that if the situation progresses and no measure is taken to curb it, the rangeland will deteriorate steadily to a point that it may not be able to carry a good plant cover that can support the diverse livestock species to sustain their livelihood. Concerning the available options for improvement, all elder groups expressed their views that though the issue is very complex and intricate at the existing stage, burning is a possible option but there may be a problem of getting enough herbaceous fuel for the fire to be effective.

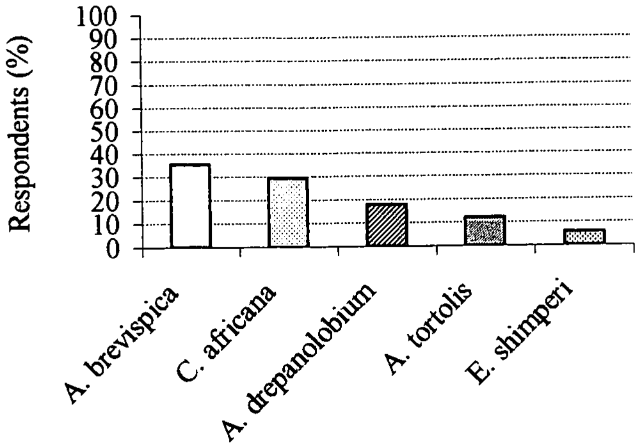


Figure 4.3 Important encroaching woody plants in the Borana rangelands as reported by the elders in the five peasant associations (respondents, n =128).

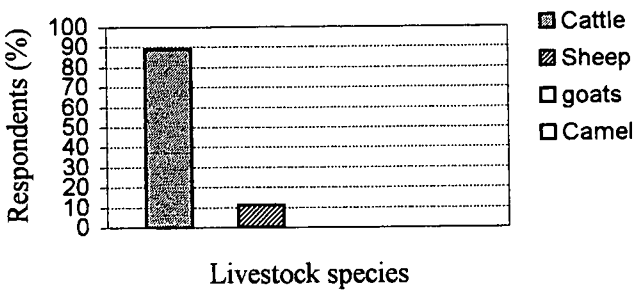


Figure 4.4 Livestock species most affected by bush encroachment.

4.4 DISCUSSION

4.4.1 Human population

Information on individual household population census in the pastoral areas of Borana rangelands is often scarce. Human population for the Borana zone during 1996 was estimated to be 1.5 million. Of these, the share for the pastoral low land areas was 33 %

(Alemayehu Reda 1998). The same report indicated that males accounted for 50.9 %, while female was 49.1 %, which may contrast to the present survey result.

The net rate of natural increase in the Borana population in 1972-1973 was in the order of 1.5 to 1.8 % per annum. When an annual migration from the Borana rangeland and urbanization rate of 5 % was stipulated, this figure was corrected to 1-1.3 % per year. At this rate of growth, the population doubling interval was estimated to be 55 years, a very low growth rate for semi-settled pastoralists such as the Borana (Meir 1987). In the late 1980's the estimate for a net population growth rate was 2.5 % (Coppock 1994) and this was found to be consistent with that of other semi-settled pastoral groups (Meir 1987), having a population doubling time of 28 years. In the western part of Borana plateau, it was reported in 1988 that human population doubled from 2.61 x 10^{-3} to 5.2 x 10^{-2} million over 15 years (Coppock 1994). This means a population growth rate closer to 5 % per annum. It seems reasonable to hypothesize from these reports and the present survey result of household size that human population in the Borana pastoral areas is increasing.

Results on male and female educational status in the Borana pastoral areas are similar to the report of Almayehu Reda (1998). Overall figures in this regard indicated that the number of pastoral children enrolled into school was very low. One of the reasons is the low distribution of schools in the pastoral areas.

4.4.2 Crop and Livestock production

4.4.2.1 Cultivation

It is evident from the present survey that all of the selected pastoral households were involved in both crop and livestock production. A few years ago, it was reported that the involvement of Borana pastoralists in crop production was limited (Holden 1989). The same report suggested an estimate of 37 % of Borana pastoralists to be involved in cultivation. Apparently, the pastoralists learnt rapidly that crops are more appropriate for long or short term rainy seasons and adopted new methods such as animal traction (Hodgson 1990). Among the peasant association selected for this survey, Did Yabello and Melbana were reported as the focal point for the introduction of cultivation into the Borana rangelands.

The widespread potential of cultivation in the Borana plateau was first reported by Agrotec/crg/sedes associates (1974) where it was stated that "one third of the breeders practice cultivation, but only on a very small scale". However, this estimate was biased on the high side since their surveys focused on households residing near the roads and towns. Even today these areas remain the dominant center for cultivation due to favourable local environments and proximity to influences of migrant outsiders (highland farmers). A drought in the early 1970s was cited as a factor in the spread of farming on the Borana plateau (Agrotec/crg/sedes associates 1974).

There are conflicting reports as to whether cultivation has been historically an important aspect of the economy of the traditional Borana. On the one hand, Asmarom (1973) reported that the Borana during the early 1960s had only negative feeling towards farmers and farming, which implied that the Borana would never engage in cultivation unless faced with no other alternatives. In contrast, Negussie (1984) noted that cultivation has occurred in the Borana plateau for over 40 years and that farmed acreage expanded after a drought in the mid 1970s.

In the open discussion of the current survey, most household respondents stressed that livestock production is still the backbone of their economy while crop farming is playing additional roles. This means that farming is an economic diversification. The ecological crisis made it difficult for the Borana pastoralists to rely on livestock for food alone.

Local informants have speculated that crop farming can be an indication of wealth status and is often associated with poor pastoralists. Drought can permanently turn poor pastoralists into crop farmers by the unfortunate depletion of their smaller herds, and in fact, can still turn wealthier pastoralists into temporary or part-time crop farmers by reducing milk production and killing milk cows and their replacements. In such cases, households would be forced to cultivate for a few years until herds recover their milk production potential.

In this study, through personal observation it was witnessed that crop farming has spread throughout the Borana rangeland. Yet, because of unreliable rainfall, growing of crops has not been successful. Successful harvests were expected as " in one out of three years" (Oba 1998). The implication of this is that with expectations that the rain will come during the rainy season, the pastoral land is cultivated and when the rain fails, it is left without vegetation cover, exposing the soil to repeated wind and raindrop erosion.

Whereas growing crops is a response to food security, crop farming transferred parts of the grazing lands to private use and this can come in conflict with livestock grazing. Particularly, farming in Borana has taken up bottomlands where moisture conditions are favourable. The bottomlands are traditionally used as a calf grazing reserve. Therefore, loss of bottom lands to cropping makes livestock vulnerable during drought. Moreover, in Borana, it is a common experience of non-selectively cultivating on some of the nutrient poor rangeland soil. Thus, in the case of failures due to unreliable rainfall, frequent abandoning of such lands can quicken their loss of fertility and potential through repeated erosion.

4.4.2.2 Livestock production, holdings and trends

In this study, results on the percentage of respondents involved in rearing individual livestock species showed in descending order the importance of cattle, goats, sheep and camels. Concerning livestock holding per household, the order remained the same except that the number of sheep was greater than camels. In both cases, similar reports were made in the previous survey (Alemayehu Reda 1998). The current survey also investigated a clear indication of a decreasing trend in individual livestock holding per household except camels, that shows an upward trend. The pattern of household holdings of cattle and goats followed the pattern of rangeland degradation. Cattle household holding was greatest in relatively better grazing sites (Dubuluk and Melbana), whereas goats had the greatest population in highly degraded areas (Did Yabello).

In general, the Borana are predominantly cattle pastoralists, but also keep camels and small ruminants. During 1996/97, cattle represented 73 % of the livestock population and goats-15 %, sheep 6.5 %, and camel 4 % (Alemayehu Reda 1998). Camel population showed a large change over time in some of the Borana pastoral areas (personal communication of the pastoralists). Coppock (1994) estimated only 1 to 2 camels per village from data collected in 1985, whereas in the current survey, this number was owned by individual households of the selected peasant associations.

Despite a high level of risk due to endemic small ruminant diseases, respondents in the five peasant association expressed an increasing interest to raise more small ruminants. The growing interest in camel keeping and small ruminant production can be explained as components of an emergency strategy to achieve food security. In a few clans of the Borana society, however, the rearing of camels is still not allowed. The small ruminant production may also help to avoid or at least minimize the need to sell cattle, which is considered as the most important means of wealth storage for Borana (Coppock 1992).

4.4.3 Cattle-rangeland management practices

4.4.3.1 Purpose of rearing cattle

Cattle are undoubtedly the most important livestock species in the Borana system. Although, today cow milk is not the main item in the diet of the Borana as it was in the past, keeping cattle for milk production continues to be the primary reason. Most elder respondents expressed memories of a time, decades ago, when milk was produced in such abundance that the surplus produced over the human need was used continuously to feed young calves. The second important contribution of cattle as ranked by the pastoralsits, was the provision of income from live sales. Male cattle are sold more regularly and provide the major income while other animals are marketed at the time of emergency needs, particularly during the drought period. Thirdly, cattle occasionally provide some meat and blood for consumption. The importance of cattle as animal traction was introduced recently following the expansion of cultivation. In addition to what are mentioned, Borana pastoralists rear cattle for breeding and restoring wealth and prestige. The Borana usually keep a high number of female animals. Cows and a few bulls are reserved to produce offspring for continuous production and accumulation of wealth. Cattle are productive capital and a relatively durable form of saving, which can be readily converted into cash at the time of need.

Like other pastoralists in Africa, the Borana also keep cattle for prestige as well as cultural purposes. The social and cultural roles the cattle play include; the price to be paid in the form of cattle for some social and cultural services (e.g. bride). Blaxter (1994) pointed out that to be without livestock is to deprive African pastoralists of a social and cultural identity.

The next most important animals that produce food, generate income and provide social values are the small ruminants. Keeping large flocks of small ruminants is a recent venture in the Borana pastoralists (Alemayehu Mengistu 1998). Small ruminants comprised about 7.4 % of the TLUs on the Borana plateau (Cossins & Upton 1987). As ranked by the pastoralists, the current survey showed the equal importance of sheep as source of meat, income generation and prestige. Goats were ranked first as a source of milk, which support the report of Alemayehu Mengistu (1998) that noted an increasing tendency of the pastoralsits to keep goats for their milk. Goat's milk is accepted as an important food for children in the dry season and for adults in times of shortage (Alemayehu Mengistu 1998).

Camels are another important livestock species next to small ruminants. Based on the interviews of household respondents, the role of camels as a source of milk and transportation purposes were both ranked first. Camels play an equivalent role in income generation and as a source of meat. Prestige and social values of camels are not that much common in the Borana system. All the household respondents expressed their views in the growing interest by the Borana pastoralsits of rearing camels. Introducing camels reflect the purposeful strategy by many Borana of incorporating camels to diversify their holdings of large livestock (Solomon Desta 2000). The Borana keep camels for their high milk yield and longer lactation period compared to cattle. The recent increase in camels is part of a household strategy to improve food security (Solomon Desta 1999).

4.4.3.2 Livestock and resource management

Most of the feed that the Borana livestock depend on are derived from natural grassland, which comprised of natural grasses and browses. This is why the ultimate goals of traditional Borana management is geared towards the management of grasslands. Various resource management practices have been employed by the Borana society. To increase productivity of their herds, in average rainfall years, households engage in practices such as rotating both "Forra" and "Warra" herds to high quality rangeland. Movement is an important management strategy for drought survival in African pastoral systems (Solomon Desta 2000). In drought situations, the Borana become more mobile, and often move outside the core of the Borana territory. Moving livestock minimizes livestock pressure, as it tends to distribute the animal over a wide range of resources, thereby reducing the concentration of animals over limited resources. Deferred grazing was also noted in the Borana society as one way of improving an overgrazed area by allowing for rest periods in a succession of growing seasons (Cossins & Upton 1988b).

With respect to feed conservation mechanism, household respondents in this study pointed out that establishment of special enclosure (local name-"kallo") is one of the popular conservation practice. This is simply standing hay surrounded by thorny bush fencing. The fencing of "kallo" requires high labour and is done jointly by the villagers. The "kallo" is mostly used in the dry seasons for feeding immature stock and lactating cows and thereby reducing grazing pressure and feed shortage during the grazing season (Figure 4.5a and b).

4.4.3.2.1 Burning

Household respondents expressed their feeling that even today, burning can be a good remedy for bush encroachment, adding that, in the absence of burning, the long term trend will probably be for the woody population to increase further. Interviewed household respondents indicated that they used to burn grazing sites once every three years to control bush, ticks and improve the nutritional quality and accessibility of grasses. These benefits from burning are well known in other pastoral systems of Africa (Hobbs & Spowart 1984; Coppock & Delting 1986). In the view of the household respondents, cattle grazing, drought and absence of fire were mostly responsible for bush encroachment. Government policy restricting fire was considered by most respondents as a major management constraint. A few of the household respondents, however, argued that government policy restricting fire was lifted some years ago. Supporting this, Coppock (1994) noted that the policy prohibiting burning was lifted in 1990. The same report pointed out that this was done because of the perception by local administrators that bush encroachment was becoming a significant threat to the production system. From these two arguments, it can be understood that the problem lies in the dissemination of the information by the local agricultural offices throughout the Borana.

Today, reserving sites for burning may be more difficult than in the past because of forage demand from a large cattle population. Yet, it is expected that the pastoralists can recommend sites for burning and local agricultural offices and non-governmental

a

b

Figure 4.5 Views on the Borana traditional grazing reserves ("kallo"): Did Harra (a) and Melbana (b).

organizations provide regulation through site evaluation, approval of methods and by helping organize the work. The household respondents expressed their interest eagerly to work on bush control with the mentioned bodies. They also recommended that burning should now be site specific because some of the grazing areas at this stage are more in need of rehabilitation (Figure 4.6, Figure 4.7a and b) of the herbaceous layer than immediate burning.

4.4.3.2.2 Mechanical bush clearing

In a few of the survey areas, it was visually observed that bush clearing activities were carried out. This is particularly on small parts of grazing areas or on small protected grazing enclosures. Household respondents expressed their views that mechanical control by cutting purely through human labour is expensive, time consuming and largely ineffective. Thus, most of the respondents showed less interest in engaging in such activities, even where they are paid or receive food-for-work aid. The lack of interest in labour intensive methods for bush clearing among the Borana may reflect time constraints as well as the liable land tenure; *i.e.* if a location becomes unusable because of bush encroachment, the people can probably still move elsewhere (Coppock 1994). Options, to move are probably declining these days, however, and this may stimulate interest in bush control among the Borana.

While the general effects of pastoralists on woody plants through wood collection may be locally significant around individual encampment, this activity is not important as a measure of bush control in a regional context (Billé & Assefa 1983). This agrees with the views of the respondents in the current survey who indicated that routine harvest of wood for cooking and construction had little effect on woody plant populations overall.

Figure 4.6 Examples of communal grazing areas suggested by the Borana elders for the possibility of improvement through burning.

a

b

Figure 4.7 Examples of communal grazing areas recommended by the Borana elders to be in need of more of rehabilitation before immediate burning: Sites are Moyatte (a) and Melbana (b).

4.4.3.3 Major problems of livestock production

While discussing this aspect, particular emphasis was given to the type of livestock species that are most relevant to the livelihood of Borana. Some of the most important problems are presented in Table 4.13. Drought (both man made and natural) is the sole cause that particularly aggravates feed shortage, animal diseases and water shortage. Further investigation is, of course, needed to identify which of these two types of drought is more critical than the other. Feed limitation is also exacerbated by a shortage of seasonal rain, overgrazing and range deterioration. In addition, labour scarcity, lack of adequate feed supplements, land alienation, bush encroachment, insecurity, poverty and illiteracy were reported to be the bottlenecks to livestock production (Alemayehu Mengistu 1998).

Some of the possible intervention concepts that can be suggested towards combating the afore mentioned constraints may include: (1) encourage monitoring of rangeland resources and establish a regular monitoring scheme of the rangeland condition and trends; (2) encourage the implementation of regular monitoring of livestock production and management problems. (3) strengthen the traditional widespread practice of feed conservation in the form of enclosures and encourage fodder banks through hay making and other forms of feed conservation; (4) set up a regular rangeland management schemes. All these, however, require policy development and community participation.

4.4.4 Indigenous ecological knowledge and perceptions of pastoralists

In all peasant association of this survey, elders reported bitterly that changes in the composition of herbaceous layer are greater than those of the woody cover. The decline in perennial grasses and an increase in unpalatable forbs and annual grass cover was a typical indicator of the change in the composition of the herbaceous layer. It was also stressed that the dynamics of the herbaceous layer is taken as the first criteria in making rangeland assessments. It is, therefore, important for the ecologists to understand the perceptions of pastoralists when interpreting trends in land cover (Oba & Kotile 2001).

Borana pastoralists have been using their indigenous ecological knowledge to manage their rangelands that reflects both the process of land degradation and land suitability (Oba & Kotile 2001). The Borana, like other pastoralists in east Africa, categorized landscapes not only in terms of season of use (Oba *et al.* 2000), but also in terms of grazing capacity (Oba & Kotile 2001). Moreover, the pastoralists identify the grazing land either as camel country, small stock country or cattle country relative to the dominant soils and associated vegetation types.

Borana elders have most importantly suggested that the rangelands are periodically perturbed by episodic events of droughts that result in mass livestock mortality and rangeland deterioration. The association of drought (man made or natural) with rangeland deterioration can be explained in such a way that pastoralsits have had to utilize the dry season grazing areas around permanent water points (deep wells) even during the rainy seasons. Such continuous grazing pressure, therefore, led to serious overgrazing, resulting in rangeland degradation.

Secondly, Borana elders suggested that the human and livestock demographic growth was contributing to rangeland degradation. The rangelands of southern Ethiopia until four decades ago were considered as the finest in east Africa (Agrotec.crg/sedes associates 1974). In the last few decades, however, it has been observed that the Borana pastoral production was on the decline. Animal and human population are growing at an increasing rate, while the rangeland resource on which they depend is diminishing both in terms of availability and productivity. The increase in human population necessitates the increase in livestock population.

Other causes of rangeland deterioration are presently associated with recent (e.g. cultivation) and historical land alienation, government policy prohibiting fire to control bush and development of water ponds. According to the respondents, land alienation began following political perturbations caused by the Anglo-Italian war (1931-1936) and subsequent ethnic conflicts, which displaced the Borana from over 60 percent of their traditional grazing lands. The displaced population continued to live and rear livestock on the remaining grazing territory.

Apart from the pressure caused by water development, a huge portion of Borana rangeland was alienated in the past regimes for the purpose of demonstration ranches. Some of the elders expressed their views that such land alienation, not only reduced key grazing lands of the Borana, but also fragmented the grazing lands and blocked the movements of the pastoralists with their livestock from one grazing area to another. The elder respondents were, however, convinced that condition and productivity of rangelands in the ranch (Figure 4.8) were far better than the communal grazing land. From the land alienation perspectives, internal factors that exhibited a substantial contribution to rangeland deterioration are encroachment of farmlands and establishment of range enclosures (Boku 2000). These result in increased grazing pressure on the remaining land regardless of the presumed livestock and human population growth in relative terms.

Figure 4.8 Partial views of the rangeland at Did Tyura ranch (government owned).

Elder respondents have a general awareness that woody vegetation reduces grass cover (Figure 4.9a and 4.9b) through increased competition for available water and nutrients and reducing the light reaching the grass layer. In addition, some woody plants are commonly thorny and thicket forming (e.g. *A. drepanolobium*) so that grasses produced beneath their canopies are out of the reach of livestock. This, therefore, may reduce the carrying capacity of the rangeland. However, it is noteworthy that some of woody plants provide leaves and podes for browsers (goats/camels) during the dry period to a large extent and to sheep and cattle to a lesser extent.

a

b

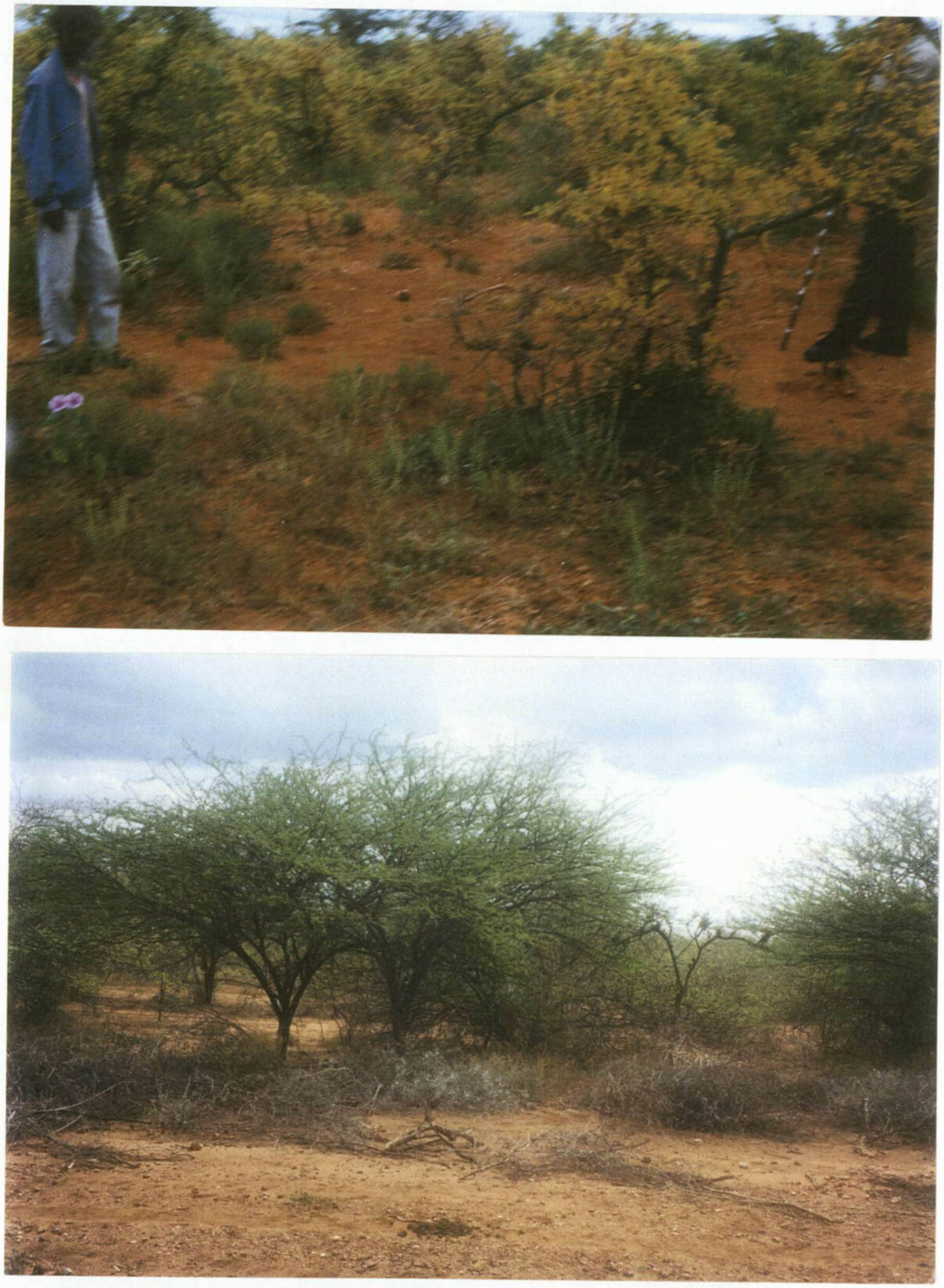


Figure 4.9 Examples of heavily woody encroached communal grazing areas in Borana. Sites: Melbana (a) and Did Yabello (b).

4.5 CONCLUSION

The following conclusions can be drawn from this study:

(i) Both livestock holdings and productivity (except camels) have shown a declining trend.

(ii) Rangeland degradation in Borana pastoral systems is related to bush encroachment and the causes are many and intricate, but the most important ones are drought, overgrazing and grazing land alienation (e.g cultivation). With regard to drought, further research and surveys must be carried out to distinguish between climatic and man-made droughts (Snyman 1998).

(iii) The type of land encroached by cultivation seems to be a greater threat to both livestock production and the traditional resource management (Solomon Desta 1999). Cultivation is taking over the valley bottoms, which have a higher soil water content and fertility. These areas were traditionally set aside for grazing by milking cows and calves during stress period (Coppock 1994). They are classified by the pastoralists as key grazing resource areas (Scoones 1990), which are vital to enable use of a vast marginal area in which without these areas the smooth functioning of the whole system would be disrupted. The competition between cultivation and livestock production for these key resource areas is high. Many elder pastoralists in the current survey are worried about the expansion of cultivation into the rangelands.

(iv) Borana pastoralists are knowledgeable of their resources and rich in knowledge of indigenous rangeland management practices. For centuries the pastoralists have been using their indigenous ecological knowledge to manage rangelands that reflects knowledge of both the process of land degradation and landscape suitability. That is the reason why the rangeland remained the finest in pastoral Africa until a few decades ago. This aspect of the pastoralists indigenous ecological knowledge is superior to the approaches used by ecologists for planning grazing management.

(v) Rangeland development programs in the Borana rangelands failed in the past due to unworkable policies. Development in the lowlands seldom considered the consequences of the interventions. Therefore, most important of all, in future, development agencies and government must work firmly with the communities on the development agendas and empower the communities to make their own decisions on resource allocation.

(vi) Educated Borana in the pastoral areas is very low. Education of the community on farming, livestock marketing *etc*. on the one hand and educating the young generation on the other will have short and long term positive consequences. Therefore, any development intervention must also give priority attention to the development of schools and educate the pastoral people.

CHAPTER 5

BOTANICAL COMPOSITION OF GRASSES IN RELATION TO LAND USE AND DISTANCE FROM WATERING POINTS

5.1 INTRODUCTION

In extensive communal arid and semi-arid rangelands of Ethiopia, herbaceous plants, notably grasses, are the major food source of grazers. Such rangelands, characterized by intensive use of a variety of resources can offer an opportunity to study changes in species composition and response of grasses to prolonged and intensive disturbance.

Grass species composition as indicator of rangeland condition is important, as species may vary significantly in their acceptability to grazing herbivores, not only due to differences in palatability, but also due to phenological differences (e.g. rhizomatous, stoloniferous or tall tufted grasses) (Smit 1994). With only a few results available on the health or condition of the grass layer of the semi-arid Borana rangeland (Ayanna & Baars 2000), the emphasis in this study was on the estimation of dry matter yield and direct measurement of the species composition. No previous studies were conducted in this rangeland area on the direct measurement of species composition changes from frequency distribution.

The objectives of this study were to investigate:

(i) the distribution and composition of grasses in three land use systems (communal, government ranch and traditional grazing reserve),

(ii) the distribution and composition of grasses along a distance gradient from water sources and,

(iii) the basal cover and occurrence of bare patches under the various land use systems and along a distance gradient from water sources.

5.2 PROCEDURE

5.2.1 Site selection

Four communal grazing areas, one government ranch (Did Tyura) and four traditional grazing reserves were selected. The four communal grazing areas selected for this study were Did-Yabello in the north, Did-Hara in the east, Dubuluk in the center and Melbana in the southwest of the Borana rangeland (Figure 3.1). These areas varied in historical intensity of pastoral use. Did-Yabello for example is the place adjacent to the government ranch and forms the border area to other pastoral groups outside Borana (Gabra and Guji). This area also showed a recent heavy expansion of cultivation that resulted in the reduction of available land for grazing. Did-Harra represented a grazing area with a relatively recent pastoral use due to immigration in response to water pond development and rehabilitation. The Dubuluk and Melbana sites represented deep well areas that had been used by the pastoralists for centuries but with different impacts. The number and capacity of deep wells in Melbana is more than those found in Dubuluk.

Two watering points were selected for each communal grazing area and the government ranch. Each traditional grazing reserve site was selected adjacent to each communal grazing area. The government ranch (Did-Tyura) is located in the northern part adjacent to Did-Yabello. Until recently, there are no reports and/or findings, which elaborated how much grazing occurred on the communal land, government ranch and the traditional grazing reserves. Therefore, the general assumption made in this study was that the grazing pressure in the communal land was greater than the government ranch and the traditional grazing reserve. Criteria for the selection of the grazing areas and watering points are presented in section 3.2.1. Establishment of the main transects, sub-transects and plots along a distance gradient from water source (near, middle and far) and plots in the traditional grazing reserves are discussed in section 3.2.1.1.

5.2.2 Data collection

The species composition of the grass layer was estimated in each selected communal grazing area, government ranch and traditional grazing reserve within a 50 m x 20 m plot, using frequency of occurrence established with the wheel point apparatus (Tidmarsh & Havenga 1955). Surveys were carried out late in the long rainy (growing) season of the year 2001 (April-May). The nearest plant and basal strikes were recorded from 300 point observations per plot. This sample size has been shown to be adequate for detailed scientific studies (Hardy & Walker 1991). When the distance of the nearest plant was further than 400 mm from the marked wheel point, it was recorded as bare ground. Point observations were spaced by 3 m intervals and records were made over the length of the plot, moving in straight parallel lines and with approximately 1 m distance among them.

5.2.3 Species identification and classification

Identification of most grasses was done in the field. For the remaining species, plants with a full inflorescens and other vegetative parts were collected and identified at the National Herbarium of the Addis Ababa University or Alemaya University. Classification of grasses was based on the succession theory described by Dyksterhuis (1949) and on the ecological information for the arid to semi-arid regions of South Africa (Foran 1976; Tainton *et al.* 1980; Vorster 1982). Accordingly, the plants were grouped into (i) highly desirable species: likely to decrease with heavy grazing (decreasers), (ii) desirable species: likely to increase with moderate heavy grazing (increaser IIa), and (iii) less desirable species: likely to increase with severe/extreme severe over grazing (increaser IIb and IIc). In addition, plants were grouped based on their life history as annuals and perennials. The grouping of plants was also supported by the opinions of herdsmen.

5.2.4 Statistical analysis

Data were analyzed via a two-way ANOVA to test differences in the intensity of communal land use (viz. Did Yabello, Did Harra, Dubuluk and Melbana) and in relation to distance from water source. Because there were no significant interaction terms between the land uses and distance gradient from water, significant differences detected through ANOVA were investigated further by pair wise comparison of means using Duncan's multiple range test. The government ranch was excluded to study the distance gradient effect because the number of watering points taken in the ranch was not adequate to study the gradient effect. A simple t-test was employed to assess the significance of difference between data variables of the three land use systems viz. the communal land, the government ranch and the traditional grazing reserves. In this case, data from the three distances (near, middle and far) were pooled for both the communal and the ranch sites separately. In this case, the number of sampling sites in the communal land was greater than the government ranch and the traditional grazing reserve. This was to ensure adequate sampling that represented the vast areas of the different grazing/browsing sites located within the communal land. For data that did not require analysis, simple descriptive statistics were employed where appropriate.

5.3 RESULTS

A total of 49 grass species were identified, out of which 32 were perennials. In addition, of these total grass species, 15 were classified as highly desirable, 10 - desirable and 24 as less desirable species (Table 5.1).

5.3.1 Life forms of grasses in relation to land use and distance gradient from water

The results of the proportion of life forms (annuals v perennials) of the grass layer among the land use systems indicated that the communal land had higher and lower percentages of annuals ($P<0.05$) and perennials ($P<0.05$), respectively, than the government ranch and traditional grazing reserve (Figure 5.1a and b). The difference in life form between the government ranch and traditional grazing reserve was not statistically significant (P>0.05). Both life forms did not show marked difference (P>0.05) between the grazing sites in the communal grazing area (Figure 5.1a and b). For the distance gradient around the water source, prominent differences were not obtained, but there was an indication of increased and decreased percentages of annuals and perennials, respectively, in moving away from the water source (Figure 5.2a and b). Examination on the relative abundance of life forms (Figure 5.3 and 5.4) indicated that annuals were slightly more abundant than perennials, irrespective of the land use, grazing sites and distance from the water source.

5.3.2 Desirability of grasses in relation to land use and distance gradient from water

The analysis of the grass layer desirability classes indicated that the proportion of highly desirable (Figure 5.5a) and desirable species (Figure 5.5b) differed (P<0.05) among the land use systems. In contrast, the proportion of less desirable species (Figure 5.5c) did not differ significantly (P>0.05) between the land use systems. The government ranch had the largest proportion of highly desirable species, followed by the traditional grazing reserve and lastly the communal area. For the desirable species, the communal area had the largest proportion, followed by the government ranch and lastly the traditional grazing reserve.

Though not significantly (P>0.05) different the less desirable species on the communal land was 55 % and 24 % higher than that of the government ranch and traditional grazing reserve sites, respectively. For the grazing sites within the communal area, significant differences (P<0.05) were noted in the proportion of desirable species (Figure 5.5b), with the greatest value being obtained in Did Yabello and the lowest in Dubuluk site. Marked variations were not found (P>0.05) among the grazing sites in the proportion of highly desirable (Figure 5.5a) and less desirable species (Figure 5.5c).

Table 5.1 Life forms, palatability and ecological grouping of grasses species of the Borana rangeland, Ethiopia.

			Distribution[3]					
			Distance from water source (communal sites only)			Land use systems		
	Life forms & (Palatability)	Ecological group[2]	Near	Middle	Far	Communal	Ranch	Traditional Grazing reserve
1. Andropogon canaliculatus, Schumacher	P (HP)	De					P	
2. Oropetium capense Stapf	A (LP)	Inc IIb	P	+	P	P		P
3. Aristida adoensis, Hochst.	A (UP)	Inc II c			P	P	P	P
4. Aristida adscensionis, L.	A (LP)	Inc II c	P	P	+	P	P	P
5. Aristida congesta	P (LP)	Inc II c	P		+	+		
6. Bothrichloa insculpta(Hochst.) A. Camus	P (IP)	Inc IIa	P	+	P	P		
7. Erichloa fatmensis (Hochst Stead.) A. Camus	A (LP)	Inc IIb	P		P	P		
8. Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	P (HP)	De	P	+	P	P		
9. Bothriochloa radicans, A. camus	P (UP)	Inc IIb	P	P	P	P	P	P
10. Cenchrus ciliaris, L.	P (HP)	De	P	P	P	C	P	P
11. Chloris myriostachya, Horst.	P (IP)	Inc IIa	P	P	P	P	P	P
12. Chrysopogon aucheri, (Boss) Stapf.	P (HP)	De	C	C	C	C	D	D
13. Cynodon dactylon, (L) pers.	P (IP)	Inc IIa	P	C	P	P		P
14. Dactyloctenium aegyptium, (L.) Pers	A (LP)	Inc IIc	P	P	P	P	P	P
15. Digitaria erantha	P (HP)	De		+		+		
16. Digitaria milanjiana, (Rendle) Stapf.	P (HP)	De	P	P	P	P	P	C
17. Elusine jaegeri, pilger	A (LP)	Inc IIb	P	P	P	P	P	
18. Elyonurus muticus	P (UP)	Inc IIb				+	P	
19. Eragrostis senni, Chiov	A (LP)	Inc IIc	+	P	P	P	P	P
20. Sporobulus nervosus Hochst.	A (LP)	Inc IIb	C	D	C	C	P	P
21. Eragrostis cilianensis Link exlutati.	A (LP)	Inc IIb	P	P	+	P	+	P
22. Eustachys paspaloides, (Vahl.) Lanza Mattei	P (HP)	De						

[1] A = annual, P = Perennial; HP - Highly palatable, IP = Intermediate palatable, LP = Less palatable, UP = Unpalatable;

[2] De = Decreaser, Inc IIa = Increaser IIa, Inc IIb = Increaser IIb, Inc IIc = Increaser IIc (for definitions see section 3.5.2.4);

[3] D= Dominant (>15%), C = Common (>5-15%), P = Present (<5%), + = Present, but ≤ 0.05%.

Table 5.1 Life forms, palatability and ecological grouping of grasses species of the Borana rangeland, Ethiopia.

			Distribution[3]					
			Distance from water source (communal sites only)			Land use systems		
	Life forms & (Palatability)	Ecological group[2]	Near	Middle	Far	Communal	Ranch	Traditional Grazing reserve
1. Andropogon canaliculatus, Schumacher	P (HP)	De					P	
2. Oropetium capense Stapf	A (LP)	Inc IIb	P	+	P	P		P
3. Aristida adoensis, Hochst.	A (UP)	Inc II c			P	P	P	P
4. Aristida adscensionis, L.	A (LP)	Inc II c	P	P	+	P	P	P
5. Aristida congesta	P (LP)	Inc II c	P		+	+		
6. Bothrichloa insculpta(Hochst.) A. Camus	P (IP)	Inc IIa	P	+	P	P		
7. Erichloa fatmensis (Hochst Stead.) A. Camus	A (LP)	Inc IIb	P		P	P		
8. Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	P (HP)	De	P	+	P	P		
9. Bothriochloa radicans, A. camus	P (UP)	Inc IIb	P	P	P	P	P	P
10. Cenchrus ciliaris, L.	P (HP)	De	P	P	P	C	P	P
11. Chloris myriostachya, Horst.	P (IP)	Inc IIa	P	P	P	P	P	P
12. Chrysopogon aucheri, (Boss) Stapf.	P (HP)	De	C	C	C	C	D	D
13. Cynodon dactylon, (L) pers.	P (IP)	Inc IIa	P	C	P	P		P
14. Dactyloctenium aegyptium, (L.) Pers	A (LP)	Inc IIc	P	P	P	P	P	P
15. Digitaria erantha	P (HP)	De		+		+		
16. Digitaria milanjiana, (Rendle) Stapf.	P (HP)	De	P	P	P	P	P	C
17. Elusine jaegeri, pilger	A (LP)	Inc IIb	P	P	P	P	P	
18. Elyonurus muticus	P (UP)	Inc IIb				+	P	
19. Eragrostis senni, Chiov	A (LP)	Inc IIc	+	P	P	P	P	P
20. Sporobulus nervosus Hochst.	A (LP)	Inc IIb	C	D	C	C	P	P
21. Eragrostis cilianensis Link exlutati.	A (LP)	Inc IIb	P	P	+	P	+	P
22. Eustachys paspaloides, (Vahl.) Lanza Mattei	P (HP)	De						

[1] A = annual, P = Perennial; HP - Highly palatable, IP = Intermediate palatable, LP = Less palatable, UP = Unpalatable;

[2] De = Decreaser, Inc IIa = Increaser IIa, Inc IIb = Increaser IIb, Inc IIc = Increaser IIc (for definitions see section 3.5.2.4);

[3] D= Dominant (>15%), C = Common (>5-15%), P = Present (<5%), + = Present, but ≤ 0.05%.

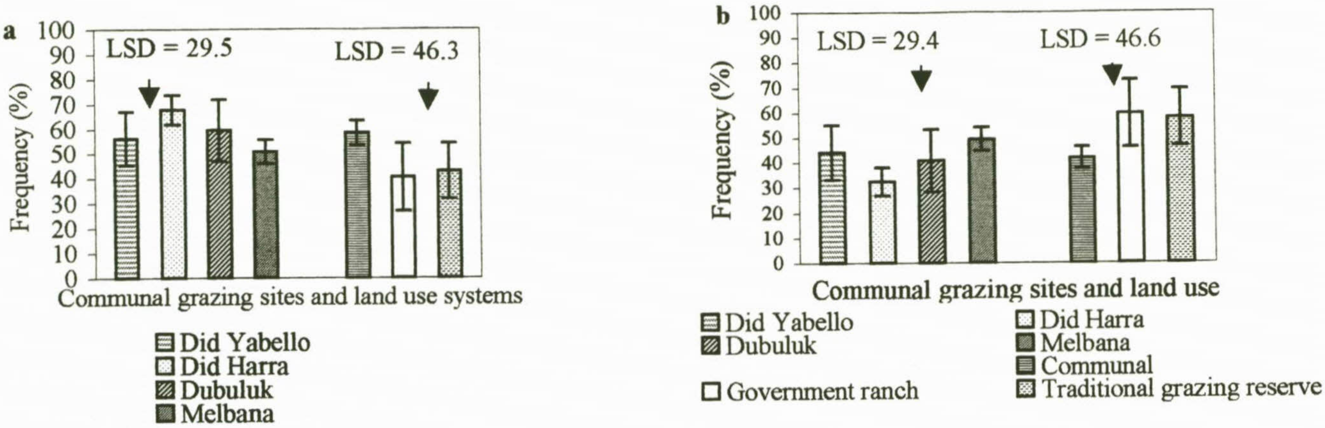


Figure 5.1 Grass species composition (%) based on frequency of occurrence of annuals (a) and perennials (b) in four communal grazing sites (n = 6) and three land use systems. Least significant differences (LSD) were calculated at the 5 % level. Bars denote the SE.

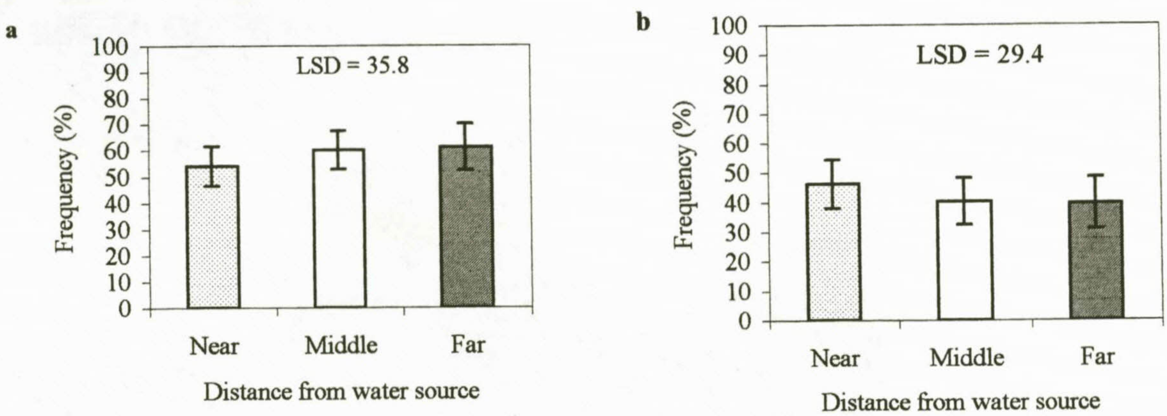


Figure 5.2 Grass species composition (%) based on frequency of occurrence of annuals (a) and perennials (b) in a distance gradient from water source. Least significant differences (LSD) were calculated at the 5 % level (n = 8). Bars denote the SE.

Considering the distance gradients from water, the proportion of highly desirable species (Figure 5.6a) was higher on near than the middle and far sites, but the difference was not statistically significant (P>0.05). Similarly, the proportion of desirable species (Figure

5.6b) was higher (P>0.05) at the middle than the near and far sites. For the less desirable species (Figure 5.6c), a marked variation did not exist (P>0.05), but the far site had the greatest proportion, followed by the middle and lastly the near site.

In terms of the relative abundance of the classes (Figure 5.7 and 5.8), less desirable species were the most abundant, followed by highly desirable species and lastly desirable species, irrespective of the distance from the water source and communal grazing sites. For the land use systems, the result is similar except that the highly desirable species were slightly more abundant than less desirable species under the government ranch.

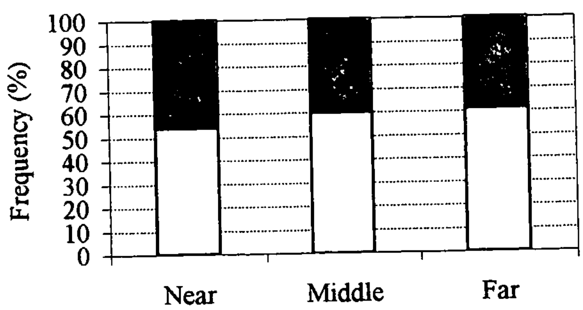


Figure 5.3 Proportional contribution of annual and perennial grasses along the
□ Annuals ■ Perennials n water.

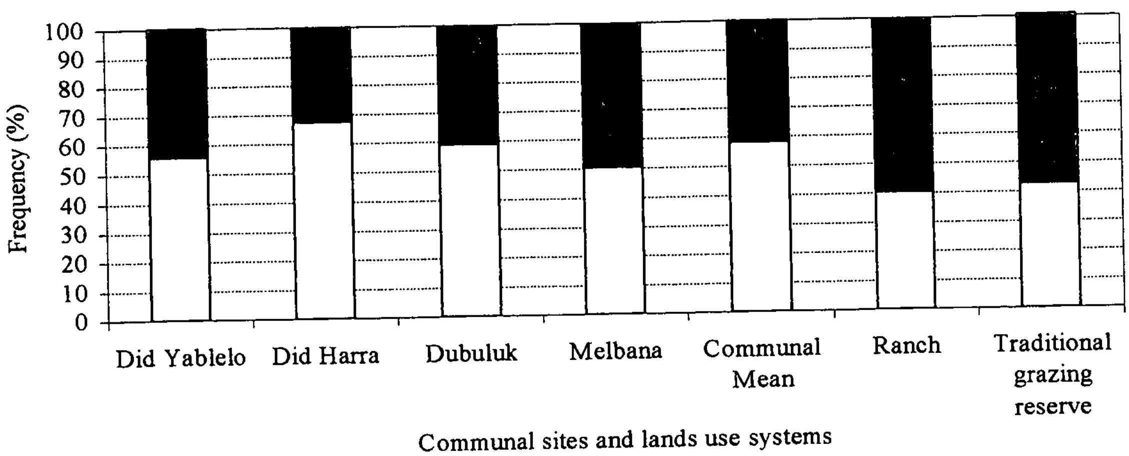


Figure 5.4 Proportional contribution of annual and perennial grasses in four communal grazing sites and three land use systems. □ Annuals ■ Perennials

5.3.3 Composition of common grass species

Common species in this context is defined as those species that were recorded in many of the study sites under each land use system and distance gradient from water source. Therefore, of the total grass species identified, 19 species were classified as commonly distributed over the sites of the land use systems and distance gradient from water source (Table 5.2). Of these, 5 species were highly desirable (*Digitaria milanjiana, Panicum coloratum, P. maximum, P. turgidum* and *Themeda triandra*). *Digitaria milanjiana* was present under the three land use systems (communal 2.8 %, ranch 1.9 % and traditional grazing reserve 5.8 %) and the three distances (near 2.3 %, middle 3.6 % and far 2.0 %). Similarly, *P. maximum* was present on the communal (2.0 %), ranch (0.5 %), traditional grazing reserve (2.0 %), near (2.1 %), middle (2.2 %) and far (1.9 %). For the land use systems the proportion of *T. triandra* was greatest under the ranch (12.19 %) and comprised less than 1 % under both the communal and traditional grazing reserve sites. Along the distance gradient from the water source, *T. triandra* made up less than 1 % in the three distance gradients from the water source. The distribution of *P. coloratum* was restricted to the communal, ranch, near and far sites but in all the cases the proportion was less than 1 %. With low percentage of occurrence (<1 %), *P. turgidum* was present under the three land use systems and in the far distance from water source.

Commonly occurring desirable species included *Cynodon dactylon, Heteropogon contortus, Lintona nutans,* and *Digitaria velutina*. *Cynodon dactylon* was present on the communal and traditional grazing reserve sites, with a higher percentage obtained in the former (4.2 %) than the later (0.9 %). For the distance gradients, the middle site had the greatest value (9.5 %) whereas the other two sites had the lowest but similar percentage values (average 1.5 %). *Heteropogon contortus* was present on the three land use system sites, with the greatest proportion being obtained on the government ranch (4.9 %). With respect to the distance gradient, the average value of *H. contortus* for the three distances was less than 1 %. *Lintona nutans* was present in all the land use systems and distance gradients from the watering point with similar but low percentage values (<1 %).

Table 5.2 Grass species composition (%) based on frequency of occurrence of common grass species in four communal grazing sites, three land use systems and distance gradients from water.

	Composition (%)									
Species	**Communal grazing sites**				**Land use systems**			**Distance gradient (communal only)**		
	Did Yabello	**Did Harra**	**Dubuluk**	**Melbana**	**Communal**	**ranch**	**Kallo[1]**	**Near**	**Middle**	**Far**
Aristida adoensis	0.45	0.35	0.07		0.22	1.59	0.40			0.29
Aristida adscensionis		0.5	0.64	0.07	0.30		0.70	0.57	0.15	0.50
Cynodon dactylon	10.64	3.76	1.70	0.78	4.22		0.90	1.55	9.47	1.36
Dactyloctenium aegyptium	0.87	0.07	0.2	3.22	1.09	0.35		2.90	0.63	2.54
Digitaria milangiana	2.30	0.07	2.78	6.07	2.81	1.86	5.79	2.27	3.61	1.98
Digitaria velutina			0.07	0.82	0.22			0.17	0.47	0.15
Elusine jageri	0.98	0.61			0.40	0.28		0.19	1.03	0.16
Eragrostis senni	0.75	0.42	0.2	0.13	0.38	0.40	0.41	0.05	0.77	0.10
Harpanchne shimperi	0.07	0.24	0.28		0.15	0.46	0.10	0.07	0.05	0.06
Heteropogon contortus	1.44	0.80	0.29	0.07	0.05	4.90	1.20	0.31	0.10	1.30
Lintona nutans	0.07	0.29			0.09	0.20	0.20	0.06	0.15	0.05
Oropetium capense			1.52	0.20	0.43	0.74	0.90	1.36	0.05	1.19
Panicum coloratum		0.41			0.10	0.74		0.35		0.31
Panicum maximum		2.09	2.44	3.61	2.03	0.50	2.01	2.11	2.23	1.85
Panicum turgidum	0.96	0.13		0.12	0.30	2.85	0.10			0.05
Pennisetum mezianum	0.15		0.46	7.42	2.01		2.37	6.36	0.41	5.56
Pennisetum stramineum		0.27	1.41		0.42	0.07	0.21		0.89	
Setaria verticillata				0.07	0.02	0.07		0.06		0.05
Themeda triandra	0.26	1.12	0.20		0.39	12.19	0.71	0.06	0.15	0.15

1 = traditional grazing reserve.

Digitaria velutina was present at all the distances away from the water source as well as only under the communal site, with all of the sites having a frequency percentage below 1 %.

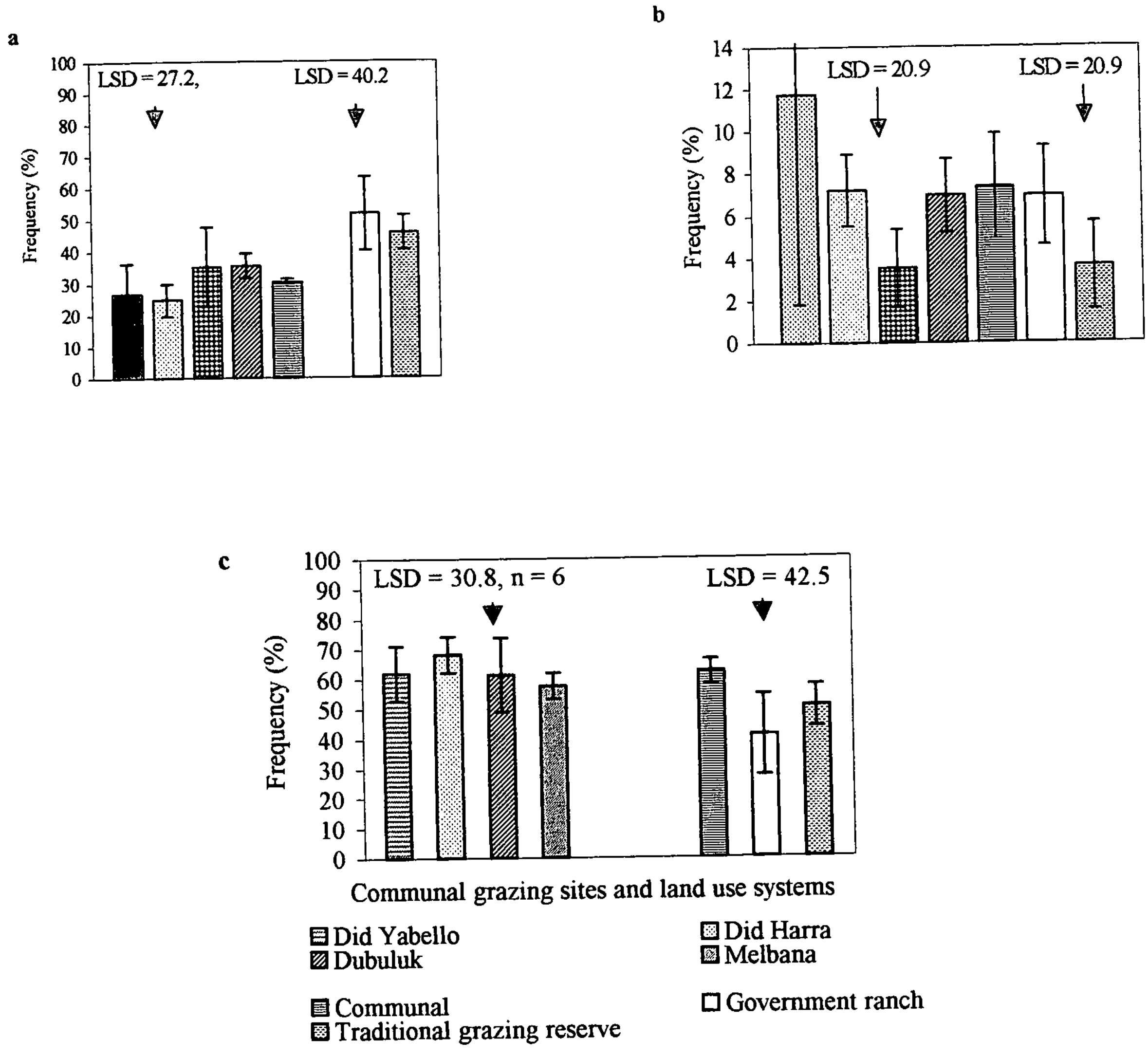


Figure 5.5 Grass species composition (%) based on frequency of occurrence of highly desirable (a), desirable (b) and less desirable species (c) in four communal grazing sites (n = 6) and three land use systems. Least significant differences (LSD) were calculated at 5 % level. Bars denote the SE.

Ten species recorded as commonly distributed were classified under the less desirable category. These species were: *Oropetium capense, Aristida adoensis, A. adscensionis, Dactyloctenium aegyptium, Elusine jaegeri, Eragrostis senni, Harpanchne shimperi, Pennisetum mezianum, P. stramineum* and *Setaria verticillata*. Considering the land use systems, except for *P. mezianum* that occurred under the communal land (2.0 %) and traditional grazing reserve (2.4 %), all the other species were present on all the three land use sites and on the three distance gradients from the water source.

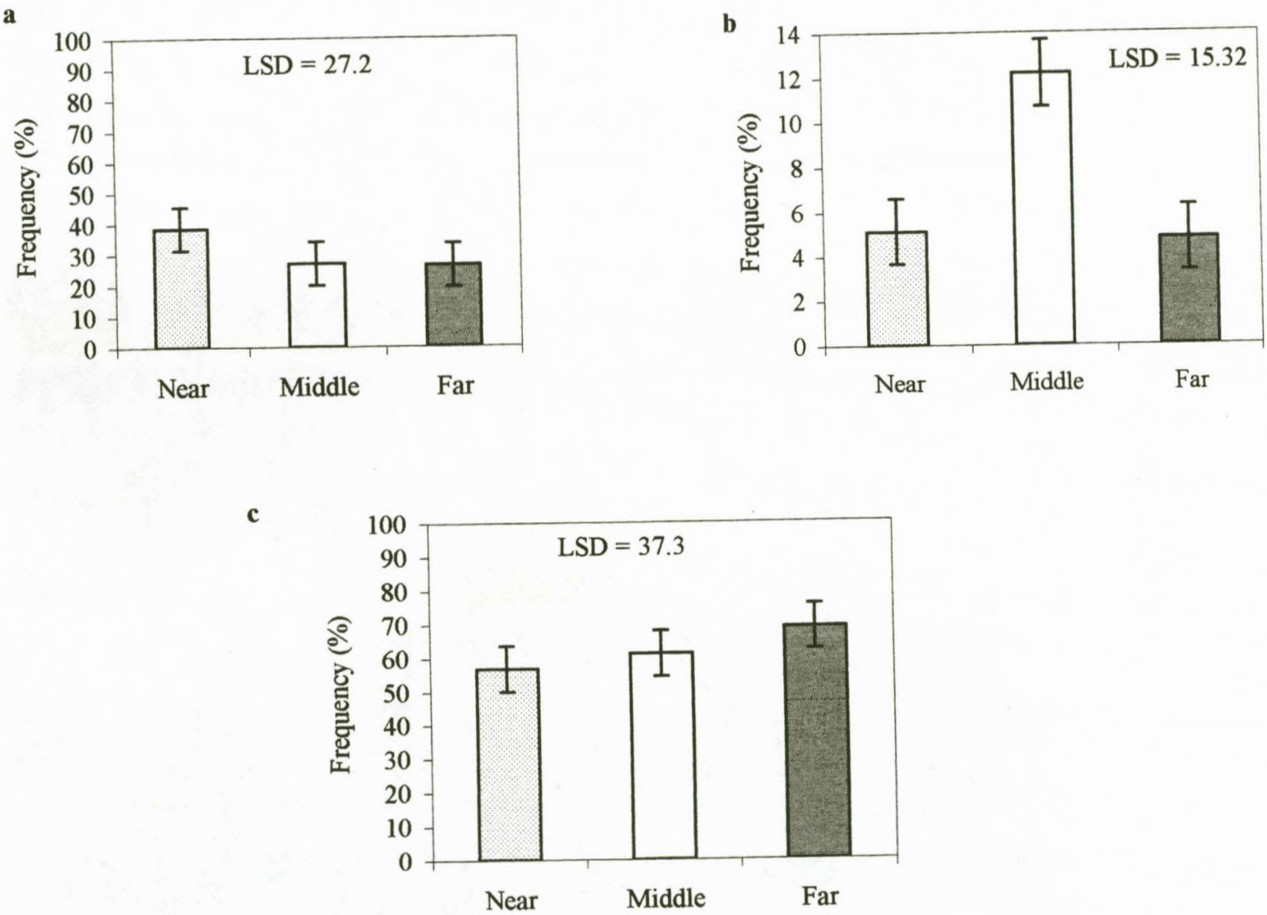


Figure 5.6 Grass species composition (%) based on frequency of occurrence of highly desirable (a), desirable (b) and less desirable (c) species in a distance gradient from water source. Least significant differences were calculated at 5 % level (n = 8). Bars denote the SE.

5.3.4 Composition of the most common species

Most common species in this section is defined as those species that were recorded to almost all experimental sites assigned both under the three land use systems and distance gradients from water source. Based on this definition, 9 species were classified as most commonly occurring species (Table 5.3). Of these, three species were highly desirable (*Chrysopogon aucheri, Cenchrus ciliaris* and *Leptothrium senegalensis*), one species - desirable (*Chloris mayriostachya*) and five species were less desirable (*Bothrichloa radicans, Eragrostis cilianensis, Sporobulus nervosus, S. pyramidalis* and *Microchloa kunthii*).

5.3.4.1 Highly desirable and desirable species

Data on highly desirable grass species (Table 5.3) revealed that, with respect to the land use system, the frequency percentage of *C. aucheri* differed significantly ($P<0.05$) between communal and government ranch, with a lower percentage obtained under the communal (14.0 %) than the government ranch. There was also a marked difference ($P<0.05$) in the percentage of *C. aucheri* between the traditional grazing reserve (27.6 %) and the communal grazing land. No significant difference ($P>0.05$) was evident between the government ranch and traditional grazing reserves. Significant variations were not detected in the frequency of occurrence of *C. aucheri* between the grazing sites within the communal land. Similarly, the percentage of *C. aucheri* did not differ ($P>0.05$) among the sites along the distance gradient from water but the near site had a slightly lower percentage (9.0 %) than the middle and the far sites (average of 13.2 %). The proportion of *C. ciliaris* was not different ($P>0.05$) between the land use systems, in the distance gradient from the water and between the grazing sites within the communal area. However, the species composition of the grazing sites of the communal area showed a relatively higher percentage at Dubuluk (7.0 %) than the other three sites (Did Yabello, Did Harra and Melbana: average of 4.2 %). *Leptothrium senegalensis* showed no difference in frequency ($P>0.05$) among the land use systems, but the value under the traditional grazing reserve (4.3 %) was slightly higher than either the communal or government ranch (average of 3.4 %).

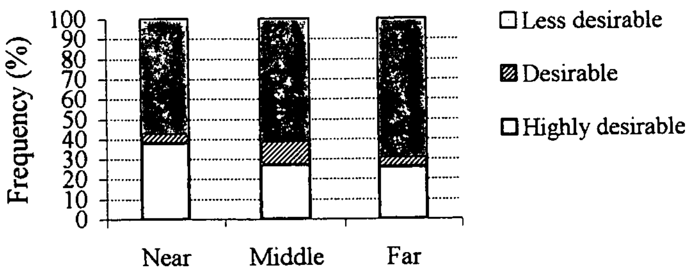


Figure 5.7 Proportional distribution of desirability groups along the distance gradient from water .

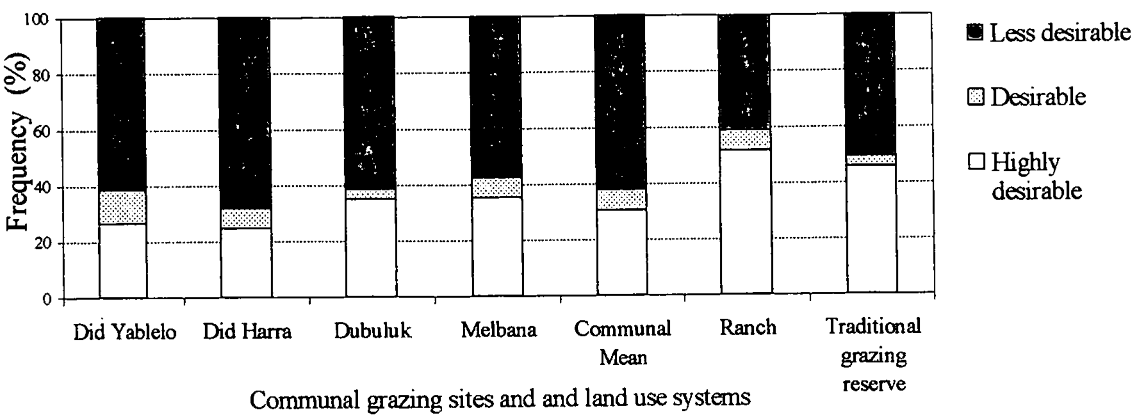


Figure 5.8 Proportional distribution of desirablility groups in four communal grazing sites and three land use systems.

In contrast, differences among the grazing sites within the communal land were prominent ($P<0.05$), with Melbana and Dubuluk area having higher values (5.4 % and 6.5 %, respectively) than the other two sites (Did Yabello 3.62 % and Did Harra 2.5 %). Differences in the frequency of *L. senegalensis* along the transects from the water source to the surrounding vegetation was not significant ($P>0.05$), but the near site had the largest frequency (4.8 %) while the middle site, the lowest (2.3 %). Similar finding was obtained for *C. mayriostachya* under the three land use systems and grazing sites within the communal, land except that Melbana had the greatest percentage (4.5 %) and Did yabello, the lowest (0.74 %). Difference along the gradient from the water point was not apparent.

Table 5.3 Grass species composition (%) based on frequency of occurrence of the most common grass species; tests of difference between four communal grazing sites, three land use systems and between distances gradients from water.

			Summary			
Species	**Communal grazing sites**		**Land use systems**		**Distance gradient from water source (communal area only)**	
Bothrichloa radicans	Did Yabello	1.65 ± 1.15^{a}	Communal	0.78 ± 0.02^{a}	Near	0.74 ± 0.68^{a}
	Did Harra	0.48 ± 0.35^{a}	Government ranch	0.41 ± 0.21^{a}	Middle	0.16 ± 0.11^{a}
	Dubuluk	0.34 ± 0.34^{a}	Traditional reserve	0.70 ± 0.70^{a}	Far	1.27 ± 0.11^{a}
	Melbana	0.64 ± 0.29^{a}				
Eragrostis cilianensis	Did Yabello	0.79 ± 0.41^{a}	Communal	0.58 ± 0.21^{a}	Near	0.06 ± 0.06^{a}
	Did Harra	0.28 ± 0.15^{a}	Government ranch	0.07 ± 0.01^{a}	Middle	1.34 ± 0.51^{a}
	Dubuluk	0.79 ± 0.16^{a}	Traditional reserve	0.30 ± 0.20^{a}	Far	0.06 ± 0.01^{a}
	Melbana	0.47 ± 0.40^{a}				
Sporobulus nervosus	Did Yabello	22.76 ± 6.04^{a}	Communal	13.28 ± 3.03^{a}	Near	14.18 ± 4.89^{a}
	Did Harra	6.69 ± 3.75^{b}	Government ranch	1.89 ± 0.71^{b}	Middle	15.25 ± 5.57^{a}
	Dubuluk	12.82 ± 6.93^{ab}	Traditional reserve	3.32 ± 1.51^{b} ***	Far	12.79 ± 5.90^{a}
	Melbana	10.86 ± 6.10^{ab} *				
Sporobulus pyramidalis	Did Yabello	21.50 ± 9.34^{a}	Communal	32.96 ± 4.54^{a}	Near	40.21 ± 8.46^{a}
	Did Harra	45.12 ± 7.33^{b}	Government ranch	$31.80 \pm 14.51^{a\ a}$	Middle	33.21 ± 7.07^{a}
	Dubuluk	36.80 ± 10.58^{a}	Traditional reserve	31.82 ± 4.78^{a}	Far	35.71 ± 8.44^{a}
	Melbana	28.45 ± 5.96^{a} *				

* = Significant ($P < 0.05$); ***= Highly significant ($P < 0.005$);
Means in the same column with different superscripts are significantly different.

Table 5.3 cont'd

	Summary					
Species	**Communal grazing sites**		**Land use systems**		**Distance gradient from water source (communal area) only)**	
Chrysopogo. aucheri	Did Yabello	13.25 ± 7.97[a]	Communal	14.01 ± 2.76[a]	Near	8.97 ± 3.16[a]
	Did Harra	13.55 ± 2.89[a]	Government ranch	23.08 ± 7.97[b]	Middle	12.73 ± 5.57[a]
	Dubuluk	16.25 ± 7.67[a]	Traditional reserve	27.66 ± 5.55[b]	Far	13.62 ± 5.76[a]
	Melbana	14.78 ± 2.94[a]		*		
	Did Tyura					
Cenchrus ciliaris	Did Yabello	2.91 ± 1.63[a]	Communal	4.67 ± 0.68[a]	Near	3.65 ± 1.14[a]
	Did Harra	4.52 ± 1.13[a]	Government ranch	4.85 ± 1.64[a]	Middle	4.59 ± 1.29[a]
	Dubuluk	6.98 ± 1.42[a]	Traditional reserve	4.77 ± 1.14[a]	Far	4.29 ± 1.26[a]
	Melbana	4.26 ± 1.02[a]				
Chloris myriostachya	Did Yabello	0.74 ± 0.45[a]	Communal	1.98 ± 0.53[a]	Near	2.46 ± 1.09[a]
	Did Harra	1.54 ± 0.84[ab]	Government ranch	0.90 ± 0.50[a]	Middle	1.75 ± 0.73[a]
	Dubuluk	1.12 ± 0.63[ab]	Traditional reserve	1.12 ± 0.65[a]	Far	2.16 ± 1.01[a]
	Melbana	4.52 ± 1.37[b] *				
Leptothrium senegalensis	Did Yabello	3.62 ± 2.10[a]	Communal	4.24 ± 0.94[a]	Near	2.22 ± 1.84[a]
	Did Harra	2.49 ± 1.56[a]	Government ranch	3.389± 2.93[a]	Middle	2.25 ± 1.74[a]
	Dubuluk	6.48 ± 0.49[a]	Traditional reserve	4.31 ± 3.12[a]	Far	2.32 ± 1.32[a]
	Melbana	5.38 ± 2.63[b] *				
Microchloa kunthii	Did Yabello	2.36 ± 1.42[a]	Communal	4.26 ± 1.06[b]	Near	2.78 ± 2.11[a]
	Did Harra	7.13 ± 3.15[b]	Government ranch	1.67 ± 0.69[a]	Middle	4.44 ± 1.47[a]
	Dubuluk	4.56 ± 1.98[ab]	Traditional grazing	8.23 ± 4.04[b] *	Far	3.10 ± 0.90[a]
	Melbana *	3.00 ± 1.47[ab]				

5.3.4.2 Less desirable species

Results of the less desirable species (Table 5.3) indicated that frequency of *S. nervosus* was significantly higher (P<0.005) under the communal grazing area (13.3 %) than the other two land use systems. For the grazing sites within the communal area, the mean value at Did Yabello (22.8 %) was higher than that of Did Harra (6.7 %), where as both of these sites did not vary markedly (P>0.05) from either of the other two grazing sites (Dubuluk and Melbana). While examining *S. pyramidalis,* significant differences (P>0.05) were not detected among the three land use systems and distances from the water source, although, regarding the later, a slightly lower value was noticed in the near than the middle and far sites. In contrast, the significant differences (P<0.05) among the sites within the communal land indicated that the mean values for Did Yabello and Melabana were lower than that of the other two sites. The frequency percentage for *B. radicans* and *C. cilianensis* was small and non-significant (P>0.05) between the three land use systems and distance gradient from water. Frequency percentage of *M. kunthii* did not differ (P>0.05) between distance gradients from water but showed significant variations (P<0.05) between the land use systems with the greatest value being obtained on the traditional grazing reserve (8.2 %) and the lowest on the government ranch (1.6 %). For the grazing sites within the communal area, the greatest value was obtained in Did Harra (7.1 %) where as the other three sites had similar values (average 3.3 %).

5.3.5 Basal cover and bare ground

The percentage basal cover was fairly low and did not change markedly (P>0.05) between the land use systems, but the traditional grazing reserve had a relatively higher value than the communal area and government ranch (Figure 5.9a). Although not significant (P>0.05), results of the grazing sites within the communal land (Figure 5.9a) indicated that Did Harra had the greatest value (5.0 %) followed by Dubuluk (3.7 %) and lastly nearly similar values for Did Yabello and Melbana (average 2.8 %). Basal cover in the sites away from water source was also low and differences non-significant (P>0.05) (Figure 5.10a).

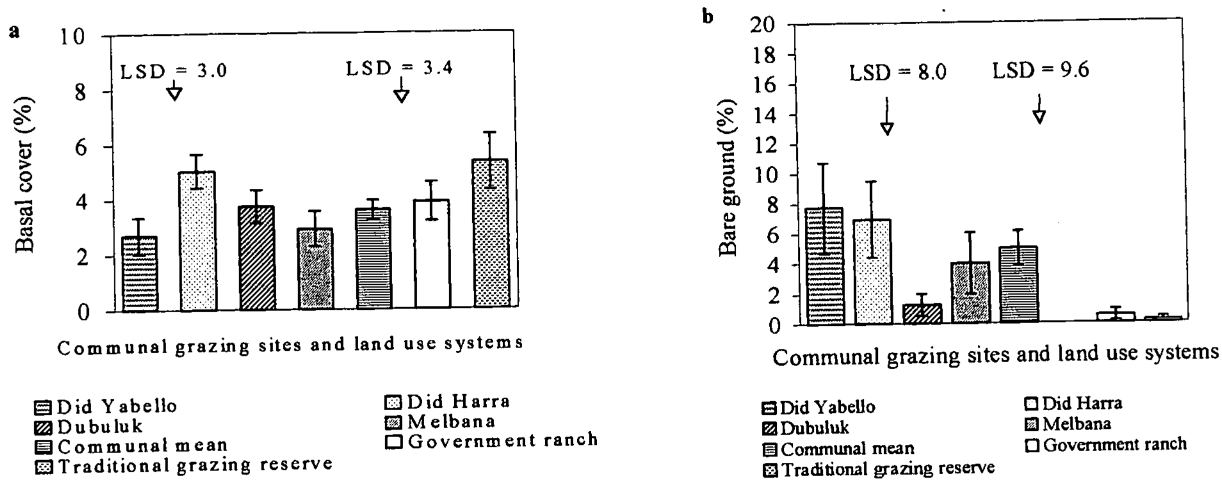


Figure 5.9 Basal cover (%) (a) and bare ground (%) (b) in four communal grazing sites (n = 6) and three land use systems. Least significant differences were calculated at 5 % level. Bars denote SE.

Data on the percentage bare ground between the land use systems revealed that the value under communal grazing area was higher (P<0.01) than the government ranch and traditional grazing reserve where as the later two had very low (P>0.05) percentages (Figure 5.9b). For the grazing sites within the communal land, the bare patches for Did Yabello and Dubuluk were significantly different (P<0.01) (mean: 7.7 % and 1.2 %, respectively) and for the rest no marked variations were recorded (P>0.05). The non-significant (P>0.05) result on a distance gradient from the water source indicated that the middle site had relatively low percentage bare patchness than the other two sites (Figure 5.10b).

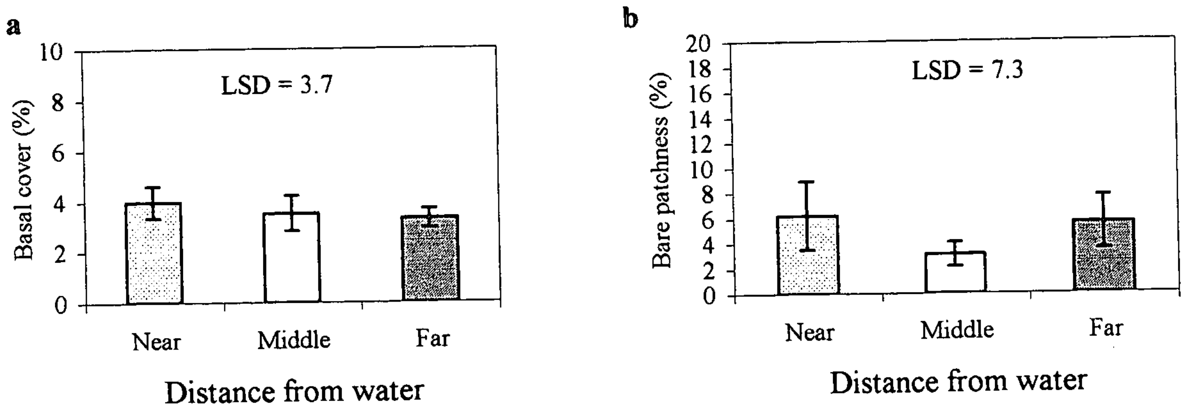


Figure 5.10 Basal cover (%) (a) and bare ground (%) (b) along the distance gradient from water. Least significant differences were calculated at 5 % level (n = 8). Bars denote the SE.

5.4 DISCUSSION

5.4.1 Life forms and desirablility

One of the main objectives of this study was to investigate whether, in the Borana rangeland, land uses had resulted in differences in selected variables of the grass layer. The results indicated that some of the attributes in communal land differ from that of other land uses. There was significantly more annuals under the communal (58.3 %) than the other land use systems (average 41.6 %). This result may suggest that perennial grasses were replaced with annuals grasses on the communal land that was subjected to higher grazing pressure than the other two land use sites. Similar reports have been frequently recorded in heavily grazed arid and semi-arid savannas of Africa (Frost *et al.* 1986; O'Connor 1991; O'Connor & Pickett 1992). When such replacement progresses, the rangeland may be ecologically disfavoured. However, even under this situation, it may not mean that herbaceous productivity declines (Kelly & Walker 1977; Shackleton 1993). Moreover, the replacement of perennials with annuals does not necessarily mean that the forage quality is reduced as many annuals are regarded to have fair to high palatability (e.g. in this study: *Setaria ustilata*, *D. velutina*, *D. aegyptium*) and may have higher crude protein levels than many perennials. Significant difference was absent with regards to both life forms along the distance gradient from water but a relatively higher abundance of annuals (average 58.3 %) than perennials was found. Similarly, no major differences between the grazing sites within the communal areas were found, but overall results showed the existence of some replacement of perennials with annuals (58.3 %) (except the ranch).

The proportion of highly desirable species was the lowest under the communal system (30.6 %), where the highest proportion of less desirable species (54.9 %) occurred. Differences in the proportion of highly desirable and less desirable species remained non-significant ($P>0.05$) between the government ranch (51.8 % and 35.4 %, respectively) and the traditional grazing reserve (46.0 % and 40.6 %, respectively). The proportion of highly desirable and less desirable species did not vary significantly between the grazing sites within the communal areas (average 30.6 % and 62.2 %, respectively) and along the distance gradient from water (average, 30.6 % and 62.2 %, respectively). In summary, it is important to note that classifications of species into highly desirable, desirable and less desirable groups relied most importantly on the merits of species with respect to their life forms and palatability. However, under high grazing pressures experienced in the communal land, such classification may not be valid in some cases, particularly when palatability is taken as a criteria and under such situations, even unpalatable species may be heavily grazed and be relatively palatable.

5.4.2 Composition of grass species

Grass species identified in this study corresponds partially with those reported in earlier studies (Jenkins *et al.* 1974; Ayanna & Baars 2000).

5.4.2.1 Common grass species

As observed in the previous section, it is clear that the frequency of occurrence of highly desirable common grass species together is generally within low to moderate range under the land use systems (communal-5.6 %, ranch-18.4 % and traditional grazing reserve-8.6 %), and in distance gradient from water source (near-7.5 %, middle-6.0 % and far 4.3 %).

The species composition based on frequency of occurrence of the common desirable grass species combined, was generally low under communal (4.5 %), ranch (5.1 %), traditional grazing reserve (2.3 %), near (2.1 %), middle (9.7 %) and far (2.9 %) sites. Of the less desirable species *P. mezianum* and *P. stramineum* were mentioned in the previous study as common to dominant (>5-20 %) (Ayanna & Baars 2000), which is in contrast with the present finding that showed a very low percentage of occurrence (2.6 % and <0.5 %, respectively). Besides, in contrast to the report of Coppock (1994), the pastoralists argued that these two species have low grazing value and are not used for calf feeding. The finding on the role of *C. dactylon* and *P. coloratum* as the sole forage species, amongst the others for feeding calves, is in agreement with the report of Coppock (1994) and Ayanna & Baars (2000). The value of *Oropetium capense* and *Digitaria velutina* were not mentioned in earlier reports. *Digitaria velutina* (long-plumed finger grass) occurs in disturbed place, growing mostly in sandy soil and is not easily confused with other grasses. It is a palatable pioneer grass, but is an annual and produces few leaves. *Oropetium capense* is a dwarf annual grass that grows in shallow soils, which is a poor grazing grass with low leaf production (Van Oudtshoorn 1992) and was visually observed to grow in bare patches of disturbed Borana rangeland.

5.4.2.2 Most common grass species

The percentage occurrence of *C. aucheri* indicated that it is one of the dominant grasses under all the land use systems and occurred commonly along the distance gradient from water. This result corresponds with earlier findings (Ayanna & Baars 2000). The existence of variations between the communal (lower value) and the other land use systems may be explained by a higher grazing impact under the communal than the other land uses.

The occurrence of *C. ciliaris* was generally low (4.6 %) and did not show variation along the distance gradient from water, between the land use systems and between the grazing sites within the communal area. An earlier report (Jenkins *et al.* 1974) indicated that it was one of the most abundant species in the Borana rangeland, which is in contrast to the present finding. Similarly, *L. senegalensis* was found to have low percentage occurrence.

Some of the important grass species identified in this study are regarded as fair to highly nutritious all year round and at all growth stage (e.g. *C. aucheri, C. ciliaris, T. triandra, L. senegalensis* and *C. myriostachya*), while others are of the greatest value, particularly during the rapid growth phases (e.g. *C. dactylon*). *Cenchrus ciliaris* and *C. aucheri* are important for calf feeding and known as the key forage species in Borana (Coppock 1994).

Of the less desirable species, *S. nervosus* was recorded in this study within the range of fair to dominant (7 %-23 %) in most of the study areas and was reported in none of the earlier studies. This species is perennial and rhizomatous (rhizomes compact with short internodes, creeping horizontally at ground level) (Gibbs *et al.* 1990) and was visually observed to invade overgrazed grasslands.

Considering the frequency of occurrence of *S. nervosus*, there existed no significant difference (P>0.05) along the distance gradient from water, but was extremely abundant on the communal land. For the grazing sites within the communal area, a significantly higher value was obtained in Did Yabello. *Sporobulus pyramidalis* was the dominant species on all study sites. Significant differences (P>0.05) was not found in the abundance of *S. pyramidalis* along the distance gradient from water and between the land use systems, but within the grazing sites, it was most abundant in Did Harra. The above two mentioned species account for 54 % of the total species composition in the near, 48.5 % in the middle and far sites as well as 46.2 % under the communal, 33.6 % under the government ranch and 35 % in the traditional grazing reserve sites. From these observations it can be said that these two species are the sole increasers in the study areas.

Results on the effect of land use system on the grass species composition suggested that *S. nervosus* might be a better indicator of grazing impact than *S. pyramidalis*. With respect to the grazing sites within the communal area, the greatest abundance of the two species occurred in the two sites with the greatest external influence.

Did Yabello borders other pastoral tribes outside the Borana. Besides, it is also the site which experiences the most recent expansion of cultivation (mainly outsiders) on land previously used for grazing and it is also the site where the government ranch is located. Did Harra is a grazing site characterized by a relative recent development and rehabilitation of water points that has resulted in heavy immigration of pastoralists in response to these watering points. This, therefore, implies that external intervention into the Borana system may be one of the important causes for compositional changes of the grass layer. This is because it contributes in one way or another to increased grazing pressure through the development of water ponds, competition for grazing and alienation of the pastoral land.

Other species, namely *B. radicans* and *E. cilianensis* existed in low numbers in all the land use systems, grazing sites and the distance gradient from water. Ayanna (2002) indicated that *B. radicans* is one of the most important forage grasses for calf feeding in the Borana. However, the present finding does not support this report because as evident even from the pastoralists *Bothrichloa radicans* is unpalatable grass with poor grazing value and hence is not used for calf feeding.

The absence of a significant effect of distance from the water source on the grass species composition confirmed the findings of Bonifica (1992) and Van Rooyen *et al.* (1990). Bonifica (1992) found no association of water point distance and species sandveld habitat around Matswere and Moris watering points in Botswana. Van Rooyen *et al.* (1990) found no association of distance from watering points on the grass species composition of savanna dune street habitats of the Kalahari Gemsbok National park in South Africa. If grazing by animals around water points affect grass species growth and composition, forming different structural features over a distance gradient, then it can be suggested in this study that grazing impact over the three distances around the water points may go beyond degradation point. In other words, in contrast to the earlier studies mentioned here, minimal to no floristic variation around the water points does not imply that the areas are undergrazed and that grazing should continue until a significant variation is detected. In this particular study, the absence of significant variation is, however, probably because the grazing disturbance has already exceeded the threshold point of degradation along the complete distance gradient.

5.4.2.3 Basal cover and bare ground

The percentage basal cover was low and did not differ significantly ($P>0.05$) between the land use systems although the traditional grazing reserve (mean of 5.3 %) was 73.6 % greater than the other land uses. Similarly, the basal cover was low and similar along a distance gradient from water (3.6 %) and among the communal grazing sites (3.6 %). This particular finding suggested that, combining all the study sites, livestock pressure may have a direct or indirect overriding effect on the vegetation cover. However, at times, fluctuation in rainfall, a common phenomenon in semi-arid Borana, may influence the cover, partially overriding the effect of livestock.

Bare ground was by far more common under the communal grazing (5 %) than the other two land uses (0.4 %). Within the communal areas, sites under external pressure (Did Yabello and Did Harra) had 182.5 % (average 7.3 %) more bare ground than the other sites. The average percentage of bare ground along a distance gradient from water was 5.01 %.

5.5 CONCLUSION

The following conclusions can be made from this study:

(i) Species composition of grasses, basal cover and bare ground can be used as key indicators of the status of the grass layer in the Borana rangeland under the current situations.

(ii) In this investigation, it appears that some of the studied variables showed significant differences between the communal and the other land uses. This suggested that grazing pressure and thus intensity and frequency of use, may be the primary cause of the observed differences. Additionally, each land use system may also represent a suit of impacts other than just grazing pressure and needs further investigation.

(iii) Differences along a distance gradient from the water source were not significant for all the investigated variables. This is probably because the grazing disturbance has already exceeded a certain threshold of degradation gradient along the entire length of the distance gradient.

(iv) An interesting finding in the communal area is that key increaser species (*S. nervosus* and *S. pyramidalis*) and bare ground had the greatest abundance in the grazing sites which experienced external interventions in the form of water development and rehabilitation, competition for and alienation of grazing land. This, therefore, implies that external pressure into the Borana system may be one of the most contributing factors that exacerbates the changes in the vegetation composition and cover of semi-arid Borana rangeland.

(v) The decreased basal cover, as well as increased abundance of annual species on the communal land as a result of grazing pressure, can promote the potential risk of soil erosion.

CHAPTER 6

ASSESSMENT OF WOODY VEGETATION IN RELATION TO LAND USE AND DISTANCE FROM WATER

6.1 INTRODUCTION

The process of open grassland being transformed into dense woody cover can be termed as bush encroachment (Barnes 1979). The general theory of woody plant invasion in overgrazed savannas was presented by Walter (1954) and further developed by Walker & Noy-Meir (1982) and Noy-Meir (1982). This model describes savanna as a system of two functionally separate soil layers and two vegetation components with different life forms. It also states that a healthy grass layer may outcompete woody species for water in the surface soil. Therefore, a decrease in the grass layer, e.g. by overgrazing, results in woody plants to have access to soil water that could otherwise have been utilized by the grasses (Walker & Noy-Meir 1982, Bland 1985).

A few studies have reported that there has been an increase of woody plants in the study areas during the last few decades (Ayana & Baars 2000). In addressing this problem, the studies were simply preliminary and focused primarily on woody vegetation canopy cover. Quantitative data on species composition and height class distribution are limited. Attempts were not made in the past to investigate the distribution and structure of woody plants in different land management systems as well as along a distance gradient from a point of reference (e.g. water point). In addition, there is a lack of information on the common use of indigenous woody plants by the pastoralists.

The current investigation was undertaken to assess:

(i) the forage and traditional values of identified woody plants,

(ii) the distribution and composition of woody plants in three land use systems (communal, ranch and traditional grazing reserves) and

(iii) woody vegetation structure along a distance gradient from the main water source.

6.2 PROCEDURE

6.2.1 Study sites, plots and sub-plots

The same grazing areas, transects, sub-transects and main plots mentioned in section 5.2.1 were used for the purpose of this study. In the center of each main plot, three 10 m x 10 m sub-plots were marked. The sub-plots were evenly spaced along the length of the main plot and were used to record variables of the woody vegetation layer.

6.2.2 Survey of the woody vegetation layer

All rooted live woody plants were recorded and counted in each sub-plot for the analysis of density and species composition. Plants were recorded by species, and according to height divided into one of eight height classes: >0-0.5 m; >0.5-1 m; >1-1.5 m; >1.5-2 m; >2-3 m; >3-4 m; >4-5 m and >5 m. When multiple stems occurred, an arbitrary decision was made to count a stem as a separate individual if it was > 400 mm from the nearest stem. Information on the use of identified woody plants was acquired from the pastoralists through open ended group discussions made with ethnic elders and leaders.

6.2.3 Species identification

The same procedure to identify species was followed as described in section 5.2.3. Exceptional in this case was that the opinion of herdsmen and pastoral elders was highly appreciated for the identification of most species in the field using a field guide of woody plant species of that area.

6.2.4 Data analysis

Differences in total woody plants and height class densities in the four communal land use (Did Yabello, Did Harra, Dubuluk and Melbana) and in relation to distance from water were tested by a two way ANOVA following the procedure described in section 5.2.4. A simple t-test was also conducted similarly to assess the significance of differences between the three land use systems (communal land, government ranch and traditional grazing reserves). Woody plant data were standardized to Tree Equivalent ha^{-1} (1 TE = 1 tree, 1.5 m high) for some comparisons (Teague *et al.* 1981). Prior to standardization, the mid point of each height class was multiplied by the number of individuals in the class and summed for all classes separately. Those data that do not require analysis were presented by simple descriptive statistics.

6.3 RESULTS

For all study sites combined, 54 woody plant species were recorded, of which 10 species were *Acacia* species (Table 6.1).

6.3.1 Common uses of woody plants

Based on the opinions of the pastoralists gathered in an open ended group discussions (n = 18; average seven people per group), it was found that 85 % of the total recorded woody plants have forage values to livestock species. With respect to preference, 48 % was reported to be used by the four livestock species (sheep, goat, camel and cattle), 28 % by all except cattle, 9 % only by the main browsers (goats and camels) and the others, used by only either the individual or group of species. With respect to palatability, it was mentioned that 76 % have low palatability, four species (*Boswellia hildebrantii, Combretum molle, Euclea shimperi* and *Acacia* sp (unidentified) were foraged only during extreme drought conditions when there is no choice. Seven species were believed to have fair to good palatability. For the woody plants with fair to good palatability, four species (*Cadaba farinsoa*, unidentified sp (local name kete), *Ormocarpum trichocarpum* and *Rhus natalensis*) were reported to be used by the four livestock species, one species (*Acacia brevispica*) by all except cattle, and the other two (*Cordia gharaf* and *Hibiscus sparseaculeatus*) by the main browsers (goats and camels). Leaves were indicated as the major edible portion of most of the plants. Other than the forage value, the role of woody plants for traditional use was discussed (Table 6.1). Accordingly, 70 % of the total woody plants identified in this study were reported to be utilized for traditional purpose. These included fencing and fire wood (16 species), home construction (6 species), wood and fibre for making household utensils (16 species), medicines for people and livestock (12 species), food for people during years of average or below-average rainfall (16 species), extracts for leather tanning and dyes (6 species), fumigation of insects and microbial fumigation of milk-processing containers (7 species), and for spiritual or ceremonial purposes (3 species).

6.3.2 Species richness

Analysis of woody plant species diversity along a distance gradient from the water indicated that the highest number of species was recorded in the middle site (42), followed by the far (38) and the near site (34) (Table 6.2). Fifty three percent of the species recorded were common to all distances, 6 % only to the near and middle sites, 8 % to the middle and far sites, 2 % to the near and far sites, 8 % only to the near site, 10 % to the middle site, and 12 % to the far site. The most common species in total were found to be the most important contributors to the total woody plant density along the total distance gradients from water. As far as the land use systems are concerned, clearly the highest number of species was recorded under communal use (46), followed by the government ranch (31) and thirdly the traditional grazing reserve (17) sites (Table 6.2). In total, 26 % of the total woody plants registered on plots under the various land use systems were common to the three land uses, 25 % only to communal and government ranch, 2 % to communal and traditional grazing reserve, and none was registered only on the ranch and traditional grazing reserve, 34 % only to the communal, 8 % to the government ranch and 4 % to the traditional grazing reserve site. For the grazing sites within the communal land, Did Yabello had the greatest species number (34), where as the other three sites had nearly a similar number (average of 26) (Table 6.2).

6.3.3 Density of all woody plants combined

Data on the density of all woody plants combined indicated that marked difference ($P<0.001$) exists between the communal and government ranch versus the traditional grazing reserve (Figure 6.1). Accordingly, the density under the communal site (a mean of 1 083 TE ha^{-1}) was 158 % higher than the woody plants of the traditional grazing reserve site. Similarly, the government ranch with a mean of 1 188 TE ha^{-1} had a density of 182 % higher woody plants than the traditional grazing reserve. Densities under the communal and government ranch were remarkably similar ($P >0.05$), although the latter had 10 % more woody plants than the former.

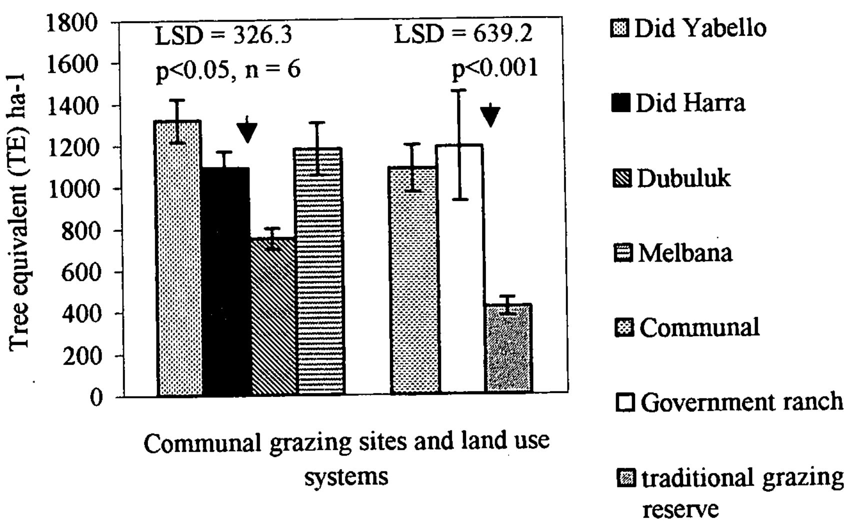


Figure 6.1 Total density of woody plants (TE ha^{-1}) in four communal grazing sites and under three land use systems (mean ± Y-error bars (SE)).

Table 6.1 Scientific and vernacular name, growth form, livestock and other traditional household uses of native woody plants identified in Borana rangelands, Ethiopia.

Scientific name	**Vernacular name[1]**	**Growth form[2]**	**Feed for livestock[3]**				**Major Edible portion[4]**	**Traditional utilization[5]**
			Goats	**Camel**	**Sheep**	**Cattle**		
Acacia brevispica	Hamaressa	S	√	√**	√	x	Leaves/fruits	Wood for construction (termite resistant); root extracts have medicinal value
Acacia bussei	Halo	T	√	√	√	x	leaves	extracts for tanning, pigments; hard wood for fencing, fire wood and utensils; indicator of onset of wet seasons by green flush; bark stripes for rope and matting
Acacia drepanolobium	Fulesa	T	√	√	√	x	leaves	Edible gum during drought
Acacia nilotica	Burquqe	T	√	√	√	√	Leaves/fruits (podes)	Firewood; fencing; bark extract for red dyes; pod extract for black dyes
Acacia Senegal	Hidado	T	√	x	√	x	Leaves	Gum Arabic; firewood; fencing
Acacia seyal	Wachu	T	√	√	√	x	Leaves/fruits	Extracts for red pigments; bark extracts to make paint for wooden handicrafts; fencing; firewood; gum; root has medicinal value for camels
Acacia sp	Bokosa	S/T	√	√	√*	x	Leaves	_
Acacia tortilis	Tedecha	T	√	√	√	√		Shade tree; wood for axe handles
Acacia mellifera	Sapansa	T	√	√	√	x	Leaves/fruits	Bark burned for fumigation; wood for fencing
Acacia etbaica	Alkebesa	T	√	√	√		Leaves/fruits	Firewood; fencing; shade tree
Albizia amara (Roxb.) Boiv.	Ondode	S/T (?)	x	√	x	x	Leaves	_
Aloe sp	Hargessa	F	x	x	x	x		_
Ampelocissus schimperiana (A.Rich.) planch.	Robi	S/T (?)	x	x	x	x		_
Asparagus racemosus willd.	Serite	S/T (?)	√	√	√	x	Leaves	_

[1]= Borana Oromiffaa; [2]= Source: Coppock (1998)
[3,4] = Interview of herdsmen and pastoral elders
[5]= Source: 1-Interview of herdsmen and pastoral elders (n = 126, 7 people per group), and 2-Coppock (1998)
* = only palatable in small amount when no choice ** = Fair to good forage values; √ -palatable; x –unpalatable, ind = unidentified

Table 6.1 cont'd

Scientific name	Vernacular name[1]	Growth form[2]	Feed for livestock[3]				Major Edible portion[4]	Traditional utilization[5]
			Goats	Camel	Sheep	Cattle		
Balanites aegyptica	Badana	T	√	√	√	√	Leaves	Leaves of new shoots chewed into paste for application for lesions; edible fruit; scent wood; gum; fumigation wood for milk containers; wood for utensils like butter whisk and butter spoons; construction wood; firewood.
Boscia angustifolia	Kalkacha	T	√	√	√	√	Leaves	Carving wood for mortars and pestles for grinding grain and making coffee cups; twigs used as cleaning utensils.
Boswellia hildebrantii	Dakara	T	√	√	√	√*		Bark extracts for medicines, paste and dyes; edible root; incense; good fire wood
Cadaba farinosa Forssk.	Dumeso	S/T (?)	√	√	√	√**	leaves	_
Canthium setiflorum	Ladan	S	√	√	√	√	leaves	Edible fruit; scent wood; fumigation wood
Combretum molle	Rukesa	T	x	x	x	√*		Scent wood; shade tree
Commiphora africana	Hamessa	T	√	√	√	x	Leaves	Live fencing; wood for utensils like coffee cup, camel bell milk pots and bowls
Commiphora fluviflora	Chalaka	T	√	√	√	x	Leaves	Live fencing; sap used as soap; fibres to construct milk pots and coffee cups; spines are poisonous
Commiphora spp	Omecho	S/T	√	√	√	x	Leaves	_
Cordia gharaf	Medera	S/T	√	√**	x	x	leaves	Edible fruit important for drought; gum is chewed; wood for fencing; carving wood for ceremonial sticks
Cyphostemma sp	Chobi loni	F	√	√	√	√	All	Edible fruits and leaves; other extracts for wound healing
Dichrostachys cinerea	Jirme	T	√	√	√	√	Leaves	Firewood; fencing; carved into utensils such as pestles; seed extracts for black dyes; extracts have medicinal value
Endostemen tereticaulis	Urgo	F	x	x	x	X		Branches used for sweeping; fumigation wood
Euclea shimperi	Miesa	S	√	√	√	√*	leaves	Important ceremonial plant, root extracts are medicine; edible fruit; wood for construction

Table 6.1 cont'd

Scientific name	Vernacular name[1]	Growth form[2]	Feed for livestock[3]				Major Edible portion[4]	Traditional utilization[5]
			Goats	Camel	Sheep	Cattle		
Gardenia volkensii	Gambeela	S	x	x	x	x		Wood used for carving utensils; edible fruit; shade tree
Euphorbia tirucalli	Ano	F (Su)	x	x	x	X		Wood for troughs; sap for skin sores; wood beams used to split rocks for well construction
Grewia bicolor	Aroressa	S	√	√	√	√	Leaves	Edible fruit; wood used for construction, spears and sticks; tea from boiled seeds; fibre for rope
Grewia tembensis	Deeka	S	√	√	√	√	Leaves	Edible fruits; branches used for arrows and construction
			√	√	√	√		
Grewia villosa	Ogomdi	S	√	√	√	√	Leaves	Edible fruit; fibres used for weaving; edible root during drought
Hibiscus spareaculeatus Bak.f.	Dununu	S/T (?)	√	√**	x	x	Leaves	_
Ind	Kete	S/T (?)	√	√	√	√**	Leaves	_
Ind	Chalo	S/T	√	√	√	x	leaves	_
Ind	Dabasso	S/T	x	x	x	x		
Ind	Gurbi		√	√	√	√	Leaves	_
Ind	Tiro	S/T	x	x	x	x		_
Lannea floccose	Handaraka	T	√	√	√	√	Leaves	Edible fruit; wood carved into utensils; extracts as medicinal stomach anti-acid; ceremonial sticks
Lycium shawii Roem & Schult	Fursa	S (?)	√	√	x	x	Leaves	_
*Olea africana***	Ejersa	T	√	√	√	√	Leaves	Edible fruit; bark stripes for construction; fumigation wood; fire wood; strong construction wood; shade tree; sticks have ceremonial value

Table 6.1 cont'd

Scientific name	Vernacular name[1]	Growth form[2]	Feed for livestock[3]				Major Edible portion[4]	Traditional utilization[5]
			Goats	Camel	Sheep	Cattle		
Ormocaprum trichocarpum (Taub.) Engl.	Walchamal	S/T (?)	√**	√	√	√	Leaves	_
Ormocarpum mimosoides	Butiye	S	√	√	√	x	Leaves	Wood for fencing; extracts have medicinal value
Pappea capensis	Bika	T	√	√	√	√	Leaves	Edible fruit; firewood; shade tree
Phyllanthus somalensis	Diri	S	√	√	√	√	Leaves	Bark stripes for fencing and bed construction; fibres for construction and weaving water containers
Plectranthus sp	Baranbaressa	S	√	√	√	√	Leaves	Twig extracts have medicinal value for punctures and cuts
Premna resinosa	Tateesa	S	√	√	√	x	Leaves	Edible fruit; fumigation wood
Rhus natalensis	Debobesa	S	√**	√	√	√	Leaves	Edible fruit; extracts have medicinal value
Sansevieria abyssinica	Chake	Su	√	x	√	√	leaves	Sisal-like fibres woven into roofing mats for huts; bark stripes for construction; source of water in dry seasons.
Sericocomopis pallida (S.moore) Schinz	Dergu	S (?)	x	√	x	x	all	_
Solanum somalense	Hidi gaga	S	x	x	x	x		Seed and root extracts have medicinal value
Steganotaenia araliaceae Hochst.	Lukaluke	S/T (?)	√	√	√	x	Leaves	_
Terminalia brownii	Biresa	T	√	√	√	x	Leaves	Incense; fumigation wood; bark extracts for yellow dyes; wood carved into pestles; bark extracts for medicine; shade tree

Table 6.2 Number of woody plant species recorded in the various land use systems, along a distance gradient from water and in the four communal grazing areas.

Sites	Number of species
Land use systems	
Communal	46
Government ranch	31
Traditional grazing reserve	17
Commonly distributed on	
Communal and ranch	26
Communal and traditional reserve	15
Ranch and traditional reserve	13
Distance from water source	
Near	34
Middle	42
Far	38
Commonly distributed on	
Near and middle	30
Near and far	28
Middle and far	31
Communal grazing sites	
Did Yabello	34
Did Harra	25
Dubuluk	25
Melbana	28

Within the sites of the communal grazing land (Figure 6.1), significant differences (P<0.05) were recorded in the densities of the three sites (Did Yabello = 1 318 TE ha^{-1}, Did Harra = 1 088 TE ha^{-1} and Melbana = 1 178 TE ha^{-1}) where 76 %, 45 % and 57 % more woody plants than the Dubuluk grazing site were found, respectively. Results on along a distance gradient from water (Figure 6.2) revealed that differences were not significant (P>0.05). However, densities at the near (a mean of 1 185 TE ha^{-1}) and far (1 124 TE ha^{-1}) sites were 18 % and 12 % higher than middle site, respectively.

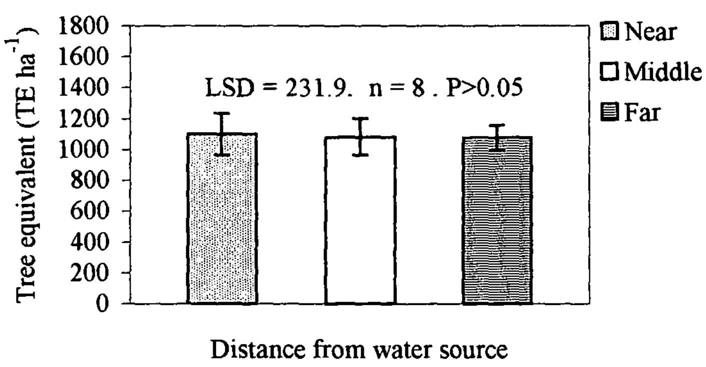


Figure 6.2 Total density of woody plants (TE ha^{-1}) along a distance gradient from water (mean ± Y-error bars (SE)).

6.3.4 Density and proportional distribution of height classes

The results of analysis on height class densities for all woody plants combined under the various land use systems and along a distance gradient from water are presented in Table 6.3. Considering the land use systems, density in the height class of >0-0.5 m was not different (P>0.05) between the three land use systems. For the height class >0.5-1 m, the density on the government ranch (a mean of 372 TE ha^{-1}) was 148 % higher than that of the traditional grazing reserves (P<0.05). Although not significant (P>0.05), the government ranch also had a 71 % higher tree density than the communal sites. Similarly, the difference between the communal and the traditional grazing reserve was not apparent. For the height class >1-1.5 m, densities on the communal sites (a mean of 203 TE ha^{-1}) and government ranch sites (a mean of 231 TE ha^{-1}) were considerably higher by 227 % and 273 % than the traditional grazing reserves, respectively.

Large differences (P<0.01) were obtained for the woody plant density in the height class of >1.5-2 m between the three land use systems. The communal area (a mean of 204 TE ha^{-1}) had 582 % and 974 % higher tree density (>1.5-2 m) than the government and traditional grazing reserve, respectively. The density at the government ranch was 205 % higher than at the traditional grazing reserve. Woody plants in the height class >2-4 m were not recorded on the traditional grazing reserve sites and for the other two sites the differences were not significant (P>0.05). No woody plants were recorded in the traditional grazing reserve in the height class >4-5 m, but woody plant density in this height class for the other two sites differed significantly (P<0.05), with the government ranch (a mean of 66 TE ha^{-1}) having 200 % more woody plants than the communal site. The density of woody plants above 5 m in height showed that traditional grazing reserve (a mean of TE ha^{-1}) was 66.7 % higher than the government ranch sites (P< 0.05).

Along the distance gradient from water, woody plants in the >0-0.5 m height class occurred in a significantly (P<0.05) higher density at the far (a mean of 130 TE ha^{-1}) site compared to the middle (73 TE ha^{-1}) site. No significant (P>0.05) differences were noted for the other height classes (Table 6.3) along the distance gradient from water. Two significant differences were established in woody plant densities between the grazing sites within the communal land. Firstly, there was significantly (P<0.01) fewer plants (>0-0.5 m) at Dubuluk than at the other two other grazing sites (Did Harra and Did Yabello). Dubuluk had less than 69 % of the woody plant density than the Did Harra and Did Yabello sites. Densities of woody plants >5 m were nearly the same (a mean of 30 TE ha^{-1}) at Dubuluk and Melbana, but differed significantly (P<0.01) from the other two sites, having less than 67 % and 80 % of what was present at Did Harra and Did Yabello sites, respectively. Secondly, there were significantly (P<0.05) more plants

(>0.5-1 m) at Melbana than at Did Harra site. In addition, differences in the densities of woody plants in the >1-1.5 m height class at Dubuluk compared to Melbana and Did Yabello were significant ($P<0.05$). Consequently, the woody plant density at Dubuluk (a mean of 120 TE ha^{-1}) was less than 43 % and 57 % of the density at Melbana and Did Yabello, respectively.

Proportionally, woody plants in the first three height classes (>0-0.5 m, >0.5-1 m, >1-1.5 m) accounted for the largest proportion of total density in all the land use systems (Figure 6.3) and along the distance gradient from water (Figure 6.4, 6.5 and 6.6), whereas the last two (>4-5 m and >5 m) contributed the lowest density. The sum of the percentages of the first three height classes along the distance gradient from the water were: near - 82 %, middle-75 % and far-78 %, while the last two height classes were: near-2 %, middle-4 % and far %. Regarding the land use systems, the first three height classes (>0-0.5 m, >0.5-1 m, >1-1.5 m) had the following distribution in total: communal-75 %, government ranch-90 % and traditional grazing reserve-96 %. For the last two classes (>4-5 m and >5 m), the totals were: communal-3 %, government ranch-1 % and traditional grazing reserve-4 %.

6.3.5 Most common woody plants

Data on total density of most common woody plants are presented in Table 6.4.

6.3.5.1 Distance gradient

An increasing trend in tree equivalent density was noted *for Acacia etbaica, A. nilotica* and *Commiphora africana* along the distance gradient away from water. *Acacia etbaica* occurred in lower ($P<0.001$) density at the near (2 TE ha^{-1}) than at the middle (16 TE ha^{-1}) and far (26 TE ha^{-1}) sites.

Table 6.3 Total woody plant density (mean ± SE TE ha^{-1}) of height classes and test of difference for the communal grazing sites, the land use systems and along a distance gradient from water.

			Summary			
Height Class	**Communal grazing sites**		**Land use systems**		**Distance from water source (only communal)**	
>0-0.5	Did Yabello	112.98 ± 25.76^{a}	Communal	90.45 ± 13.96^{a}	Near	93.75 ± 24.89^{ab}
	Did Harra	114.82 ± 34.85^{a}	Ranch	135 ± 18.07^{a}	Middle	63.89 ± 14.04^{a}
	Dubuluk	35.19 ± 9.03^{b}	Kallo	126.39 ± 48.03^{a}	Far	127.08 ± 28.61^{b}
	Melbana	98.81 ± 25.97^{ab}				*
		**				
>0.5-1	Did Yabello	227.79 ± 45.87^{ab}	Communal	218.10 ± 31.51^{ab}	Near	281.25 ± 67.84^{a}
	Did Harra	180.55 ± 47.21^{a}	Ranch	372.23 ± 103.94^{a}	Middle	195.83 ± 61.51^{a}
	Dubuluk	205.56 ± 66.61^{ab}	Kallo	150.00 ± 18.00^{b}	Far	177.08 ±22.69^{a}
	Melbana	258.34 ± 94.04^{b}		*		
		*				
>1-1.5	Did Yabello	282.41 ± 104.26^{a}	Communal	203.66 ± 34.81^{a}	Near	243.06 ± 87.91^{a}
	Did Harra	199.08 ±47.79^{ab}	Ranch	231.48 ± 69.02^{a}	Middle	204.86 ± 53.75^{a}
	Dubuluk	120.37 ± 19.85^{b}	Kallo	62.50 ± 34.72^{b}	Far	163.19 ± 29.42^{a}
	Melbana	212.97 ± 78.11^{a}		*		
		*				
>1.5-2	Did Yabello	181.482 ± 74.07	Communal	204.16 ± 35.05^{a}	Near	165.28 ± 35.03^{a}
	Did Harra	233.35 ± 95.24	Ranch	58.35 ± 23.81^{b}	Middle	252.78 ± 89.93^{a}
	Dubuluk	175.00 ± 71.43	Kallo	19.44 ± 19.44^{c}	Far	194.44 ± 47.03^{a}
	Melbana	226.89 ± 92.59		**		

*= Significant ($P < 0.05$); ** = Highly significant ($P < 0.01$)

Means in the same column with different superscripts are significantly different.

Table 6.3 cont'd

				Summary		
Height Class	**Communal grazing sites**		**Land use systems**		**Distance from water source (communal areas only)**	
>2-3	Did Yabello	268.51 ± 88.89 [a]	Communal	217.59 ± 38.11 [a]	Near	222.22 ± 52.47 [a]
	Did Harra	166.67 ± 35.13 [a]	Ranch	194.45 ± 90.42 [a]	Middle	173.61 ± 74.52 [a]
	Dubuluk	175.93 ± 63.19 [a]	Kallo	0	Far	256.94 ± 74.15 [a]
	Melbana	259.26 ± 108.91 [a]				
>3-4	Did Yabello	103.71 ± 25.92 [a]	Communal	68.06 ± 14.26 [a]	Near	48.61 ± 25.18 [a]
	Did Harra	103.71 ± 32.79 [a]	Ranch	103.71 ± 51.84 [a]	Middle	58.33 ± 24.36 [a]
	Dubuluk	0	Kallo	0	Far	97.22 ± 24.36 [a]
	Melbana	64.82 ± 23.89 [a]				
>4-5	Did Yabello	33.33 ± 20.74 [a]	Communal	22.22 ± 7.76 [a]	Near	12.50 ± 12.49 [a]
	Did Harra	16.68 ± 16.39 [a]	Ranch	66.68 ± 48.64 [b]	Middle	25.00 ± 16.36 [a]
	Dubuluk	16.68 ± 16.39 [a]	Kallo	0	Far	12.50 ± 12.49 [a]
	Melbana	0		*		
>5	Did Yabello	152.79 ± 73.57 [a]	Communal	76.39 ± [ab]	Near	45.83 ± 29.99 [a]
	Did Harra	91.68 ± 91.64 [ca]	Ranch	30.57 ± 30.55 [a]	Middle	114.58 ± 76.94 [b]
	Dubuluk	30.57 ± 30.55 [b]	Kallo	91.67 ± 50.00 [b]	Far	68.75 ± 48.20 [ab]
	Melbana	30.57 ± 30.55 [b]		*		*
		**				

The difference of *A. nilotica* was also significant ($P<0.001$), with the near site having 81 % and 83 % less woody plants than the middle and far sites, respectively. For *C. africana* the trend indicated that density at the far site (mean of 371.1 TE ha^{-1}) was 122 % and 133 % higher ($P<0.001$) than at the near and middle sites, respectively. In contrast the density of *Acacia seyal* revealed the reverse trend although the difference between the near (26 TE ha^{-1}) and the middle (15 TE ha^{-1}) sites was not significant ($P>0.05$), whereas the others differed significantly ($P<0.01$).

The density of *Acacia drepanolobium* differed markedly different between near and middle ($P<0.001$), middle and far ($P<0.01$) and near and far ($P<0.05$) sites. The density at the middle site was 94 % and 81 % less than at the near and far sites, respectively. The density at the near site was 219 % higher than at the far site. Similarly, density of *A. brevispica* differed significantly between the near and middle ($P<0.001$), middle and far ($P<0.01$) and near and far ($P<0.01$) sites. Although a similar trend was noticed for *Lannea floccosa*, the difference was not apparent. For *Grewia tembensis*, the differences in density between the near, middle and far sites were not significant ($P>0.05$). *Acacia tortolis* and *Ormocarpum mimosoides* had the highest density (82 TE ha^{-1}, $P<0.05$; 57 TE ha^{-1}, $P< 0.01$, respectively) at the middle sites. The near and the far sites did not show statistically significant difference for both species ($P>0.05$).

6.3.5.2 Land use systems

Density of *Acacia drepanolobium* differed markedly ($P<0.001$) between the communal and traditional grazing reserve, government ranch and traditional grazing reserve ($P<0.001$) and communal and government ranch ($P<0.01$) (Table 6.4). The density at the grazing reserve was 95 % and 99 % less than at the government ranch and communal land, respectively.

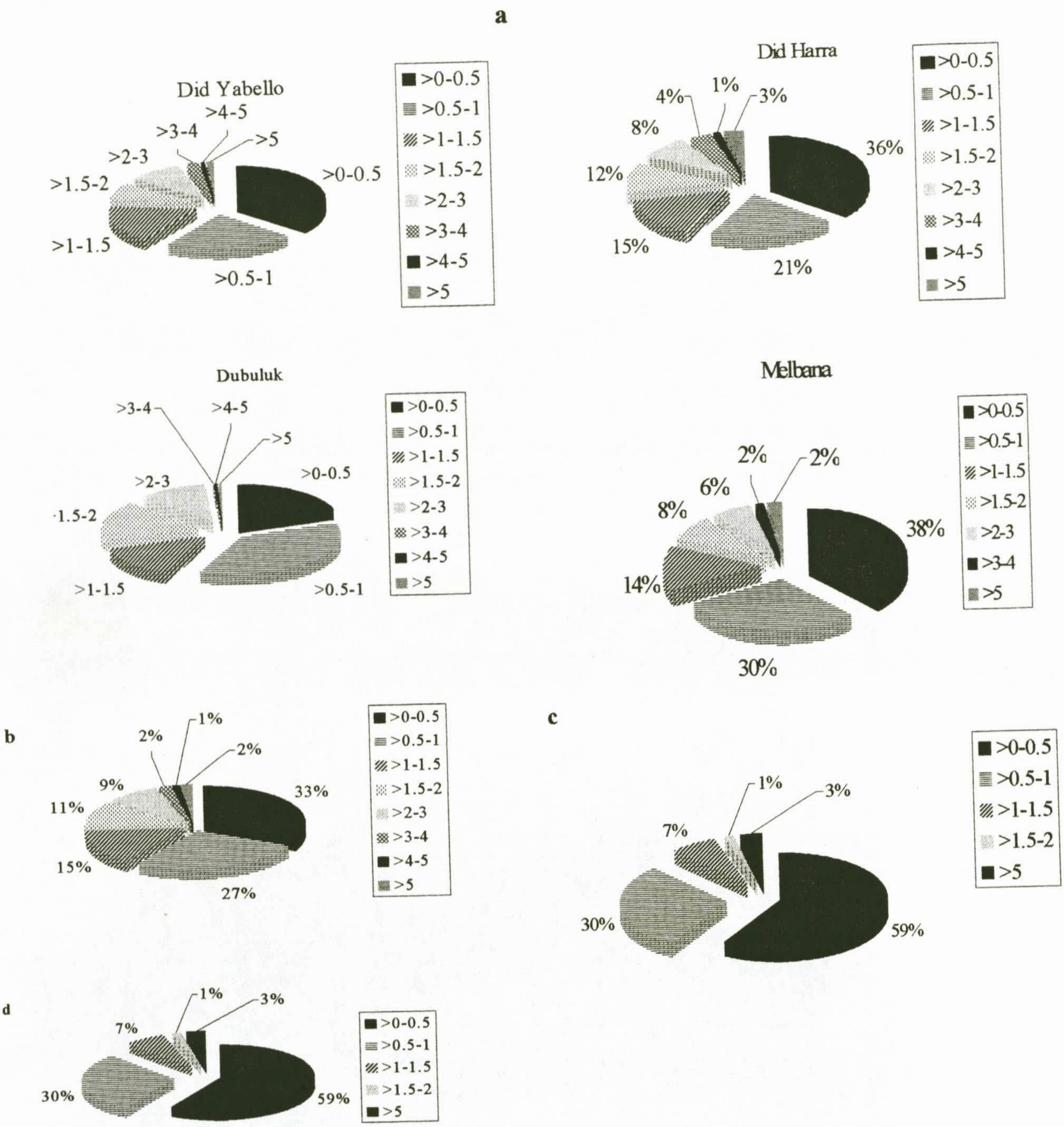


Figure 6.3 Proportional distribution of height classes of all woody plants (number ha^{-1}) under the land use systems for (a) grazing sites within the communal area, (b) communal mean, (c) government ranch, (d) traditional grazing reserve.

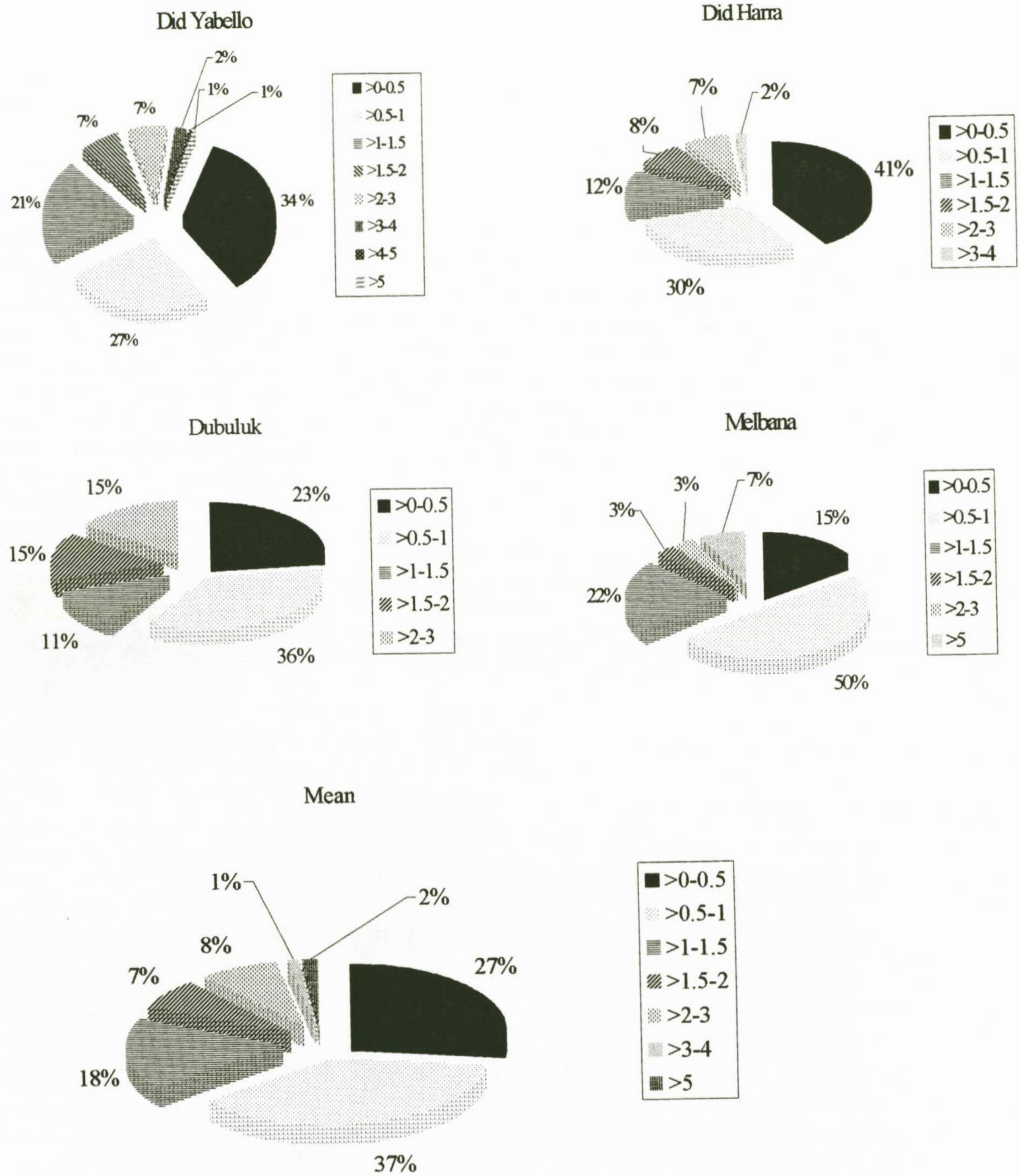


Figure 6.4 Proportional distribution of height classes of all woody plants (number ha^{-1}) at the near (mean) sites from water sources (communal sites = 4).

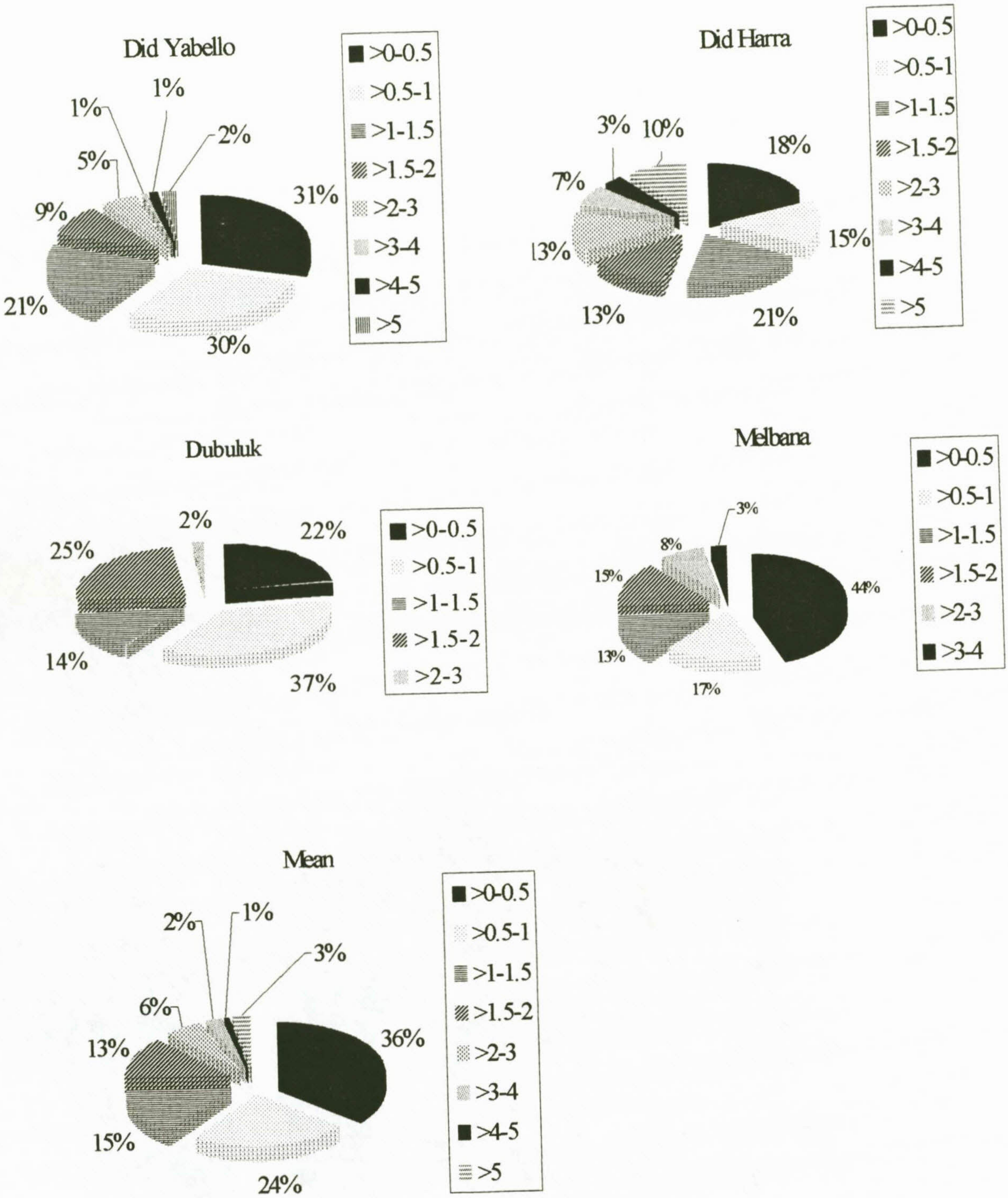


Figure 6.5 Proportional distribution of height classes of all woody plants (number ha^{-1}) at the middle sites from water sources (communal sites = 4).

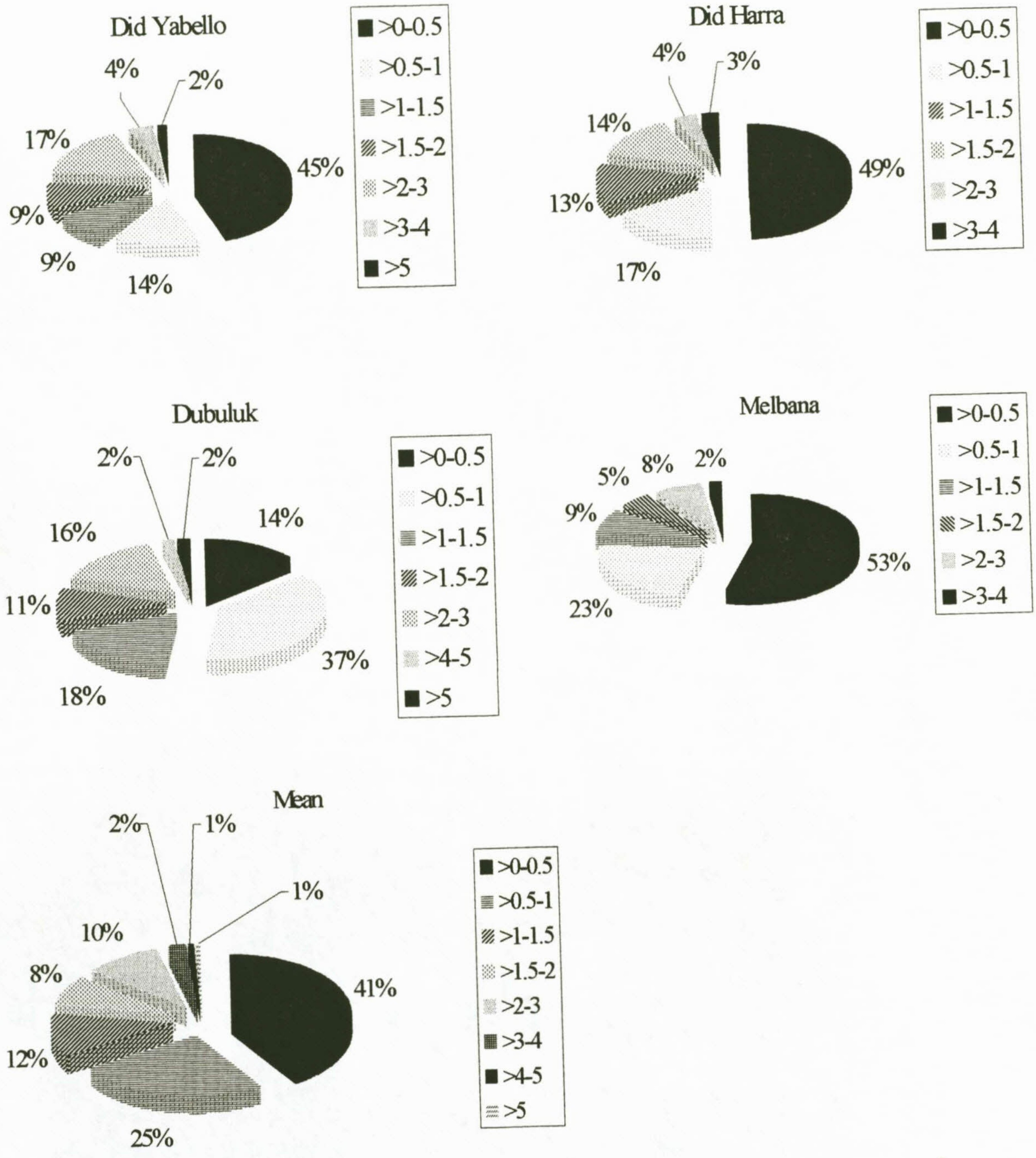


Figure 6.6 Proportional distribution of height classes of all woody plants (number ha^{-1}) at the far sites from water sources (communal sites = 4).

The plant density at the communal area was 280 % higher than the at government ranch. The density of *Acacia tortilis* differed similarly, with the traditional grazing reserve being 94 % and 98 % less dense than the government ranch and communal area respectively. The density at the communal area was 299 % higher than at the government ranch. Results on *A. nilotica* indicated that significant difference in density was obtained between the communal and ranch, communal and traditional grazing reserve (P<0.001), and government ranch and traditional grazing reserve (P<0.05). The traditional grazing reserve had less than 83 % and 97 % of the densities recorded in the government ranch and communal land, respectively. The communal land had more than 600 % of the density recorded at the government ranch. Density of *Acacia seyal* did not differ (P>0.05) significantly among the land use systems.

There was no significant difference (P>0.05) in the density of *A. brevispica* (TE ha^{-1}) between the communal and government ranch. Density of *Acacia brevispica* was not recorded in the traditional grazing reserve. For *A. etbaica*, marked variation in density (P< 0.05) was revealed only between communal (16 TE ha^{-1}) and traditional grazing reserve (4 TE ha^{-1}) sites. Significant difference (P<0.05) for *C. africana* revealed that the communal area had 282 % and 222 % higher density than the government ranch and traditional grazing reserve sites respectively. The density of *Lannea floccosa* was the lowest at the ranch (3 TE ha^{-1}) and the highest at the communal area (64 TE ha^{-1}). The density of *Grewia tembensis* did not differ (P>0.05) between the land use systems. For *O. mimosoides*, the density difference was only apparent (P<0.05) between the communal (21 TE ha^{-1}) and the government ranch (79 TE ha^{-1}).

6.3.5.3 Grazing sites within the communal area

Data on *A. drepanolobium* showed a significantly higher (P<0.05) density at Did Harra than at Melbana (Table 6.4). The density difference between Did Harra and Did Yabello was not apparent, although the latter had a 15 % higher density than the former.

Table 6.4 Density of common woody plant species (mean ± SE TE ha^{-1}) under land use systems and along distance gradients from water

Height class	Communal grazing sites				Land use systems			Distance from water (communal only)		
	Did Yabello	Did Harra	Dubuluk	Melbana	Communal	Government ranch	Traditional reserve	Near	Middle	Far
Acacia. drepanolobium	123.34 ^{ab} ± 68.62	141.67 ^{a} ± 128.55	-	40.83 ^{b} ± 44.67 *	81.16 ^{a} ± 37.38	21.32 ^{b} ± 21.29	1.39 ^{c} ± 1.39 ***	177.47 ^{a} ± 83.76	10.43 ^{b} ± 7.74	55.59 ^{c} ± 31.18 ***
Acacia etbaica	0.23 ^{a} ± 0.21	28.74 ^{b} ± 25.51	-	36.14 ^{b} ± 36.10 ***	16.26 a ± 2.01	9.27 ^{ab} ± 5.10	4.17 ^{b} ± 4.17 *	0.18 ^{a} ± 2.21	19.48 ^{b} ± 15.51	29.20 ^{b} ± 21.40 ***
Acacia tortilis	91.50 ^{ab} ± 42.65	107.43 ^{a} ± 81.88	40.00 ^{b} ± 17.30	59.00 ^{cb} ± 28.53 **	66.71 ^{a} ± 23.54	16.69 ^{b} ± 11.65	1.38 ^{c} ± 1.38	51.41 ^{a} + 19.71	102.11 ^{b} ± 53.79	46.51 ^{a} + 13.37 *
Acacia nilotica	20.37 ^{a} ± 19.28	68.52 ^{b} ± 39.19	46.30 ^{ab} ± 26.35	2.78 ^{c} ± 2.78 ***	34.49 ^{a} ± 13.00	5.56 ^{b} ± 4.54	1.38 ^{c} ± 1.38 ***	5.56 ^{a} ± 3.42	46.53 ^{b} ± 25.60	51.39 ^{c} ± 18.57 ***
Acacia seyal	42.62 ^{a} ± 24.74	-	18.54 ^{a} ± 11.71	2.82 ^{b} ± 1.89 ***	15.97 ^{a} ± 7.30	14.85 ^{a} ± 14.81	18.06 ^{a} ±11.87	21.56 ^{a} ± 10.74	19.50 ^{a} ± 15.57	6.98 ^{b} ± 4.46 **
Acacia brevispica	266.65 ^{a} ± 162.8	-	2.79 ^{b} ± 2.78	- ***	62.22 ^{a} ± 44.73	64.86 ^{a} ± 51.72	-	121.34 ^{a} ± 104.84	9.34 ^{b} ± 46.69	58.35 ^{c} ± 32.44 ***
Commiphora africana	139.50 ^{a} ±118.62	451.50 ^{b} ± 119.85	210.75 ^{ac} ± 78.51	157.43 ^{ac} ± 74.74 *	237.28 ^{a} ± 59.31	62.06 ^{b} ± 50.08	73.61 ^{b} ± 32.02 *	170.15 ^{a} ± 16.03	162.58 ^{a} ± 55.98	379.10 ^{b} ± 122.94 ***
Lannea floccossa	35.19 ^{a} ±17.78	80.58 ^{bc} ± 37.17	40.74 ^{ab} ± 7.94	99.10 ^{bc} ± 53.57 *	63.89 ^{a} ± 16.82	2.81 ^{b} ± 1.9	15.28 ^{ab} ± 10.49 ***	88.20 ^{a} ± 31.01	43.07 ^{a} ± 19.40	60.44 ^{a} ± 22.80
Grewia tembensis	110.17 ^{ac} ± 58.74	43.54 ^{b} ± 28.41	32.50 ^{b} ± 375.45	29.17 ^{b} ± 18.30 ***	56.90 ^{a} ± 94.38	91.67 ^{a} ± 50.46	41.67 ^{a} ± 33.06 *	51.36 ^{a} ± 38.20	58.91 ^{a} ± 30.65	60.42 ^{a} ± 24.05
Ormocarpum mimosoides	25.04 ^{a} ± 23.90	0.96 ^{b} ± 0.93	25.03 ^{a} ± 19.96	31.51 ^{a} ± 20.62 ***	20.60 ^{a} ± 9.04	78.71 ^{b} ± 67.87	47.22 ^{a} ± 41.85 **	27.10 ^{a} ± 14.56	19.48 ^{a} ± 41.74	15.32 ^{a} ± 12.23

* = Significant ($P < 0.05$); **/*** = Highly significant ($P < 0.01/0.001$); Means in the same column with different superscripts are significantly different.

Plant density of *A. etbaica* was the lowest (P<0.01) at Did Yabello and the highest at Melbana. In the case of *A. tortilis*, marked difference (P<0.01) was obtained between Did Harra (107 TE ha^{-1}) and Dubuluk (40 TE ha^{-1}); and between Melbana (59 TE ha^{-1}) and Did Harra (P<0.05). Results on the density of *A. nilotica* indicated that it was highest at Did Harra (69 TE ha^{-1}) and lowest at Melbana (3 TE ha^{-1}). *Acacia seyal* occurred in significantly lower density (P<0.005) at Melbana (3 TE ha^{-1}) than Dubuluk (19 TE ha^{-1}) and Did Yabello (43 TE ha^{-1}). *Acacia brevispica* was recorded only at Did Yabello and Dubuluk sites, with far higher density being recorded at Did Yabello (266 TE ha^{-1}) than at Dubuluk (3 TE ha^{-1}). Tree equivalent density of *C. africana* at Did Harra was higher (P<0.05) by 224 %, 114 % and 186 % than at Did Yabello, Dubuluk and Melbana sites, respectively. For *L. floccosa*, the density was highest at Melbana and lowest at Did Yabello. The highest density for *G. tembensis* was recorded at Did Yabello (110 TE ha^{-1}) and the lowest at Melbana (29 TE ha^{-1}). *Ormocarpum mimosoides* had the lowest density (1 TE ha^{-1}) at Did Harra and highest at Melbana (31 TE ha^{-1}).

6.3.5.4 Proportional distribution of height classes

The proportional distribution of height classes of the common woody plant species is presented in Figures 6.7 to 6.11. Most of the species had in total the largest proportion in the height range >0-1.5 m (first three classes) and the lowest proportion within the height range >4 m (last two classes). The proportion of the first three classes (in total) for *A. drepanolobium* was nearly 71 %, 100 % and 74 % in the near, middle and far distances from water; and 58 % and 100 % on the communal, government ranch and traditional grazing reserve respectively. For *A. tortolis*, the proportion of the first three height classes (>0-1.5) was: near - 63 %, middle-40 %, far-66 %, communal-65 %, government ranch and traditional grazing reserve-100%. The proportion of the first three height classes (0.1-1.5 m) for *A. nilotica* was less than 50 % in the middle and far sites whereas it was 51 %, 50 % and 100 % on the communal, government ranch and traditional grazing reserve, respectively. The distribution of the first three height classes

(>0-1.5 m) for *Acacia seyal* was more than 80 % in the middle and far sites; and under the land use systems, the range was 58-100 %. *Acacia brevispica* was not recorded at the traditional grazing reserve, but 56 % of this vegetation from the mentioned class (>0-1.5 m) was distributed over the communal and government ranch sites. The distribution of the first three height classes for *A. brevispica* (>0-1.5 m) along a distance gradient from water was: near-59 %, middle-50 % and far-63 %. For *G. tembensis* the distribution of this height class ranged between 92-97 % along the distance gradient from water, and 92-100 % under the land use systems. The same data were recorded for *O. mimosoides* and *L. floccosa*. The proportional distribution in the >0-1.5 m height class of *C. africana* was 100 % at the government ranch and traditional grazing reserve, 52 % at the communal, 51 % at the near, 70 % at middle and 79 % at the far sites.

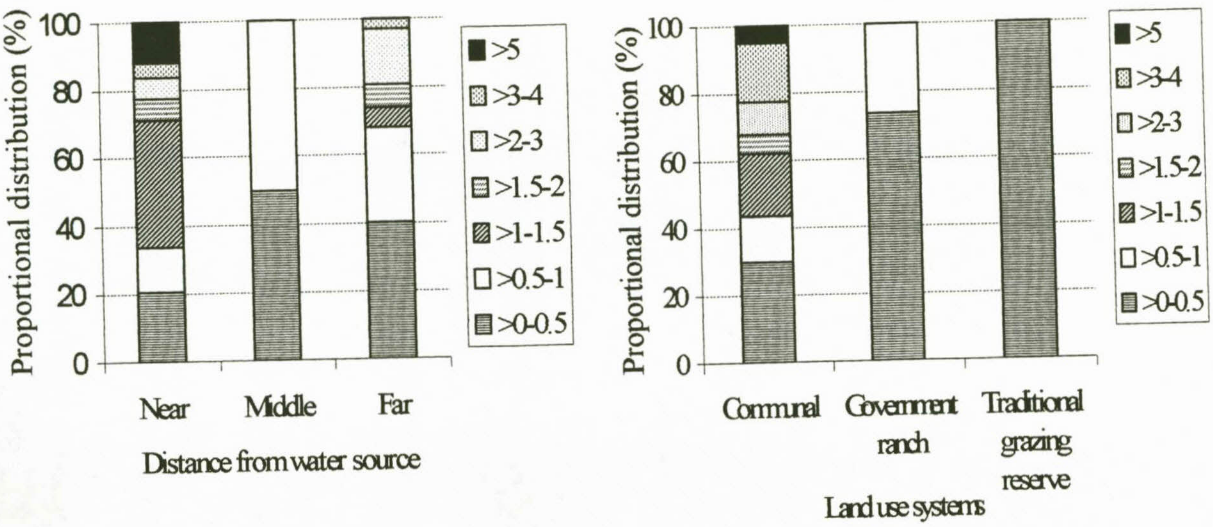
6.4 DISCUSSION

6.4.1 Common use of woody plants

Woody plants that were recorded in this particular study and not mentioned in earlier reports (Wilding 1984) were: *Cadaba farinosa, Ormocarpum trichocarpum, Hibiscus sparseaculeatus, Ampelocissus schimperiana, Asparagus racemosus, Lycium shawii, Seriocomopsis pallida* and *Steganotaenia araliaceae.*

The first three species were indicated by the pastoralists as having good forage value. Other important woody plants that should receive development and research attention as forage resources include browses such as *Cordia gharaf, Rhus natalensis, Grewia tembensis* and unidentified species locally known as "Kete". *Euclea shimperi, Dichrostachys cinerea, Pappea capensis, Acacia etbaica, Grewia bicolor, O. mimosoides, Acacia tortolis, Balanites aegyptica* were reported earlier (Coppock 1994) to also deserve attention as forage resource. In the present finding, however, except *A. tortilis*, the pastoralists indicated that the rest have low forage value. Particularly, *E. shimperi*, which, despite reportedly extremely low forage value, is favoured by cattle, sheep, goats and camels, as it is often the only source of feed under extreme drought conditions. *Acacia brevispica* was found to be one of the most important browse species, which is exclusively browsed by goats and camels.

a



b

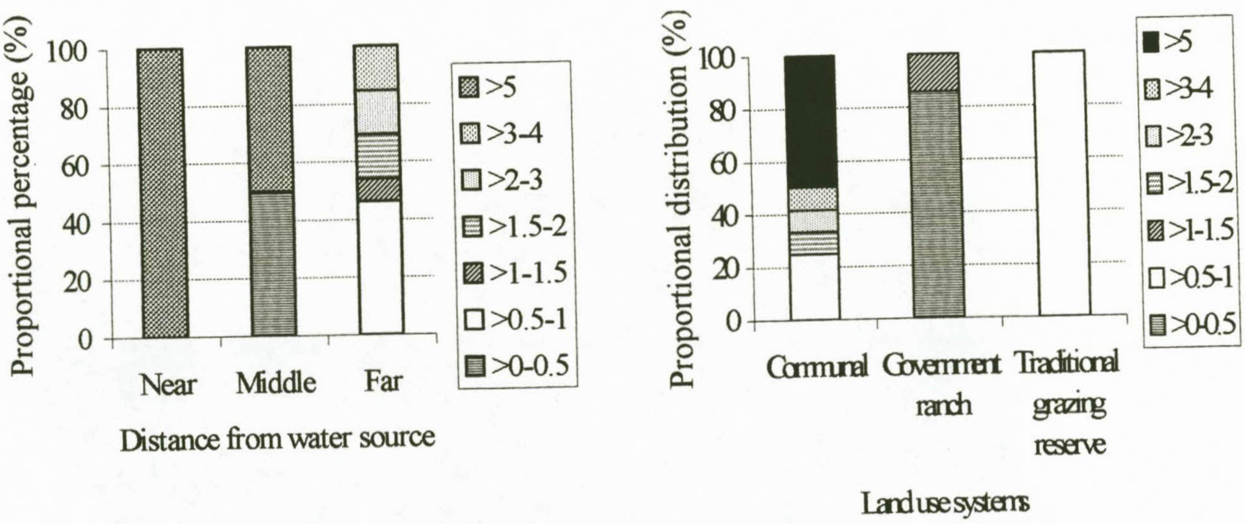
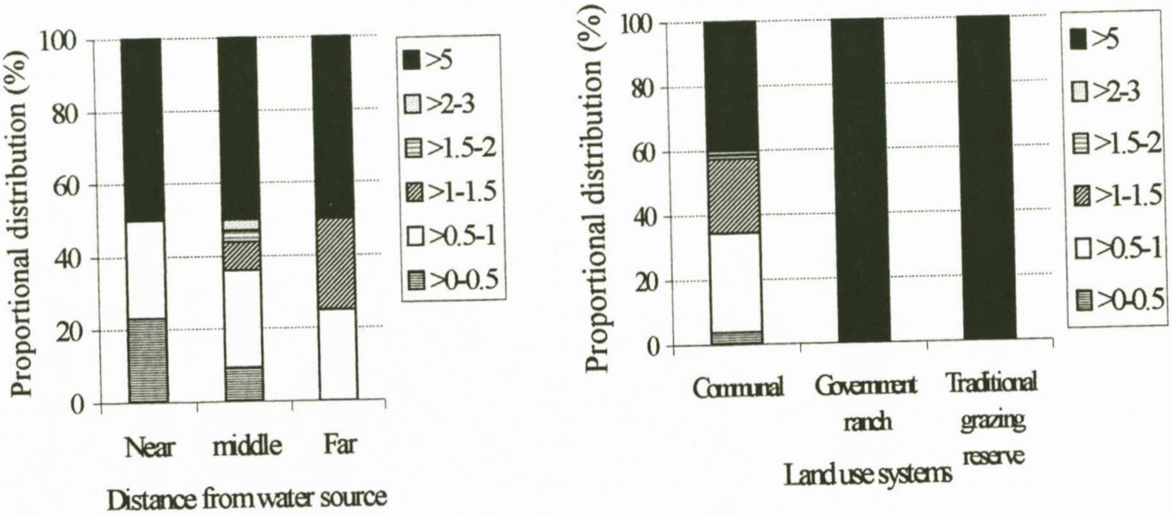


Figure 6.7 Proportional distribution of height classes along the distance gradient from water and under various land use systems for (a) *Acacia drepanolobium*, and (b) *A. etbaica*.

a



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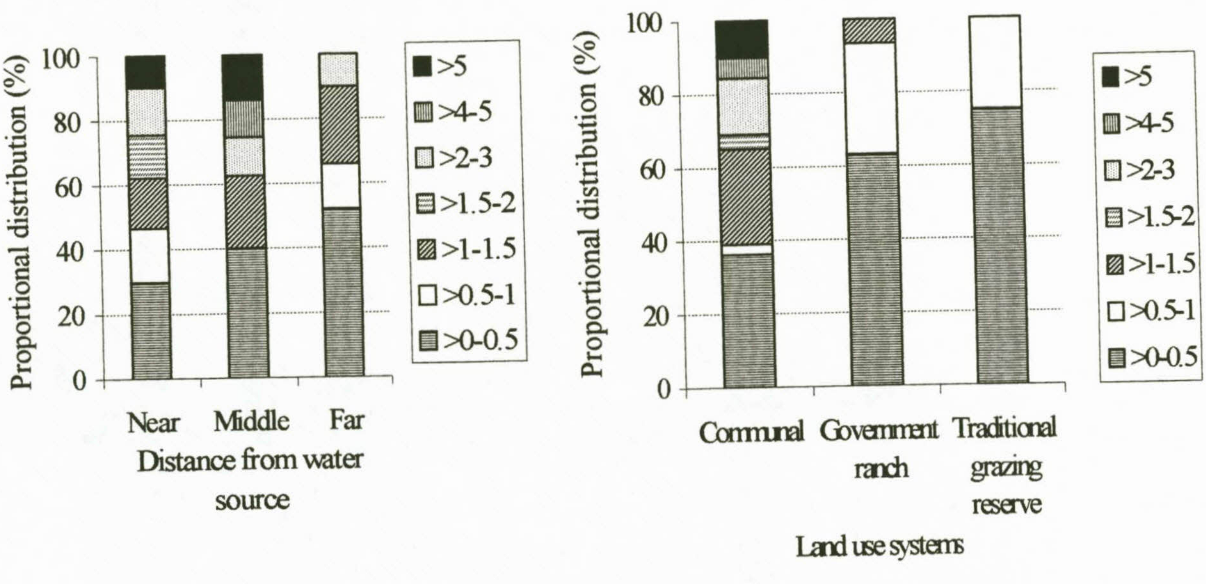
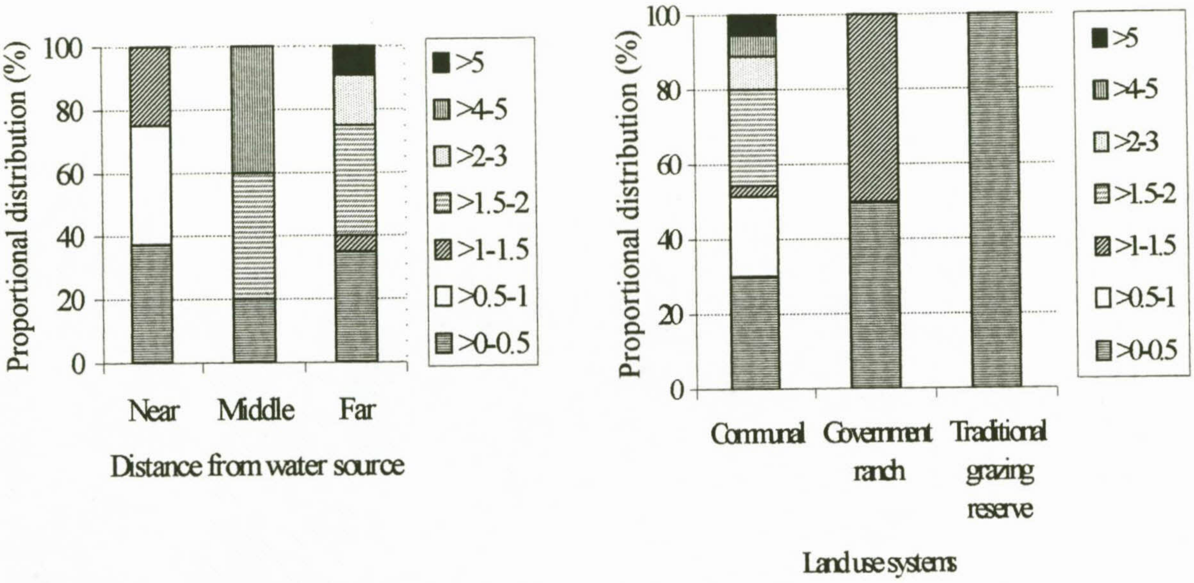


Figure 6. 8 Proportional distribution of height classes along the distance gradient from water and under various land use systems for (a) *Acacia mellifera*, and (b) *A. tortilis*.

a



b

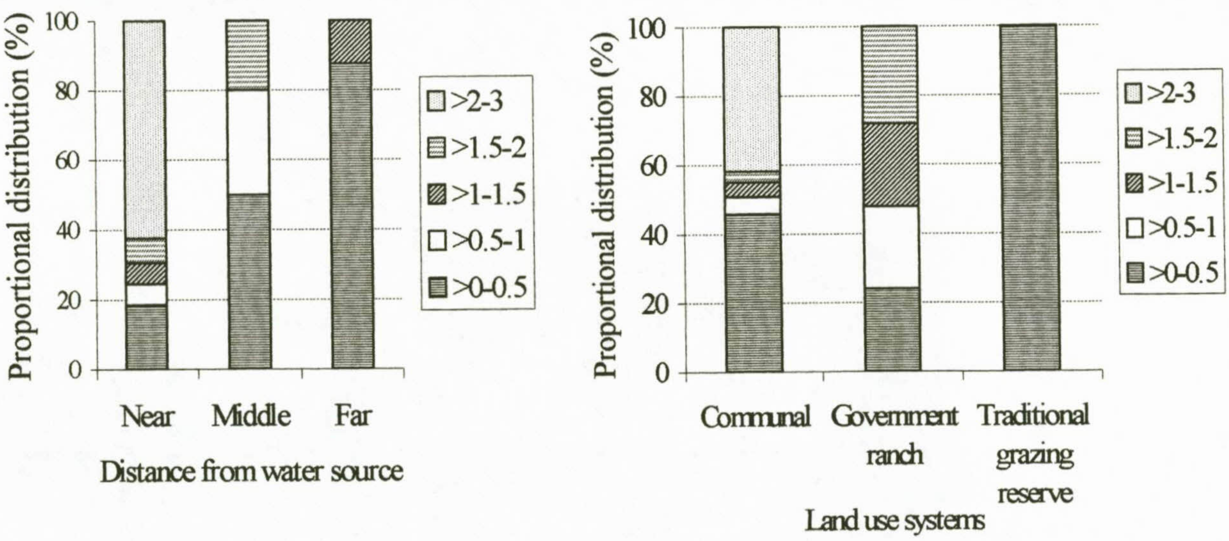
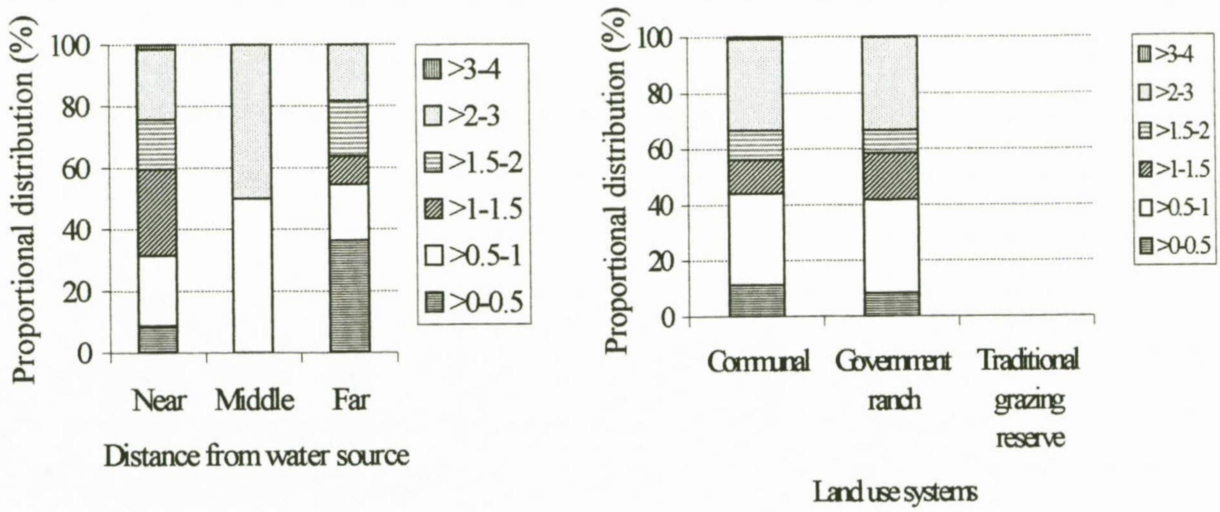


Figure 6. 9 Proportional distribution of height classes along the distance gradient from water and under various land use systems for (a) *Acacia nilotica*, and (b) *A. seyal*.

a



b

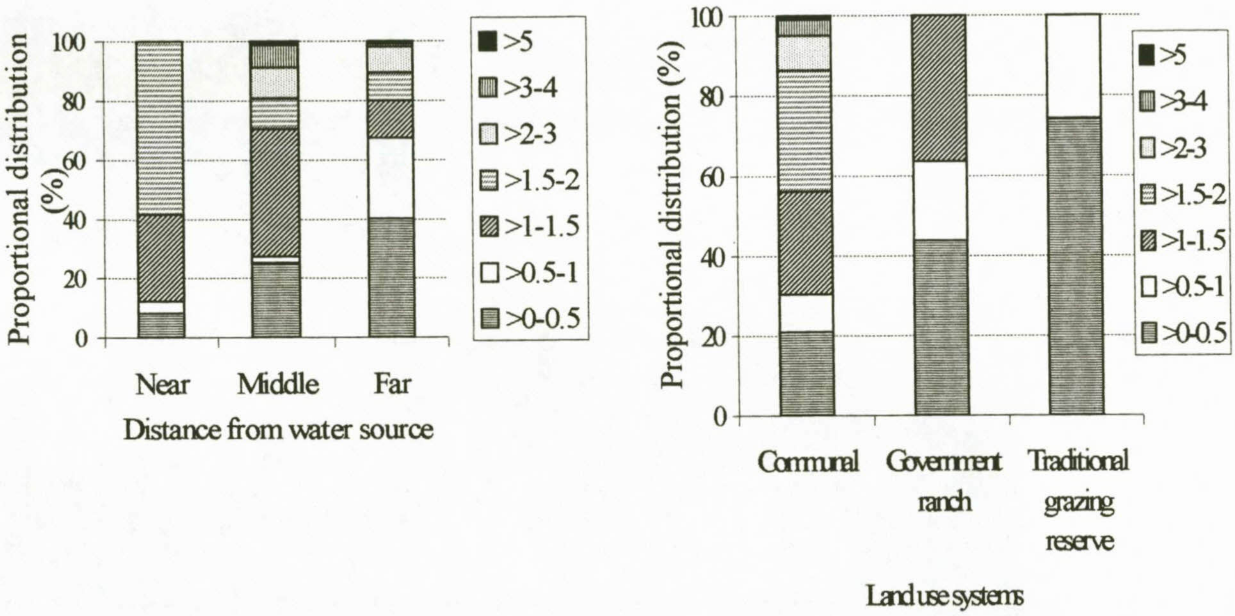
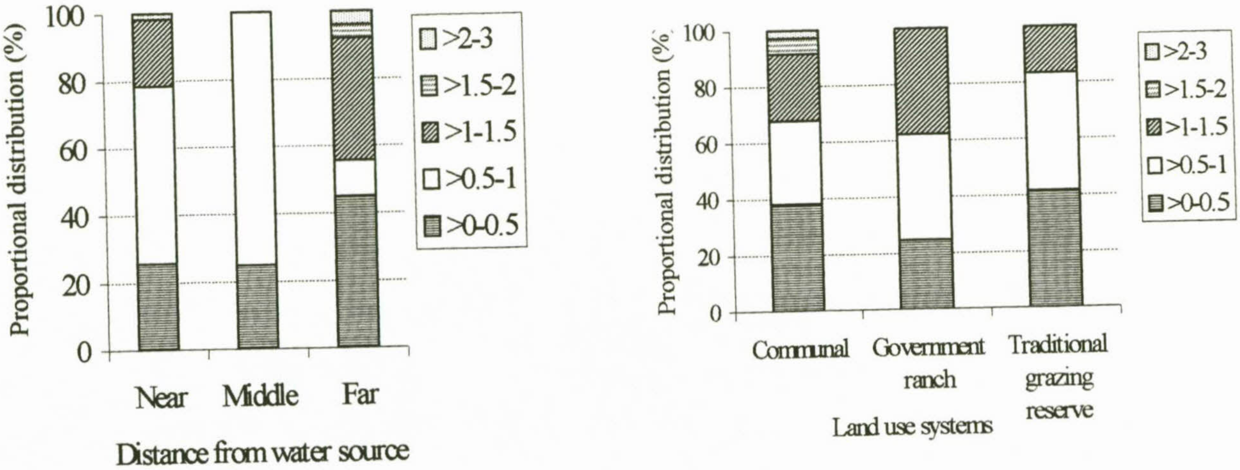


Figure 6.10 Proportional distribution of height classes along the distance gradient from water and under various land use systems for (a) *Acacia brevispica*, and (b) *C. africana*.

a



b

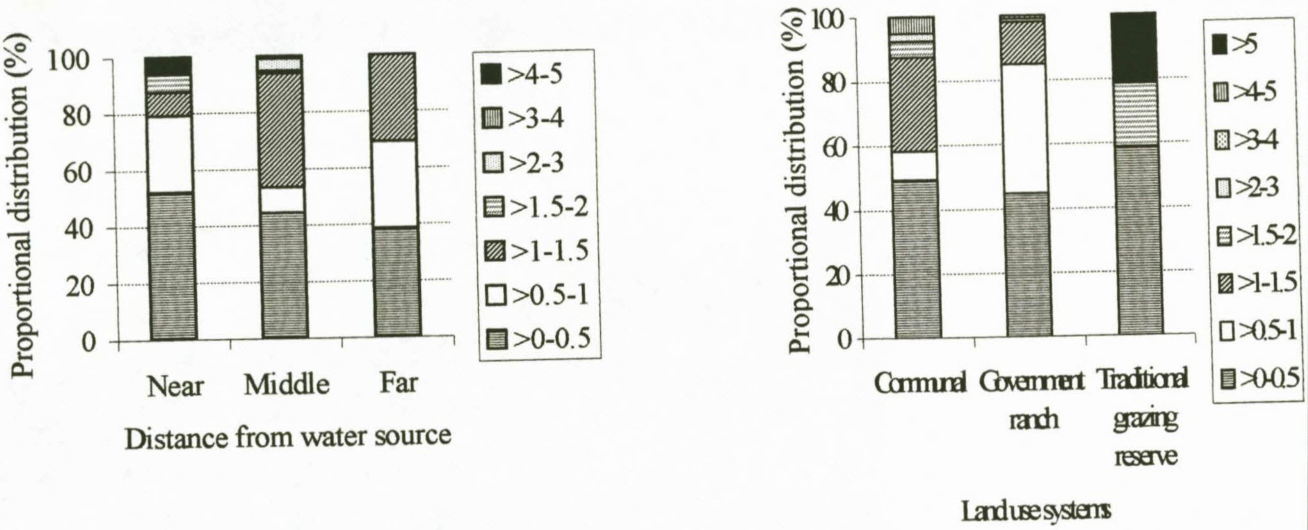


Figure 6.11 Proportional distribution of height classes along the distance gradient from water and under various land use systems for (a) *Grewia tembensis*, and (b) *Ormocarpum mimosoides*.

Acacia drepanolobium, *Albizia amara* and *Acacia mellifera* were reported earlier as having poor forage value (Coppock 1994), which is in agreement with the present finding. In fact, there may be an abundance and a variety of browse species in Borana rangelands although not all are suitable forages based on morphological features and/or variable concentration and types of compounds, such as polyphenolics. In this particular study, *Aloe* species, *Ampelocissus schimperiana*, *Endostemen tereticaulis*, *Euphorbia tirucalli*, *Gardenia volkensii*, and *Solanum somalense* were found not to have sufficient forage value. Such unpalatable species, some having high polyphenolics, tend to be abundant in the Borana rangelands (Woodward 1988). While this suggests that heavy browsing pressure might have led to the persistence of unpalatable and less palatable plants, site specific effects may also be a factor. Notwithstanding, it was theorized that plants on nutrient-poor (eroded) soils have 'more to lose' from excessive herbivory, and may consequently invest more resources into concentrating and/or building defensive compounds and/or physical defenses (Coley *et al.* 1985).

As previously mentioned some woody plants have traditional medicinal values for human beings and animals (livestock) (Table 6.1). It is not surprising that the Borana have an excellent knowledge and experience of using such native plants. In this regard, plants used for this purpose may play a role in developing more sustainable health practices in situations where imported drugs are expensive or unavailable. Research to confirm stated properties of various plant compounds is thus required.

6.4.2 Total density of woody plants

As mentioned earlier, the traditional grazing reserve had a significant lower density of woody plants expressed in terms of tree equivalent than the other land use systems. In addition, there was no marked difference between the communal and government ranch sites in the total density of woody plants. In the previous chapter, it was mentioned that the grass composition did not vary much between the ranch and traditional grazing reserve, whereas in this study, the woody plant density was found to differ considerably.

Based on the results under the land use systems, it can be speculated that the government ranch represents an area with a history of heavy grazing some years back, and hence woody plants had increased, and consequently the stocking rate was reduced (perhaps due, in part, to the heavy utilization of grasses). In recent history, the ranch has been in a phase of recovery in terms of improved herbaceous layer, most specifically with an improved grass species composition.

The lower density of woody plants on the traditional grazing reserve can also be ascribed to the maintenance of a nearly optimum stocking rate as well as recurrent mechanical clearance of woody plants. This is one of the management options that the Borana pastoralists practice to maintain good grass cover in such enclosures.

Within the communal area, sites with a greater external influence (Did Yabello and Did Harra) and with a long history of heavy grazing impact in response to the concentration of large capacity deep wells (Melbana) had significantly more woody plants than the fourth site, Dubuluk. This last site, similar to Melbana, is an area with a deep well, but with a fewer concentration of wells of lower capacity. In Did Harra, an earlier preliminary survey reported a density of 640 TE ha^{-1} (Coppock 1995), which has nearly doubled in the present finding. No marked variation was observed in the total density of woody plants along the distance gradient from water, neither did it show an increasing or decreasing trend with distance away from the water points. The absence of significant variation may explain the occurrence of severe disturbance beyond the degradation gradient.

The hypothesized average number of woody plants in the semi-arid Borana rangeland regarded as a threshold value above which it can be ascribed as severely encroached was 1100 TE ha^{-1} (Billé & Assefa 1984). So therefore, except for the traditional grazing reserve, overall figures (see section 6.3.3) in this investigation showed the increased advancement of woody plants in the study areas. Bush encroachment was also visually observed in a number of grazing sites outside the study areas.

Heavy grazing pressure is considered one of the most important factors that cause bush encroachment. An increase in woody vegetation has been commonly reported to occur as a response to heavy grazing (Norton-Griffiths 1979; Cumming 1982; Sabitti & Wein 1988; Belsky 1989; à Tchie & Gakahu 1989). The ban on burning the grazing land with heavy fuel load, which was proclaimed during the mid 1970's at national level, has also contributed to the expansion of woody vegetation in the Borana rangelands. Results obtained in one of the grazing sites within the communal area (Did Yabello) suggested that cultivation practices, inappropriate to pastoral systems, seems to contribute to an increase of woody plants. Another factor that may be considered as a potential contributor to a high woody plant density is the nature of soil. Results of the soil analysis (Chapter 7) indicated that the soil of the study areas are sandy soil, which are regarded as most susceptible to woody plant increases (Booth & Barker 1981). However, the expectations that sandy soils are more prone to bush encroachment are subject to criticism. Another opinion on woody encroachment is that it is facilitated by grazing that modifies the competitive relations among grasses and woody seedlings for soil water, an interaction which may be more pronounced on fine texture soil than on sandy soils (Walker *et al.* 1981; Walker 1985; Knoop & Walker 1985). In this case the increase in woody vegetation was most likely due to a combination of determinants including a higher density of livestock, reduced mobility of livestock, and a high rainfall that favoured the establishment and survival of woody seedlings (Coppock 1995). Generally, it can be concluded that the overall increase in woody plants in the study areas appears to be due to a gradual thickening of existing stands rather than the expansion of plants into new areas.

6.4.3 Woody plant density and the proportional distribution of height classes

The results of the effects of different land use systems on woody plants indicated that the government ranch and communal area were comparable in terms of the densities for most of the height classes, which in turn were significantly higher than those on the traditional grazing reserve. However, large trees (>5 m) was more abundant on the traditional grazing reserve. This is probably due to the fact that, at the grazing reserve, the pastoralists kept some of the trees to provide shade to the animals. Along the distance gradient from the water, the tree density was generally similar at all distances, showing minimal variations. Considering the grazing sites, it was shown that Dubuluk had fewer woody plants in most of the height classes than the other grazing sites.

Evaluations of the height class distribution of woody plants in the study area revealed the highest abundance in the first three height classes (>0-1.5 m) regardless of land use (75-96 %), and distance from water (75-82 %). In contrast, very few woody plants exceeded a height of 4 m. Subsequently, the abundance of woody plants in the last two height classes (>4-5 m and > 5 m) was very low on all land use systems (1-4 %, and along the distance gradient from water. The dominance of small, low growing plants in woody encroached rangelands was reported in Africa (Friedel 1985, Van Vegten 1981) and Australia (Childes & Walker 1987). Van Vegten (1981) speculated that this is a result of a special genotype with stunted growth and a short life span. This may not hold true for the study area and the abundance of smaller woody plants is more likely a consequence of the spatial and temporal pattern of competition for water and nutrients between the closely spaced woody plants.

The large proportion of low growing plants at the traditional grazing reserve is possibly due to the coppice growth after frequent mechanical clearance of the woody plants. Some pastoralists considered, these abundant low growing woody plants in the communal grazing area, as a 'weed problem'. The higher densities of woody plants in the smaller size classes may indicate the potential for lasting increases. However, smaller size classes (<2 m tall) are more susceptible to fire provided that there is a good understorey of herbaceous plants to support a hot fire (Norton-Griffiths 1979; à Tchie & Gakahu 1989).

6.4.4 Common woody plants

Of the common woody plants identified in the study areas, the most important encroaching species in descending order are: *C. africana, A. drepanolobium, A. brevispica, A. tortilis G. tembensis* and *L. floccosa*. *Acacia drepanolobium* was reported earlier (Coppock 1994) as one of the most conspicuous examples of encroachment by woody plants in the Borana rangelands. This species was found to increase on vertisols (Tamene 1990), while results of this study showed that *A. drepanolobium* is also able to increase on the upland red soil.

The overall trend of the density of individual woody species along the distance gradient from water was not consistent. *Commiphora africana* had the highest density in the furthest zone. Contrary to this, *A. brevispica, A. drepanolobium* and *A. seyal* had the highest density in the immediate vicinity of the water. These results imply that these three species may be good indicators of the disturbance gradient that can occur beyond the degradation gradient. The second hypothesis is that ingested seeds of these species during browsing may not be digested by the browsers. Therefore, the animals carry the seeds through the intestine and excrete them in feces around the watering points during the watering period. This may promote the growth and abundance of these woody plants in the near proximity of the watering points.

All encroaching species had the highest density on the communal land followed by the government ranch and lastly, the traditional grazing reserve. *Acacia brevispica* was not recorded on the traditional grazing reserve. This is because it is frequently cleared by the pastoralists as it does not have forage value for the types of animals that are usually kept in the reserve (usually young calves and milking cows) and also because they believe that this species reduces the understorey grass production.

Considering the grazing sites within the communal area, the prevalence of the most important encroaching woody plants follows the pattern of the intensity of use of the rangeland. As discussed earlier, sites with greater external pressure (Did Yabello and Did Harra) exhibit severe intensity of use and in this case, are focal areas exhibiting the highest density of the most important encroaching species (*C. africana, A. drepanolobium, A. brevispica* and *G. tembensis*). Other species that showed similar results include: *A. tortolis, A. seyal* (highest in Did Yabello), *A. nilotica* (highest in Did Harra) and *L. floccosa* (highest in Melbana). Taking all the study areas and species into account, the largest proportion of encroaching vegetation falls in the height classes that ranged between >0-1.5 m.

6.5 CONCLUSIONS

The following general conclusions can be drawn from this investigation:

(i) There is clear indication of the advancement of severe woody encroachment in the semi-arid Borana rangelands.

(ii) The most important factor that attributes to increased woody vegetation in the semi-arid Borana rangeland is heavy grazing pressure. Other attributing factors include: inappropriate cultivation, reduced mobility of livestock due to settlement and the nature of the soil.

(iii) The problem of woody encroachment in Borana rangelands seems solvable in that the most abundant size classes (0.1-2 m) fall within the range that is vulnerable to burning. Burning needs, however, to take place during the right season when there is a good herbaceous understorey cover.

(iv) The most important encroaching species in the semi-arid Borana rangeland are *C. africana, G. tembensis, A. drepanolobium* and *A. brevispica*.

(v) Examination of *A. drepanolobium* indicated that the distribution of this species is not restricted to vertisols and under the right conditions, it will also increase on the adjacent upland red soils.

CHAPTER 7

SOIL CHARACTERISTICS IN RELATION TO RANGELAND DEGRADATION

7.1 INTRODUCTION

Nutrients such as nitrates, phosphorous, anions, cations and various trace elements are essential to plants (Bell 1982). These elements act as determinants of the composition, structure and productivity of vegetation. It has long been recognized that semi-arid and arid regions of the world are sensitive ecosystems (Evenari *et al.* 1982; Schlesinger *et al.* 1996). Next to the growth limitations imposed by low availability of water, low rates of net primary productivity in arid and semi-arid ecosystems are most often attributed to low availability of nutrients (West & Skujins 1978; Fisher *et al.* 1988; Zhang & Zak 1998). In arid ecosystems, nitrogen (N) and phosphorus (P) are consistently the most limiting nutrients (Snyman 2002).

As in nearly all terrestrial environments, most of the nutrients taken up from the soil by plants in arid ecosystems arise from nutrient cycling rather than native soil origin (Charley & Cowling 1968). Climate and geographical history are of major importance in determining soil properties on a regional and continental scale (Kosmas *et al.* 1993). Landscape position and land use may be the dominant determinants of soil properties under a hill slope. Landscape positions influence runoff, drainage, soil temperature, and soil erosion and consequently soil formation (Aandahl 1948). Differences in soil formation along a hillside result in differences in soil properties (Brubaker *et al.* 1993), which can affect the pattern of plant production, litter production and decomposition. All of these can be related back to local C and N processes (Hobbie 1996). Soil physical properties such as texture and pH have been shown to be correlated to landscape position (Ovalles & Collins 1986). Land use integrates several environmental attributes, which influences nutrient export (Young *et al.* 1996). Land use and soil management practices influence the soil nutrient related processes, such as erosion, oxidation, mineralization and leaching (Lepsch *et al.* 1994), and consequently modify the process of transport and redistribution of nutrients. In rangelands, the type of cover can be a factor influencing the organic carbon content of the soil (Grigal & Ohmann 1992), and moreover soils through land use change also produce considerable alteration (Fu *et al.* 2000).

Grazing by livestock is often regarded as one of the main causes of vegetation and soil degradation in the rangelands of Africa (Sinclair & Fryxell 1985; Warren & Khogali 1992). However, as Dodd (1994) pointed out in a review paper on desertification and land degradation in sub-saharan Africa, " It is common to attribute undesirable changes to livestock and desirable changes to good weather". Indeed, in Ethiopian rangelands, the impact of livestock grazing on soil degradation is not documented because of the scarcity of data obtained under a controlled stocking rate and herd composition and over a period long enough to allow for the effects to be manifested.

The effect of livestock grazing on rangeland proceeds from three processes (Hiernaux *et al.* 1999): plant defoliation due to animal foraging, soil and litter trampling and deposition of faeces and urine. Practically the effects of these processes are hardly separable, but their magnitude and direction may vary independently from one another as they are diversely influenced by soil texture (Valentin 1985) and soil-water content (Hoogmoed & Stroosnijder 1984), herbage phenological status (Hiernaux & Turner 1996), animal species involved (Floate 1981), the stocking rate and type of herd management (Milchunas *et al.* 1998). Each of these processes have short-term effects on vegetation or soils and their retention over time carries long-term effects on the species composition of the vegetation and the ability of the soil to support plant production (Floate 1981).

High grazing pressure has been shown to result in the loss of perennial grasses, reduced ground cover and potential erosion over large areas (Gardener *et al.* 1990). The importance of plant cover for reducing runoff and soil loss is well recognized (Gifford 1985). A good plant cover impedes the flow of runoff water, increasing infiltration and it resists the erosive force of flowing water (Snyman 1998). When soil erosion occurs, it results in the loss of nutrients (West 1991), particularly carbon and nitrogen due to restriction of feedbacks in carbon and nitrogen cycle between plants, atmosphere and soil (Schlesinger *et al.* 1990; Snyman 1999a).

The hooves of grazing animals exert large pressure on soil (Webb & Clark 1981), with the degree of structural damage largely determined by soil-water content at the time of trampling (Warren *et al.* 1986). Two processes can occur in response to trampling: namely; soil compaction, which affects structural form through the loss of pore volume and soil remoulding. This in turn which affects structural stability through the progressive weakening of the soil aggregates as rain water is incorporated and bond between particles are distributed (Mullins & Fraser 1980).

Many studies have identified soil nutrients and their availability to be important factors controlling net primary productivity (Pastor & Post 1986; Seastedt 1991; Snyman 2002). Therefore, describing spatial variability and distribution of nutrients in relation to land use and a disturbance regime is critical for predicting rates of ecosystem processes (Schimel *et al.* 1991), understanding how the ecosystem works (Townsend *et al.* 1995) and assessing future land use change on nutrients (Kosmas *et al.* 2000). In the semi-arid Borana rangelands, where there has been a scarcity of information on soil chracteristics, this topic needs to be one of the focal points of ecological research.

The objectives of this study were to evaluate the status of soil nutrients and physical characteristics:

(i) under three land use systems (communal, government ranch and traditional grazing reserve) and
(ii) along distance gradients from water points (near, middle and far sites).

7.2 PROCEDURE

7.2.1 Soil sampling

Soil sampling was conducted at the end of the growing season (May – June 2001). During each sampling, topsoil samples (to a depth of 200 mm) were taken from each experimental plot (see section 3.2.2.1) at 10 random locations per plot. Each set of 10 samples was bulked, thoroughly mixed, air dried and passed through a 2 mm mesh screen to be ready for later analysis. Three sub samples were taken for analysis.

7.2.2 Physical analysis of soil

Soil texture (particle size) of the experimental samples was determined by means of standard Bouyoucos (hydrometer) method (Day 1965). Analysis conducted included percentages of clay, sand and silt.

7.2.3 Chemical analysis

Analysis conducted included pH (1:2.5 soil water relation extract), percentage total nitrogen (N), percentage organic C, available phosphorus (P) and exchangeable cations, viz. sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca). The Kieldahl method was used to determine percentage total N (Van Reeuwijk 1992). Colorimetric method was employed to analyze the percentage organic C (Baker 1976). The exchangeable cations were extracted with ammonium acetate and analyzed using atomic absorption spectroscopy (Jackson 1970). Available phosphorous was below detectable level by the Bray and Kurt 1-method (Olsen & Sommers 1982).

7.2.4 Soil bulk density

For the determination of soil bulk density, two replicates 100 cm^3 soil cores were taken from each experimental plot using 50 mm wide metallic rings hammered into the top soil. Sampling of soil cores was performed one month after the end of the rainy season. Bulk density was determined by oven-drying at 105°C for 48 hours.

7.2.5 Soil compaction

An estimate of soil compaction was obtained from 20 point measurements per experimental plot with a simple rod penetrometer (Friedel 1987). Compaction readings were taken to a depth of 6 mm. Points were placed 1 m apart on two parallel lines spaced 2 m apart. The length of each line was 10 m. Readings were proportionally taken on open areas and under woody habitats and the values were pooled. Values obtained were then compared with 80 point measurements from a cattle foot path, as a means of standardizing against the potential compaction, and expressed as percentage soil penetration. These data were collected during the short rainy season (September 2002). Measurements were taken about 18 hours after at least 25 mm of rain had fallen, in the absence of which, this amount of rain was simulated by using a water sprinkler.

7.2.6 Data analysis

Analysis of all the soil data was done using ANOVA and *t-test* and following similar procedures indicated in section 5.2.4. Mean results of the soil chemical and physical analysis were presented graphically using Microsoft Excel graphics.

7.3 RESULTS

7.3.1 Exchangeable cations

Results on the exchangeable cations revealed that no marked differences ($P>0.05$) occur in the Ca content of soil under the three land use systems (Figure 7.1a), along the distance gradient from water source (Figure 7.2a), and among the grazing sites within the communal area (Figure7.3a). However, considering the distance gradient, the far site (mean of 15.15 $cmol_c\ kg^{-1}$) had 62.5 % and 48.0 % more Ca than the near and middle sites, respectively. In the communal grazing area, the lowest non-significant Ca content was obtained from the soil collected around Did Yabello, whereas the highest was recorded in the Dubuluk grazing area.

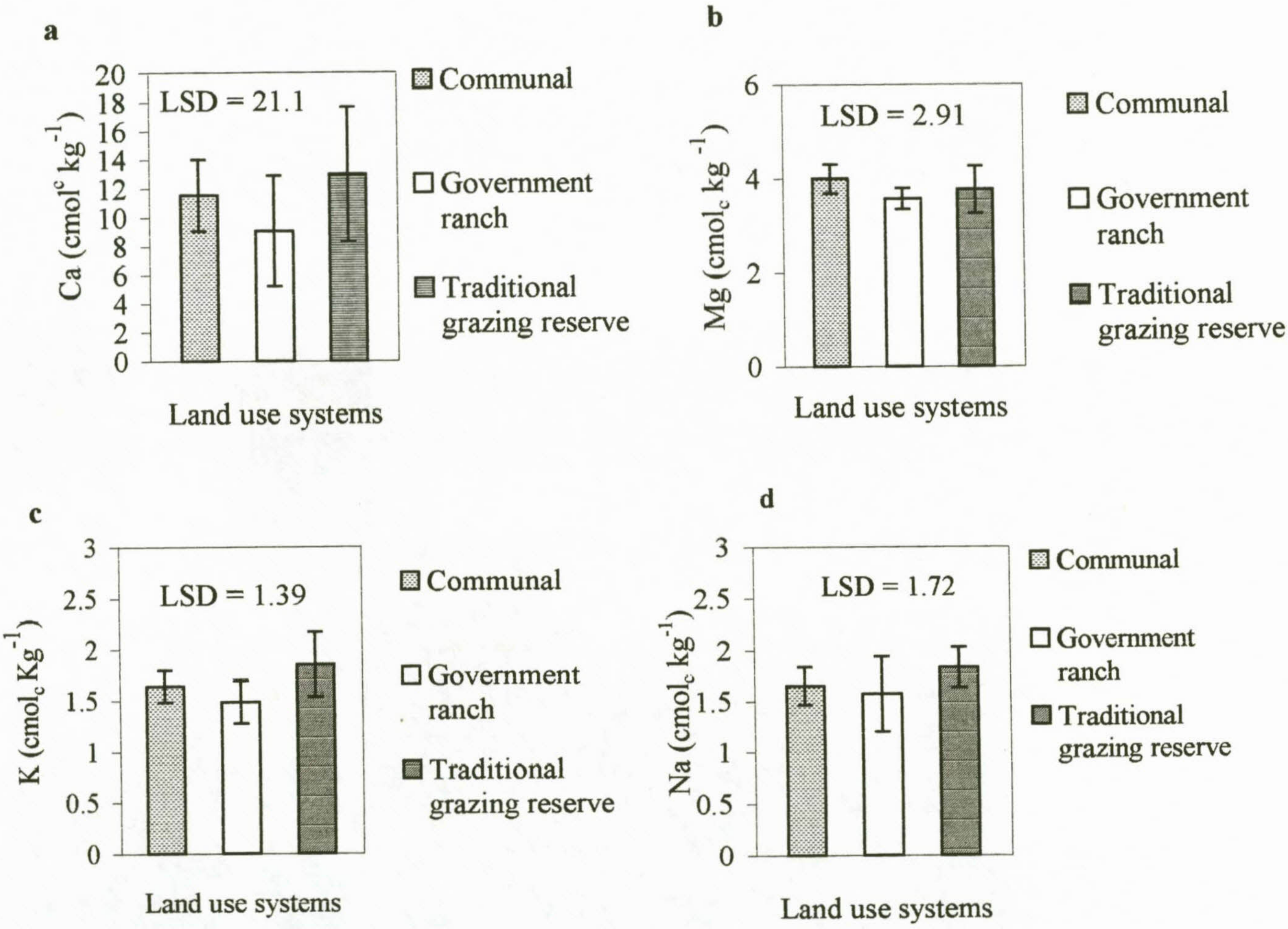


Figure 7.1 The calcium (Ca) (a), magnesium (Mg) (b), potassium (K) (c) and sodium (Na) (d) content ($cmol_c\ kg^{-1}$) of topsoil sampled at the end of the growing season under three land use systems in the semi-arid Borana rangeland. Least significant differences (LSD) were calculated at the 5 % level. Y error bars denote SE.

Conclusive differences in the Mg content of soil were generally lacking (P>0.05) between the land use systems (Figure 7.1b), along a distance radius around water points (Figure 7.2b) and among the four grazing sites in the communal land (Figure 7.3b).

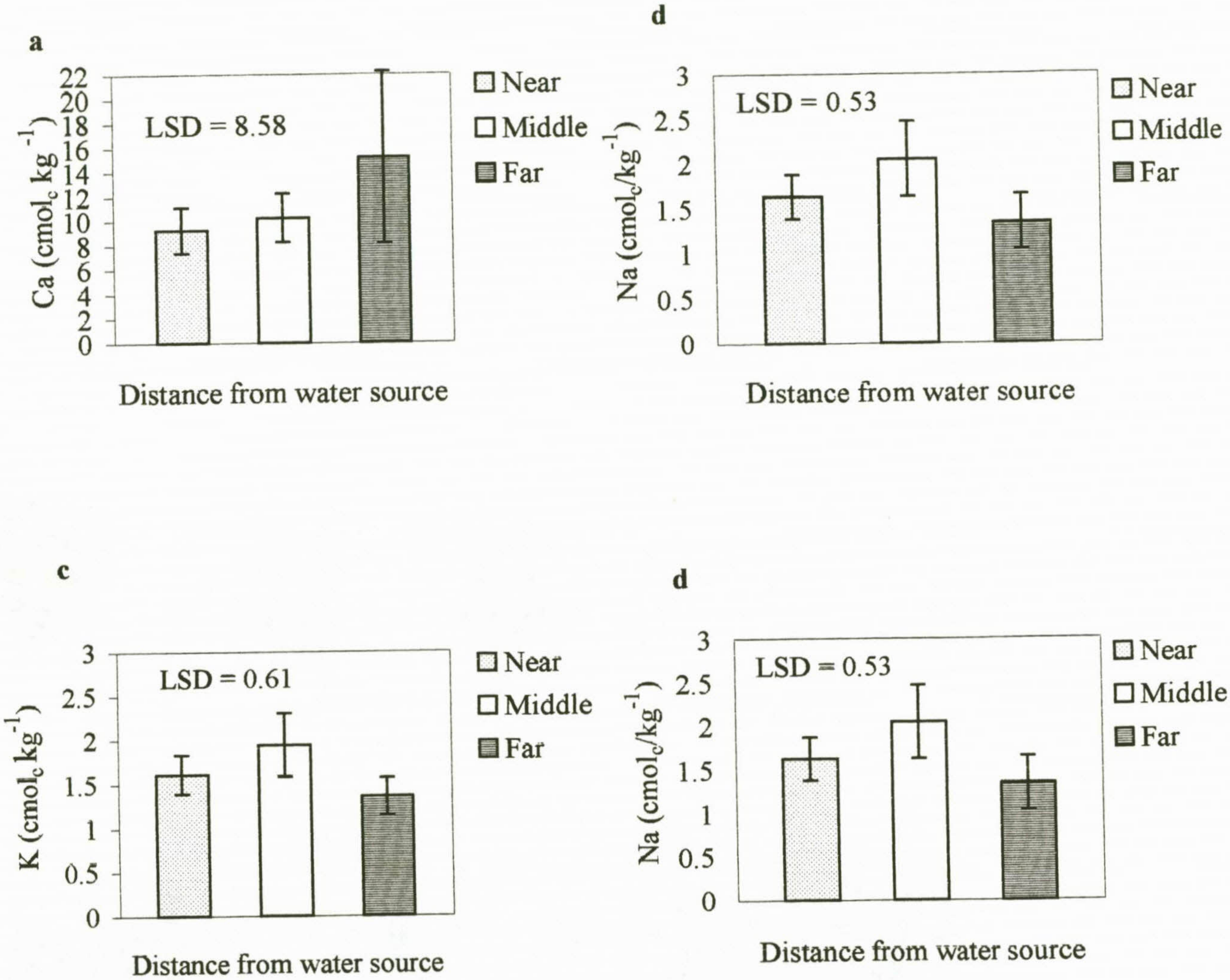


Figure 7.2 The calcium (Ca) (a), magnesium (Mg) (b), potassium (K) (c) and sodium (Na) (d) content (cmol$_c$ kg $^{-1}$) of topsoil sampled at the end of the growing season along distance gradients from water in the semi-arid Borana rangeland. Least significant differences (LSD) were calculated at the 5 % level (n = 8). Y error bars denote SE.

In respect to K, prominent differences (P>0.05) were not observed under the land use systems (Figure 7.1c), distance gradient from water source (Figure 7.2c) and among the communal grazing sites (Figure 7.3c). Similarly Na displayed no apparent variations under the land use systems (Figure 7.1d), along the distance gradient from water (Figure 7.2d), and among the grazing sites in the communal area (Figure 7.3d).

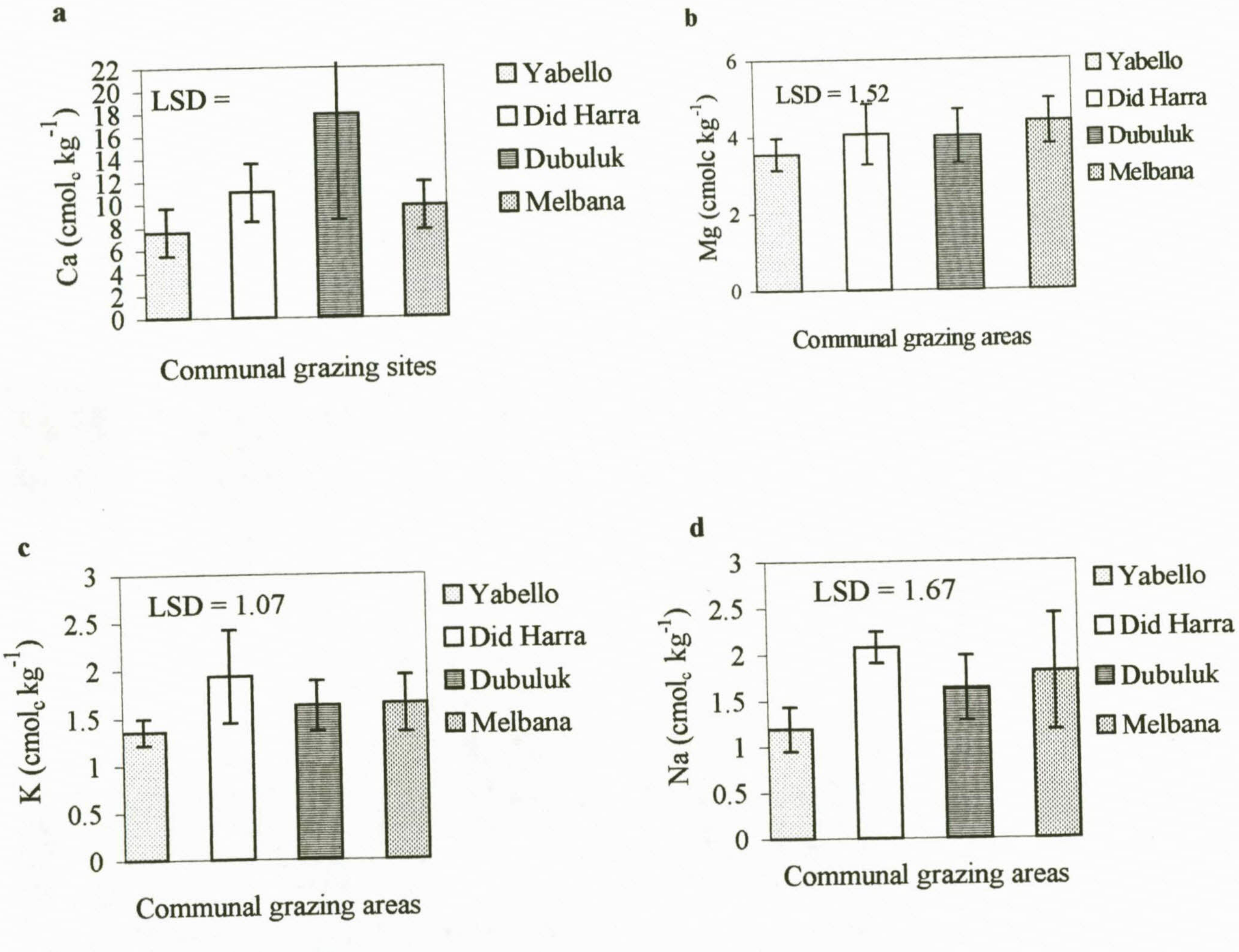
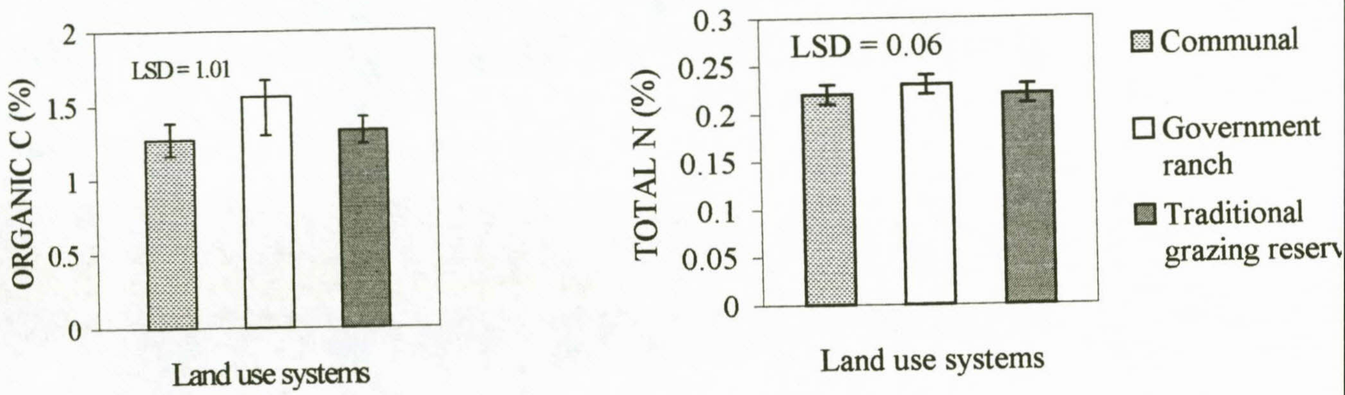


Figure 7.3 The calcium (Ca) (a), magnesium (Mg) (b), potassium (K) (c) and sodium (Na) (d) content (cmol$_c$ kg^{-1}) of topsoil sampled at the end of the growing season in the four communal grazing areas in the semi-arid Borana rangeland. Least significant differences (LSD) were calculated at the 5 % level (n = 6). Y error bars denote SE.

7.3.2 Organic C and total N

Results of the organic C percentage were remarkably similar (P>0.05) in the three land use systems (Figure 7.4a), distance gradient from water (Figure 7.4b) and the four grazing sites in the communal land (Figure 7.5a). Likewise, the total nitrogen percentage did not show marked difference between the land use systems (Figure 7.4a), distances from the water points (Figure 7.4b) and the four communal grazing sites (Figure 7.5b).

a



b

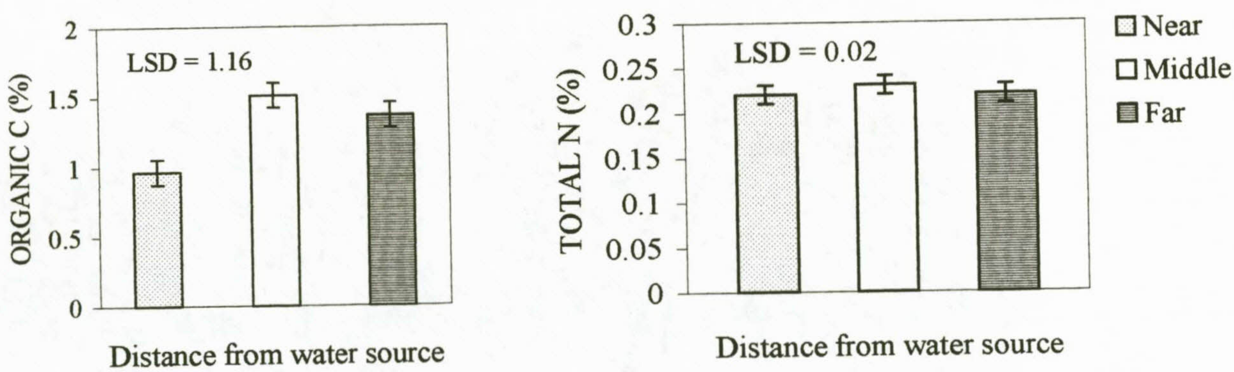


Figure 7.4 The organic C and total N percentage of topsoil sampled at the end of the growing season in the three land use systems (a) and distance gradient from water source (b). Least significant differences (LSD) were calculated at the 5 % level. Y error bars denote SE.

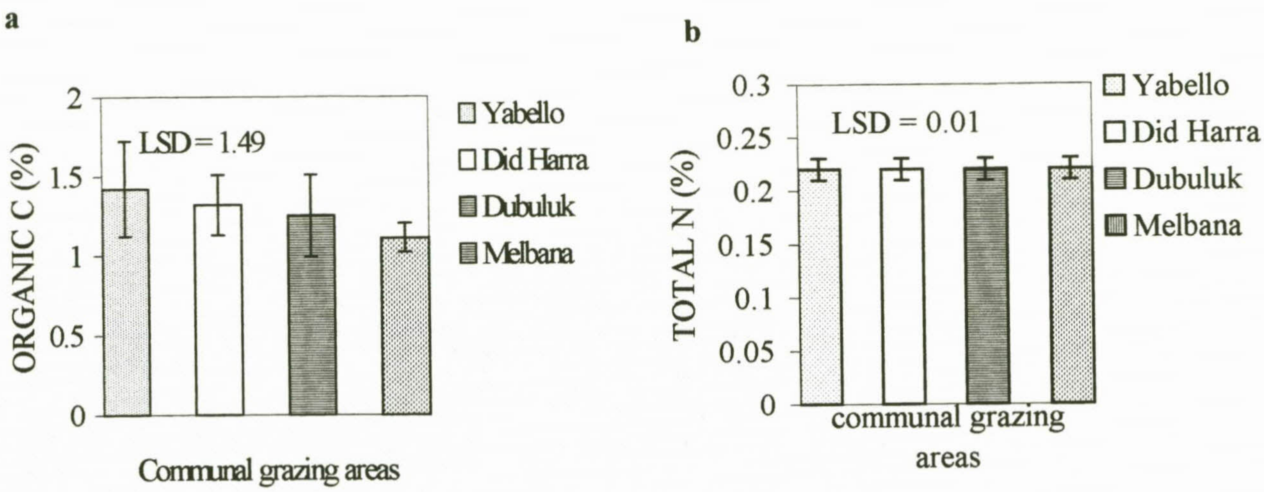


Figure 7.5 The percentage organic C (a) and total N (b) of topsoil sampled at the end of the growing season in four communal grazing areas. Least significant differences (LSD) were calculated at the 5 % level. Y error bars denote SE.

7.3.3 Soil texture, bulk density and pH

Results on soil texture (Table 7.1) revealed that the sand, silt and clay content were similar to that of the three land use systems (average = 69.84 %, 22 % and 8.16 %, respectively). Along the distance gradient from water and in the grazing sites of the communal area, the difference remained low (average = sand-71.8 %, silt-21.0 % and clay-7.5%). Concerning the bulk density, differences between land use systems (Table 7.1), distance from water and the four communal grazing sites were not significant (P>0.05).

Results of the soil pH (Table 7.1) indicated that there was no variation among the three land use systems (average = 6.78), along the distance gradient from water (average = 6.41) and among the communal grazing sites (average = 6.41).

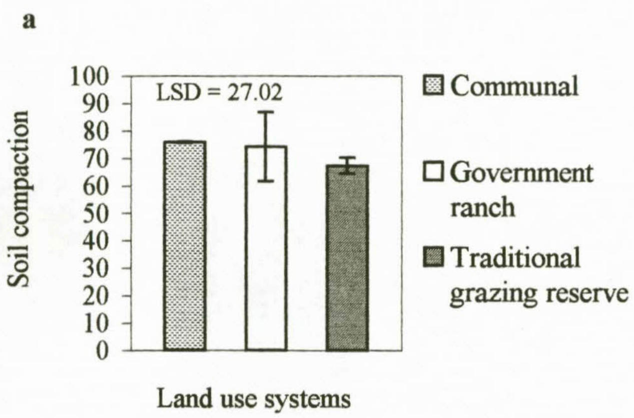
Table 7.1 Texture composition (%), bulk density and pH (mean ± SE) of topsoil sampled from land use systems and distance gradient around water source in the Borana rangelands

Study sites	Soil properties				
	Total sand (%)	**Total silt (%)**	**Total clay (%)**	**Bulk density ($g\ cm^{-3}$)**	**pH**
Communal grazing areas (n = 6/area)					
Did Yabello	69.43 ± 6.83	18.85 ± 4.11	11.68 ± 4.83	1.45 ± 0.05	6.51 ± 0.07
Did Harra	68.36 ± 4.31	25.80 ± 3.74	5.84 ± 0.74	1.43 ± 0.03	6.34 ± 0.10
Dubuluk	75.11 ± 5.49	18.53 ± 5.03	6.36 ± 0.51	1.43 ± 0.04	6.41 ± 0.04
Melbana	73.26 ± 4.91	20.84 ± 5.06	5.91 ± 1.24	1.42 ± 0.04	6.37 ± 0.04
Land use systems					
Communal land (n =24)	70.69 ± 2.83	22.02 ± 2.61	7.30 ± 1.15	1.43 ± 0.002	6.58 ± 0.13
Government Ranch (n = 6)	72.04 ± 4.45	22.18 ± 4.35	5.78 ± 0.26	1.47 ± 0.01	6.71 ± 0.10
Traditional grazing Reserve (n = 4)	66.80 ± 4.13	21.78 ± 2.28	11.42 ± 3.36	1.41 ± 0.01	6.98 ± 0.36
Distance gradient From water source[1]					
Near	75.2 ± 3.75	17.59 ± 3.96	7.21 ± 0.94	1.47 ± 0.03	6.34 ± 0.06
Middle	68.3 ± 4.27	25.06 ± 3.72	6.94 ± 0.68	1.41 ± 0.03	6.51 ± 0.03
Far	71.5 ± 5.61	20.36 ± 3.71	8.45 ± 3.84	1.42 ± 0.04	6.72 ± 0.07

[1] = only communal area

7.3.4 Soil compaction

Values of soil penetration expressed in terms of a percentage of the potential compaction indicated that there was no marked differences (P>0.05) between the land use systems (Figure 7.6a), but values obtained for the traditional grazing reserve (mean of 67.3 %) was 12.7 % and 16.3 % lower than the communal and government ranch sites, respectively. Along the distance gradient from water (Figure 7.6b), the values were nearly similar (P>0.05), with an average of 76.1% for the three sites. Similarly, the four communal grazing sites (Figure 7.7) did not vary markedly (P>0.05) (average = 76.1 %).



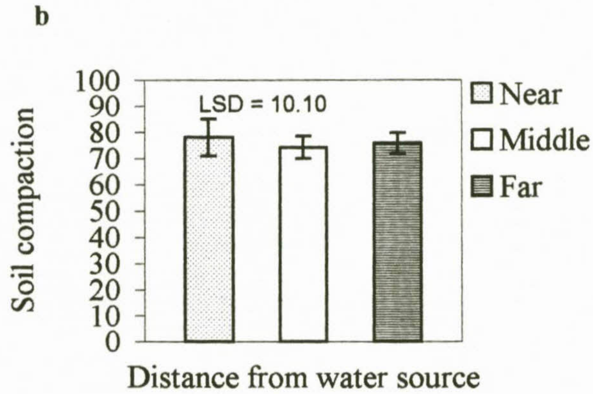


Figure 7.6 Soil compaction (expressed as a percentage of that in a cattle foot path) taken in the three land use systems (a) and distance gradients from water source (b). Least significant differences (LSD) were calculated at the 5 % level. Y error bars denote SE.

7.4 DISCUSSION

Overall results of the exchangeable cations suggested that the values ($cmol_c$ kg^{-1}) of these nutrients were generally low and differed non-significantly between the three land use systems (average = Ca-11.2, Mg-3.25, K-1.7 and Na-1.7), along the distance gradient from water (average = Ca-11.5, Mg-5.7, K-1.6 and Na-1.7) and in the four grazing sites of the communal area (average = Ca-11.5, Mg-3.9, K-1.6, and Na 1.7).

gradient from water (average = Ca-11.5, Mg-5.7, K-1.6 and Na-1.7) and in the four grazing sites of the communal area (average = Ca-11.5, Mg-3.9, K-1.6, and Na 1.7).

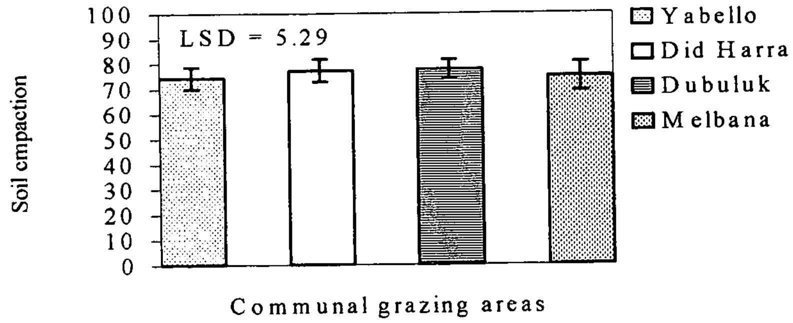


Figure 7.7 Soil compaction (expressed as a percentage of that in a cattle foot path) taken in four communal grazing areas. Least significant differenced (LSD) were calculated at the 5 % level. Y error bars denote SE

Similarly, the percent organic C and total N were generally low and differed non-significantly between the three land use systems (average = 1.4 % and 0.2 %, respectively), distance gradient from water (1.3 % and 0.2 %, respectively), and among the communal grazing sites (1.8 % and 0.2 %, respectively). All the findings in the chemical analysis of soil nutrients may indicate that the data are notable for their lack of variability within the given soil type of the semi-arid Borana rangelands.

Among the soil properties, total organic C, however, is a sensitive soil quality indicator suggesting that within a narrow range of soil, it may serve as a suitable indicator of soil fertility (Murage *et al.* 2000). Moreover, soil organic C fraction may offer further insight into soil fertility changes and the sustainability of land use and management (Barrios *et al.* 1996).

Complex spatial patterns of soil nutrients have been commonly presumed to have developed over time as a result of the interactions of climate, parental material, vegetation type and topography (Wang *et al.* 2001). Overall the rangelands of east Africa are regarded as having a low fertility. This principally was attributed to the very old age of common parental material (Pratt & Gwynne 1977).

From the results of total N and P (below detectable level), it can be speculated that all of the soils studied were markedly deficient in N and P content especially for the sustained and intensified cultivation without fertilization. This finding, therefore, seriously disputes the current practice of expanding cultivation by the poor subsistent small-scale farmers in the studied areas. Moreover, even in the presence of mineral fertilizers, the low rainfall characteristic of this region may also depress response of rangeland soils to mineral fertilizers. This is because water is assumed to be the major limiting factor to plant growth in many rangeland ecosystems (Noy-Meir 1973; Pratt & Gwynne 1977). On top of this, there is ample evidence on natural rangelands that a deficiency of N and P also severely limits the yield of rangeland grasses (Grünow *et al.* 1970).

The current findings on the soil texture of the study areas indicated that the sand fraction contributed the largest proportion (71.1 %), followed by silt (21.3 %) and lastly clay (7.7 %). This finding is in contrast with what was reported previously (Coppock 1994) on a similar soil type of the semi-arid Borana rangeland (sand-53.0 %, silt-17.0 % and clay-30.0 %). Considering the small site variation on soil texture, it is reasonable to hypothesize, based on this finding, that most parts of the Borana rangeland are sandier and shallower (Coppock 1994). Therefore, it can be assumed that these parts of the Borana rangeland are ill equipped to store nutrients and water and hence a greater vulnerability of the system to the current expanding practice of opportunistic cultivation and/or heavy grazing pressure in the communal areas.

Soil compaction expressed as a percentage of the values measured on a cattle footpath did not vary much between the three land use systems, with the percentage at the traditional grazing reserve being slightly lower than at the other two sites. This comparison cannot be done without taking into account the difference in herbaceous basal cover or the effect of trampling. Soil compaction also did not vary between the three distance gradients from water and among the communal grazing sites. The overall finding was that the soil compaction was high at all the study sites. An important contributing factor to the high soil compaction may be a low basal cover of the grassland found at all the study sites. The loss of vegetative and litter cover with degradation (Warren *et al.* 1986; Thurow *et al.* 1988; Holm *et al.* 2002) causes raindrops to have a direct impact on the soil (Lal & Elliot 1994, Russell *et al.* 2001), and may also result in the production of hydrophobic substances that can reduce infiltration (DeBano *et al.* 1970; Emmerich & Cox 1992; Snyman 1999a, 1999b). Various researchers report an increase in soil compaction due to grassland degradation and decrease in plant cover (Mworia *et al.* 1997; Domaar & Willms 1998; Broersma *et al.* 1999). In total, pH values of soil in the study areas were slightly below 7. This result is in agreement with the previous report on the Borana upland soil (Coppock 1994).

7.5 CONCLUSION

The following general conclusions can be drawn from this investigation:

(i) The contents of most of the soil nutrients in the semi-arid Borana rangelands are low.

(ii) In spite of clear differences in the livestock population densities between the communal areas and the government ranch or traditional grazing reserves, no significant difference was observed in their long-term impact on soil. This implies that even the lowest stocking rate might have exceeded the threshold number above which degradation will occur.

(iii) In the semi-arid Borana rangelands, with unreliable and low rainfall, land use for cultivation is related to soil management practices that have in general been very destructive to the soil and could cause soil erosion and hence further loss of nutrients. Moderate to serious deterioration of soils would occur when the rangeland is exploited for agriculture. Therefore, under the present soil status and climatic conditions of this area, the current practice of agriculture expansion in the rangelands must be abandoned before the soil is damaged to a critical level. It is neither sustainable nor environmental friendly to cultivate these rangelands and erosion processes may be very active under cultivation of such marginal land, resulting in further degradation.

(iv) Because of the complex nature of soil nutrient patterns which are largely dependent on land uses and topography, additional research is needed in the Borana rangelands in this regard. This would help to understand the interactive relationships among the topography, soil erosion, soil nutrient, land use and history and management of this area better.

CHAPTER 8

ASSESSMENT OF RANGELAND CONDITION IN RELATION TO LAND USE SYSTEMS AND DISTANCE FROM WATER SOURCE

8.1 INTRODUCTION

Rangelands in Ethiopia in general and those of the Borana in particular, are in danger of becoming seriously degraded, which implies that rehabilitation is a major agricultural priority in these areas. Rangeland rehabilitation must of course be preceded by a thorough assessment of the current state of health of the rangelands of these areas.

The concept rangeland condition is used to denote the changes in vegetation composition, productivity and land stability that occur when rangelands are grazed by domestic livestock (Wilson & Tupper 1982). The purpose of measuring these changes in condition and trend is based on a concern for both short and long term productivity and stability of these rangelands.

The predominant products of most pastoral rangelands in Ethiopia are milk and meat, fibre, hides and skins from grazing cattle, sheep, goats and camels. Other ventures, such as upkeep of wildlife habitat may be important in some localities, but overall they are secondary to livestock production. The Borana are predominantly cattle pastoralists. Hence, rangeland condition assessment in Borana pastoral areas needs to center on changes in the productivity of the grassland. To this effect, the rangeland condition assessment must incorporate three tiers of assessment, namely: the soil, herbaceous and shrub-tree layers.

The objectives of this study were to assess the condition of the rangeland;

(i) of different grazing sites within the communal area,

(ii) under different land use systems (communal, ranch and traditional grazing reserve) and

(iii) along distance gradients from water points.

8.2 PROCEDURE

8.2.1 Site selection and data collection

The selection of the study sites was discussed in detail in section 5.2.1 and the establishment of transects, sub-transects and survey plots in section 3.2.1.1. Species composition of the grass layer and percentage bare ground were estimated as mentioned in section 5.2.2. For details of woody vegetation sampling and measurement see section 6.2.1 and 6.2.2.

8.2.2 Methods of rangeland condition assessment

The two methods employed for the estimation of the rangeland condition in this study, were the ecological condition index (Vorster 1982) and weighted palatability composition (Barnes *et al.* 1984).

For the calculation of rangeland condition index based on ecological merits, the grass species were categorized into four classes (decreaser, increaser IIa, increaser IIb and increaser IIc) (Vorster 1982). Each class was given a relative index value, namely: decreaser = 10; increaser IIa = 7; increaser IIb = 4 and inreaser IIc = 1, after Vorster (1982). The percentage composition of grass species in each class was summed up, after which the sum for each class was multiplied by its relative index value. These amounts were then totaled to give the condition index.

The weighted palatability composition (WPC) of grasses was calculated after division of species into palatability classes (Class I-highly palatable, class II-intermediate, and class

III-less palatable/unpalatable). Less palatable and unpalatable species were grouped in this study in the same class, because on the one hand classification of species into these separate groups were not totally confident and on the other hand the abundance of unpalatable species was very low. Multipliers, *i.e.* weightings of 3, 2 and 1 for classes I, II and III respectively, were used to derive a palatability composition rating (PC) for each sample site. It is calculated as the sum of the products of the relative abundance of each species and its weighting, and is expressed as percentage of the maximum PC (viz. 300) to produce a scale ranging from 33.3 (all species in class III) to 100 (all species in class I). These PC values were then converted to weighted palatability composition (WPC) values by means of the following formula (Barnes *et al.* 1984):

WPC = (PC – 33.3) x 100 ÷ 66.7

8.2.3 Statistical analysis

Mean values were presented for total woody plants and height classes of most important encroaching woody plant species. Among the soil variables studied, only soil compaction was considered in this study. Estimation of soil compaction was discussed in section 7.2.5. Relationships between the grass, woody vegetation and soil parameters were investigated using simple correlation and regression analysis. Differences in ecological condition index and weighted palatability composition for the different communal grazing sites and in relation to distances from watering points as well as for the three land use systems were tested via a two way ANOVA and t-test, respectively (see section 5.2.4).

8.3 RESULTS

8.3.1 Ecological condition index

Concerning the land use systems, the ecological condition index value (Table 8.1) of decreaser species was the highest ($P<0.05$) on the government ranch and lowest on the communal land. The ecological condition index for the government ranch (value of 526.4) was 11.8 % and 68.9 % higher than that of the traditional and communal grazing land, respectively. For increaser IIa species, the value remained higher on the government ranch (P>0.05), followed by the communal land and lastly the traditional reserve. Index value for increasers IIb and IIc in total was the lowest on the government ranch and the highest on the communal land (Table 8.1), but the differences were not significant (P>0.05).

Along the distance gradient from water (Table 8.1), ecological index value of decreasers was not found to differ markedly (P>0.05) between the three distances, although the value at the near site was a bit lower than the middle and far sites. In contrast, the condition index value of increaser IIa species was higher (P<0.05) at the middle than the near and far sites, with the former being 390.9 % and 252.7 % higher than the latter two, respectively. Condition index of Increaser IIb and IIc did not differ significantly (P>0.05) between the three distances from water.

Table 8.1 Rangeland condition score of ecological status groups (mean ± SE) and test of difference for the various land use systems, grazing sites and distances from water.

Ecological status	Land use systems[1]			
	Communal	**Government ranch**	**Traditional grazing reserve**	
Decreasers	311.61 ± 44.09[a]	526.47 ±113.32[b]	471.39 ±78.09[b]	
Increasear IIa	34.82 ±17.76[a]	39.96 ±17.47[a]	16.10 ±12.65[a]	
Increaser IIb	207.39 ±15.96[a]	140.41 ± 59.53[a]	162.51 ± 21.50[a]	
Increaser IIc	6.99 ±1.11[a]	5.12 ± 2.22[a]	9.74 ± 4.92[a]	
	Distance gradient from water source[1]			
Decreasers	227.50 ± 73.47[a]	277.15 ± 69.84[a]	275.88 ± 67.11[a]	
Increasear IIa	13.86 ± 8.32[a]	68.07 ± 52.46[b]	19.30 ± 7.61[a]	
Increaser IIb	256.51 ± 25.02[a]	211.37 ± 23.00[a]	230.55 ± 34.23[a]	
Increaser IIc	6.97 ± 2.44[a]	6.74 ± 1.52[a]	7.43 ± 1.99[a]	
	Communal grazing sites[1]			
	Did Yabello	**Did Harra**	**Dubuluk**	**Melbana**
Decreasers	240.00 ± 89.70[a]	253.42 ± 42.98[a]	364.48 ±120.40[a]	387.9 ± 42.15[a]
Increasear IIa	85.03 ± 20.22[a]	33.94 ± 13.85[b]	13.94 ± 6.12[c]	6.37 ± 3.18[d]
Increaser IIb	197.24 ± 42.22[a]	215.80 ± 18.46[a]	218.78 ± 45.77[a]	197.74 ± 19.79[a]
Increaser IIc	5.75 ± 1.62[a]	8.69 ± 2.71[a]	6.06 ± 1.88[a]	7.46 ± 2.88[a]

[1]= Means in the same row with different superscripts are significantly different at P = 0.05. For details see Appendix 3, 4 and 5.

The ecological condition index of decreasers of the grazing sites within the communal area (Table 8.1) revealed that Dubuluk and Melbana had higher values (P>0.05) than Did Yabello and Did Harra. For increaser IIa species, the index score was the highest at Did Yabello, followed by Did Harra and in third and fourth places, Dubuluk and Melbana (P<0.05). When putting increaser IIb and IIc species together, values obtained from the four sites did not vary significantly (P>0.05). Lower values were, however, found at Did Yabello and Melbana.

Pooling the data of all ecological groups (decreasers, Increaser IIa, IIb, and IIc) (Table 8.3), the total condition index value obtained on the government ranch (value of 711) was 21.7 % and 26 % higher than the traditional grazing reserve and the communal land, respectively, whereas in the latter two the difference remained low. The differences in the total ecological condition index between the three distances were low, but the highest value was obtained in the middle site as compared to the near and far sites. As for the grazing sites within the communal area, the highest maximum total ecological conditional index value of the pooled index of the four species categories was obtained at Dubuluk and Melbana sites.

8.3.2 Weighted palatability composition (WPC)

Condition index values derived from palatability rating of grass species are presented in Table 8.2. Under the three land use systems, the highest rating score of the highly palatable class was obtained at the ranch (P<0.05), with the traditional grazing reserve and the communal land in second and third places, respectively. Palatability rating for intermediate class was similar (P>0.05), but higher on the communal area and the ranch in comparison to the traditional grazing reserve. When values for less palatable and unpalatable species were summed up, the palatability rating score was found to be the highest on the communal area, followed by the grazing reserve and lastly on the ranch, though the differences were not significant (P>0.05).

Table 8.2 Palatability composition rating (PC) of grasses (mean ± SE) for the different land use systems, grazing sites and for different distance gradients from water source.

Palatability class (Weight)	Land use systems[1]			
	Communal	Government ranch	Grazing reserve	
Highly palatable	88.00 ± 12.01 [a]	155.50 ± 34.86 [b]	115.60 ± 23.43 [b]	
Intermediate palatable	14.34 ± 4.95 [a]	13.97 ± 4.65 [a]	7.04 ± 3.28 [a]	
Less palatable	52.50 ± 4.17 [a]	35.96 ± 14.21 [a]	40.63 ± 4.95 [a]	
Unpalatable	5.97 ± 1.12 [a]	3.79 ± 0.70 [a]	9.63 ± 4.29 [a]	
	Distance gradient from water source[1]			
Highly palatable	60.90 ± 22.71 [a]	79.13 ± 20.62 [a]	76.41 ± 19.73 [a]	
Intermediate palatable	9.27 ± 2.98 [a]	23.16 ± 14.39 [b]	10.16 ± 2.93 [a]	
Less palatable	66.85 ± 6.25 [a]	53.72 ± 5.55 [a]	59.45 ± 9.23 [a]	
Unpalatable	3.95 ± 2.49 [a]	5.35 ± 1.72 [a]	5.45 ± 1.74 [a]	
	Communal grazing sites[1]			
	Did Yabello	Did Harra	Dubuluk	Melbana
Highly palatable	69.99 ± 2.699 [a]	70.98 ± 13.63 [a]	105.76 ± 37.00 [a]	105.27 ± 11.13 [a]
Intermediate palatable	25.90 ± 19.42 [a]	13.54 ± 3.21 [ab]	7.07 ±3.58 [b]	10.85 ± 3.27 [b]
Less palatable	49.14 ± 10.98 [a]	54.37 ± 4.69 [a]	55.05 ±11.32 [a]	21.46 ± 6.69 [b]
Unpalatable	5.86 ± 2.18 [a]	8.03 ± 3.15 [a]	5.36 ±1.77 [a]	4.61 ± 2.08 [a]

[1]= Means in the same row with different superscripts are significantly different at P = 0.05. For details see Appendix 6, 7 and 8.

Along the distance gradient from water (Table 8.2), the rating score of the highly palatable class was nearly similar between the three distances (P>0.05). The intermediate palatable class, however, had the highest rating score at the middle site ($P<0.05$), whereas the near and far sites had similar values. Differences of the rating score of the other two species categories (less palatable and unpalatable) were not significant ($P>0.05$) between the three distances from water, although the near site was higher than the middle and the far sites.

For the grazing sites within the communal area (Table 8.2), the highly palatable species category had the highest rating score at Dubuluk and Melbana (average 105.5) ($P>0.05$), whereas the values for the other two sites (Did Yaebllo and Did Hara) were equally the lowest (70.5). Palatability rating of the intermediate species category indicated that the value at Did Yabello was significantly higher ($P<0.05$) than Did Harra, Melbana and Dubuluk. The differences between the latter three sites were not significant ($P>0.05$). Palatability rating score of the two species put together (less palatable and unpalatable) did not differ significantly ($P>0.05$) among the grazing sites.

Pooling data of all the classes (highly palatable, intermediate palatable, less palatable and unpalatable) (Table 8.3), the derived WPC at the government ranch (55 %) was 83.3 % and 48.6 % higher than the communal area and traditional grazing reserve, respectively. The WPC was similar at the near, middle and far sites from the water. For the grazing sites within the communal area, the WPC was the lowest in Did Yabello and Did Harra (average 25 %) and the highest in Dubuluk and Melbana (36.5 %). Results of relationships indicated that a positive and strong correlation (Figure 8.1) was obtained between ecological condition index and weighted palatability composition ($r = 0.99$). Percentage of bare ground was found to correlate negatively with both ecological condition ($r = -0.79$) and WPC ($r = -0.81$) (Figure 8.2a & 8.2b). Neither condition index nor WPC was correlated with basal cover or soil compaction. Low and negative relationship ($r = -0.33$) was found between basal cover and bare ground (Figure 8.2c).

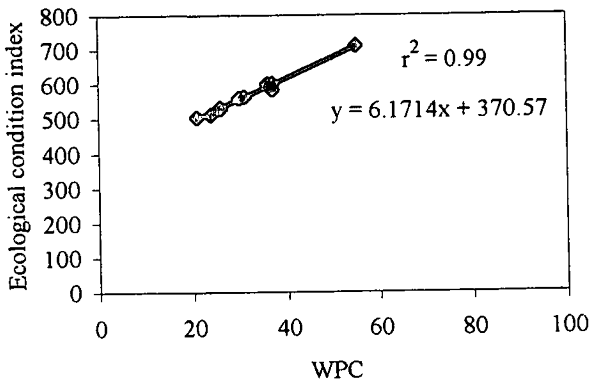


Figure 8.1 Relationship between Weighted palatability composition (WPC) and ecological condition index (n = 10).

8.3.3 Encroaching woody plants

Most important encroaching woody plant species in the study areas were *Commiphora africana, Acacia brevispica, A. drepanolobium, A. tortilis* and *Grewia tembensis*. Results on total density (TE ha^{-1}) of these encroaching woody plants under the three land use systems indicated that the density at the communal land (mean of 504 TE ha^{-1}) was 35.1 % and 327.1 % higher than the government ranch and traditional grazing reserve, respectively. Along the distance gradient from water, total density of the encroaching woody plants (TE ha^{-1}) was lower at the middle than the near and far sites, which the latter two exhibited nearly similar values (Table 8.3). As far as the grazing sites within the communal area are concerned, Dubuluk and Melbana were similar, with the lowest total density of the encroaching woody plants (average 256 TE ha^{-1}), and the greatest density being obtained at Did Harra. Individual encroaching woody plants mentioned above were evaluated with respect to the distribution of height classes (Table 8.4). Concerning the grazing sites within the communal area, the density of *A. brevispica* (woody plants ha^{-1}) for the height class >0-2 m constituted 77.9 % of the total number at Did Yabello. *Acacia brevispica* was not recorded at Did Harra and Melbana, whereas the density at Dubuluk was found to be much lower. Similarly, *A. brevispica* had the highest density proportion of the height class >0-2 m under the two land use systems (communal area and government ranch) and at the three distance gradients from water. Similar results were also observed regarding the other mentioned encroaching woody plant species in all the study areas.

Table 8.3 Summary of data for rangeland condition assessment for the different land use systems, communal grazing sites and distances from water source.

	Communal grazing sites[1]				Land use systems[2]			Distance from water[3]		
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Total woody plants (TE ha^{-1})	1318	1088	749	1178	1083	1188	419	1097	1080	1074
Encroaching woody plants (TE ha^{-1})	687	760	276	236	504	373	118	572	340	600
Condition index	529	512	603	600	560	711	584	504	563	533
Palatability index (WPC)	26	24	37	36	30	55	37	21	31	26
% basal cover	2.7	5	3.7	2.9	3.6	3.9	5.3	4	3.5	3.3
% bare ground	7.7	6.9	1.2	4	5	0.5	0.2	6.11	3.1	5.6
Soil penetration (% of cattle path)	743	772	777	746	758	743	673	781	743	759

1 = A-Did Yabello, B-Did Harra, C-Dubuluk, D-Melbana: 2 = E-Communal, F-Government ranch, G-Traditional grazing reserve; 3 = Only communal area was studied; H- Near, I-Middle, J-Far sites.

The density (woody plants ha^{-1}) of individual encroaching woody species of the height class >0-2 m was in descending order: *A. brevispica, G. tembensis, C. africana, A. drepanolobium* and *A. tortilis* on the communal land; and *C. africana, G. tembensis, A. drepanolobium, A. tortilis* and *A. brevispica* on the government ranch. Concerning the grazing sites within the communal area, the descending order of the density of encroaching woody plants in the height class >0-0.2 m at Did Yabello was *A. brevispica, C. africana, G. tembensis, A. drepanolobium* and *A. tortilis*. For the other three sites (Did Harra, Dubuluk and Melbana), the general order was: *C. africana, G. tembensis, A. drepanolobium, A. tortilis* and *A. brevispica*. Along the distance gradient from water, the descending order of the density of encroaching woody plants in the height class >0-0.2 m was as follows: Near - *C. africana, A. brevispica, A. drepanolobium/ G. tembensis* and *A. tortolis*: Middle/far - *A. brevispica, G. temebensis, A. tortilis, A drepanolobium* and *C. africana*. Correlation and regression analysis results indicated that there was no relationship between TE density of total woody plants and either ecological condition index or WPC. Tree equivalent density of total woody plants was negatively correlated with grass basal cover (r = -0.67) and positively with the percentage bare ground (r =

0.64) (Figure 8.3a and 8.3b). There was no correlation found between TE density of total woody plants and soil compaction (% cattle path).

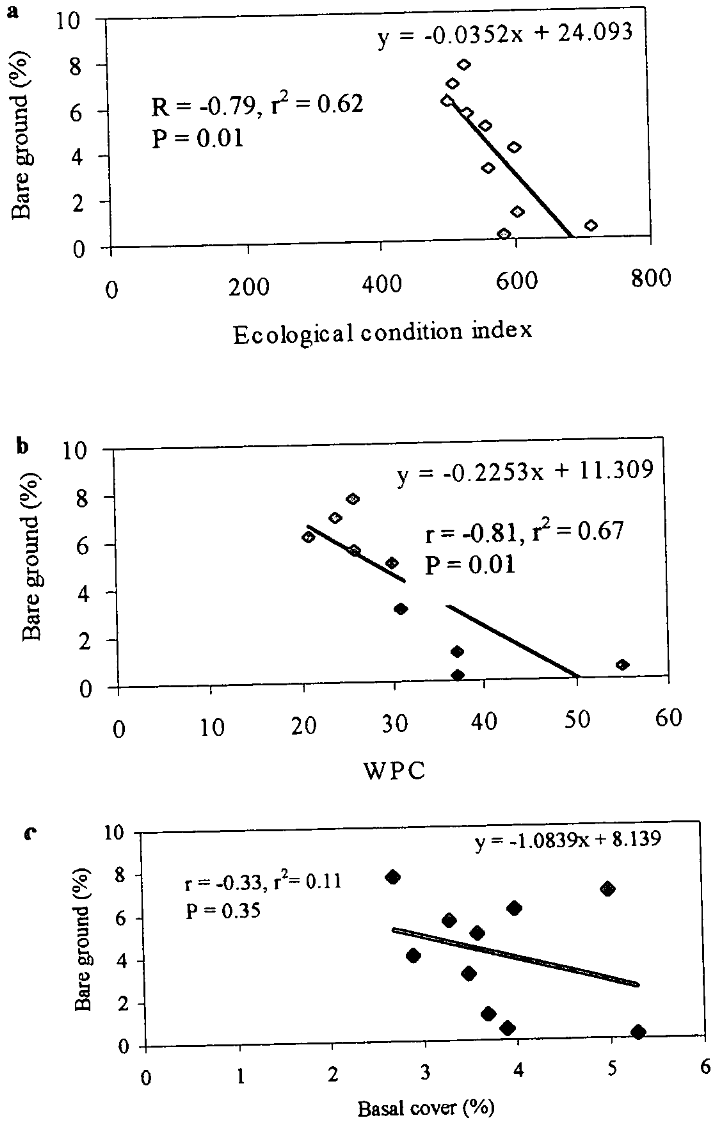


Figure 8.2 Correlation of bare ground (%) with ecological condition (a), weighted palatability composition (WPC) (b) and basal cover(c) (n = 10).

Table 8.4 Density by height classes of five encroaching woody plant species in four communal grazing sites, two land use systems and three distance gradients from water source.

		Density (woody plants ha^{-1})								
						Land use systems		Distance from water source (only communal areas)		
Species	**Height Class (m)**	**Did Yabello**	**Did Harra**	**Dubuluk**	**Melbana**	**Communal**	**Ranch**	**Near**	**Middle**	**Far**
Acacia brevispica	>0-0.5	38.89	0	0	0	51	6	12	38	104
	>0.5-1	33.33	0	5.56	0	43	22	17	0	113
	>1-2	133.33	0	0	0	109	24	75	79	175
	>2-3.	38.89	0	0	0	31	1	17	21	54
	>3-4	19.44	0	0	0	10	0	4	13	13
	>4	0	0	0	0	3	0	0	5	4
Acacia drepanolobium	>0-0.5	40	33	0	17	20	61	38	5	17
	>0.5-1	38	11	0	22	15	22	25	0	21
	>1-2	37	6	0	17	14	0	29	0	13
	>2-3.	28	0	0	6	8	0	12	0	13
	>3-4	6	11	0	0	6	0	8	4	4
	>4	0	33	0	0	8	0	24	0	0
Acacia tortolis	>0-0.5	28	0	28	28	19	22	8	17	33
	>0.5-1	11	0	0	0	3	17	0	0	8
	>1-2	37	6	13	16	12	6	17	7	13
	>2-3.	0	25	12	6	10	0	8	19	4
	>3-4	6	6	0	0	3	0	0	0	8
	>4	13	12	0	9	8	0	5	18	0

Table 8.4 cont'd

Species	Height Class (m)	Density (woody plants ha^{-1}) Communal grazing sites: Did Yabello	Did Harra	Dubuluk	Melbana	Land use systems: Communal	Ranch	Distance from water source (only communal areas): Near	Middle	Far
Commiphora africana	>0-0.5	78	128	39	145	47	223	125	0	17
	>0.5-1	44	189	100	78	51	220	149	0	8
	>1-2	67	211	78	33	24	86	58	0	12
	>2-3.	6	44	33	17	8	0	13	4	8
	>3-4	0	22	0	0	3	0	0	0	10
	>4	7	0	6	0	0	0	0	0	0
Grewia tembensis	>0-0.5	67	211	0	22	78	45	29	21	183
	>0.5-1	56	17	11	17	29	45	38	40	8
	>1-2	61	0	17	17	28	61	25	37	21
	>2-3.	6	0	6	0	3	0	4	0	4
	>3-4	0	0	0	0	0	0	0	0	0
	>4	0	0	0	0	0	0	0	0	0

Tree equivalents ha^{-1} of encroaching woody plants was negatively correlated with ecological condition index and WPC (r= -0.60) (Figure 8.4a & 8.4b). There was no relationship between TE density of encroaching woody plants and basal cover, but the correlation with percentage bare ground (Figure 8.5) was strong and positive (r = 0.87). Neither TE density of total and encroaching woody plants nor basal cover was correlated with soil compaction. There was positive, but low correlation (r = 0.50) between percentage bare ground and soil compaction (Figure 8.6).

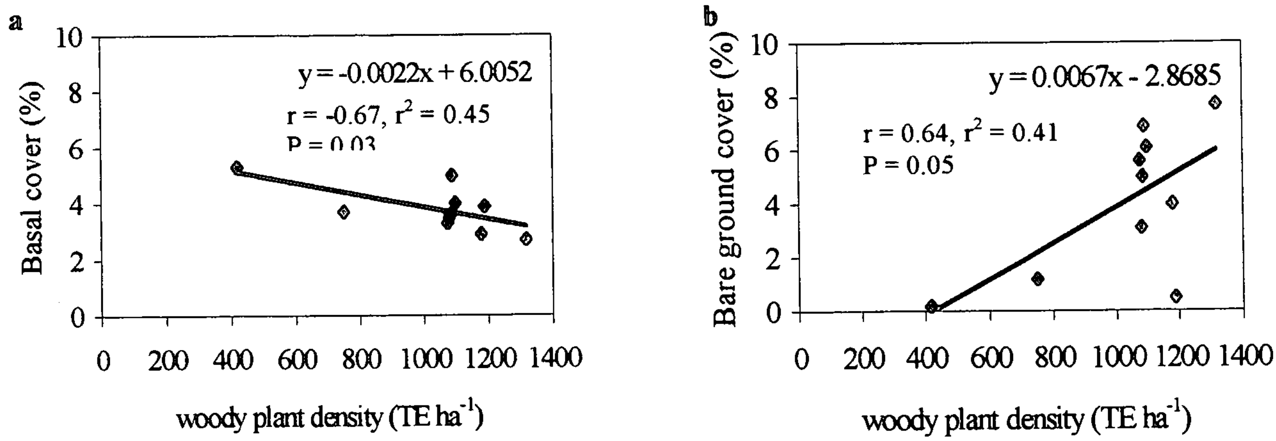


Figure 8.3 Correlation between density of all woody plants (TE ha $^{-1}$) and grass basal cover (%) (a), and bare ground (%) (b) (n = 10).

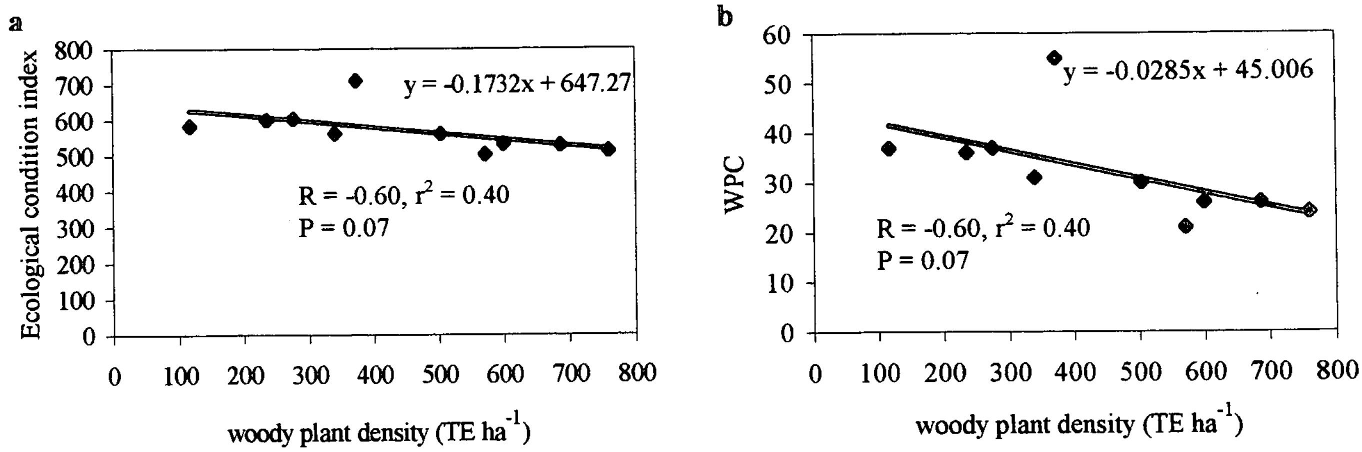


Figure 8.4 Correlation of total density of encroaching woody plants with ecological condition index (a), and weighted palatability composition (WPC) (b) (n = 10).

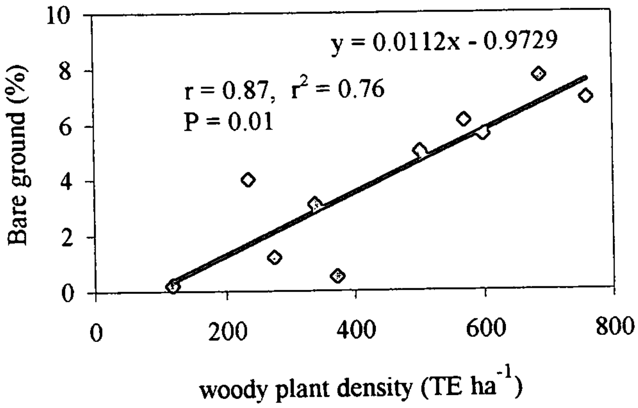


Figure 8.5 Relationship between total density of encroaching woody plants (TE ha^{-1}) and bare ground (%) (n = 10).

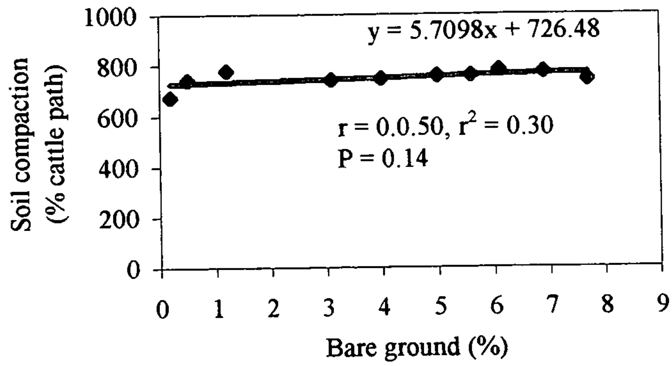


Figure 8.6 Relationship between bare ground (%) and soil compaction (as a % of cattle path) (n = 10).

8. 4 DISCUSSION

8.4.1 Ecological and weighted palatability composition (WPC)

Results of the ecological condition index under the various land use systems revealed a higher value at the government ranch (Table 8.3) than the communal area and traditional grazing reserve. This may indicates a relatively moderate condition of the grass layer on the government ranch. The rangeland condition, when viewed from ecological condition index, was not satisfactory in the traditional grazing reserve and communal land, both of which have nearly similar values (average 572). Along the distance gradient from water, the ecological condition index was low and similar at the near, middle and far sites (average 533), reflecting a universal poor condition of the grass layer. As for the grazing sites within the communal area, Dubuluk and Melbana had a relatively better ecological condition index (average 602) than Did Yabello and Did Harra (average 520).

Concerning WPC, similar patterns were noted with respect to the different land use systems, distance gradient from water and communal grazing sites. Accordingly, regarding the land use systems, WPC was relatively better at the government ranch (55 %), whereas the values for the communal area and traditional grazing reserve were low (average 33 %). This may lead to the speculation that, when assessed on the palatability composition of grasses, the rangeland at the government ranch was in a moderate condition, whereas that of the grazing reserve and communal land were in a poor condition. Along the distance gradient from water, WPC was similar at the three distance sites (average 26 %), which shows a value far below expected, suggesting a poor state of the grassland condition even at a distance away from watering point. Weighted palatability composition was low and similar (average 25 %) at Did Yabello and Did Harra, but was relatively higher at the other two sites (Dubuluk and Melbana) (average 37 %). As discussed in Chapter 6, the former two grazing sites represent areas with relatively greater external influence on the Borana rangeland that resulted in reduced grazing land and increased livestock pressure.

A strong and positive relationship between the ecological condition index and WPC is expected, because all decreasers are highly palatable; all increaser IIa species except *Enteropogon simplex* are moderately palatable and all increaser IIb & IIc, except *Harpachne shimperi* and *Digitaria velutina* are less palatable or unpalatable. Of the decreaser species, *Cenchrus ciliaris, Chrysopogon aucheri* and *Lepthotrium senegalensis* can be considered as key indicator species, where as *Sporobulus nervosus* and *S. pyramidalis* can be taken as the most important indicator species from increaser groups in all study areas. The negative correlation observed between bare ground and either ecological condition index or WPC in the current study is in contrast to the work of Friedel (1987) who noted that there was no relationship at all.

The absence of relationship between basal cover and either ecological condition index or WPC as investigated in this study was reported elsewhere (Friedel 1987).

8.4.2 Encroaching woody plants

The five woody plants mentioned in the previous section were also reported as the most important encroachers in the Borana rangelands (Coppock 1994). Total woody plant density (TE ha^{-1}) of encroaching woody plants was higher on the communal land than the government ranch and traditional grazing reserve. In contrast, density of all woody plants combined was higher on the government ranch, followed by the communal land and traditional grazing reserve. Along a distance gradient from water, the difference between the near, middle and far sites in the total TE density of encroaching woody plants was higher than the difference in the TE density of all woody plants combined. Total tree equivalent ha^{-1} of encroaching woody plants at the middle site (average 340) was 40 % and 3.3 % lower than the near and far sites, respectively. There is no clear cut explanation for this result. Concerning the grazing site within the communal area, the TE density of all encroaching woody plants was the highest at the two sites with a greater external influence into the Borana system (Did Yabello: 687 TE ha^{-1} and Did Harra: 760 TE ha^{-1}).

Height class distribution of all encroaching woody plants (Table 8.4) in most of the study areas indicated that the largest density proportion (range: >50-100 %) was attributed to the height class >0-2 m. Largest population of low growing woody plants in rangelands (e.g. 1-2 m) was interpreted as a typical characteristic of woody encroachment (Van Vegeten 1981; Friedel 1985; Childes & Walker 1987).

8.4.3 Relationship between variables

The absence of any significant correlation between total woody plant density and condition indices (ecological condition index and WPC) indicates that woody plants may not affect the botanical composition of grasses further below a certain threshold density level. In addition, it can also be interpreted that these two components of the rangeland are different entities and hence they can be viewed separately, while assessing the condition of rangelands. This can be further illustrated in that rangelands with better condition indices, but with a high density of woody plants as observed at the government ranch (present study), are not necessarily in good condition.

A negative correlation between total woody plants and grass basal cover indicated that as the density of woody plants increases on the rangeland, the grass cover may be reduced. From the observed positive correlation between woody plant density and bare ground, it can be concluded that, beyond a certain threshold density, woody plants may suppress the grass layer because of severe competition for available water, nutrients and a reduction of light reaching the grasses may be severe. A negative relationship between the TE density of encroaching woody plants and either of the condition indices demonstrates the apparent influence of these woody plants on the botanical composition of the grass layer. From this it can be concluded that the effect of encroaching woody plants on the productivity and composition of the grass layer is substantial. Therefore, while attempting to control bush, local planning and execution should at large be geared towards focusing first on such encroaching woody plants that was shown to have the most adverse effect on the quality (botanical composition) and productivity of the grass layer. However, this finding did not deal specifically with the effect of individual encroacher species separately. Therefore, further research needs to be carried out to examine and identify relevant woody plant species that have the greatest effect in this respect. Preliminary surveys were conducted in Borana plateau to evaluate the interaction between some of the mentioned encroaching woody plant species and their surrounding grass layer, which basically focused on the forage production aspect of the grass layer. These included the apparent positive or neutral effect of *A. tortilis* and *A. drepanolobium* (Coppock 1994; Tamene 1990) on the grass layer opposed to the negative effects of *Acacia horrida*, *A. seyal* and *A. brevispica* (Solomon Kebede 1989, Tamene 1990). A major hypothesis to explain these opposing interactions is variation in the root and crown morphology of the woody plants. Lateral roots may confer greater competition for grasses (e.g. *A. horrida*, *A. brevispica*), whereas taproots, and elevated open crowns (e.g *A. drepanolobium*) may have only minor effects.

Tree equivalent density of encroaching woody plants and grass basal cover were not correlated. The relationship between TE density of encroaching woody plants and bare ground was stronger than that of TE density of all woody plants. This may indicate that encroaching woody plants can better explain the degree of bare patchness than the total woody plant density. The presence of a positive significant correlation between the bare ground and soil compaction (% cattle path) may illustrate that bareness may contribute to the compaction of the soil due to the exposure of the soil for wind and water erosion.

8.5 CONCLUSION

From this study the following general conclusions can be drawn:

(i) Despite the fact that the Borana rangeland is largely used by grazers (cattle), the importance of assessing more than the grass component (e.g. woody plants and soil) needs to be of primary concern in rangeland condition assessment.

(ii) The absence of significant correlations between either the grass, woody plants or soil in some instances suggests that the changes that occur in these three components may require separate assessment and do not need to be combined into a single condition index.

(iii) The condition assessment results indicated that the government ranch had a better grass species composition than the other land use sites. However, when overall vegetation was assessed, the rangeland was not in a good condition because of heavy bush encroachment. The communal rangeland was generally in poor condition. Although there was no bush encroachment problem in the traditional grazing reserve, the rangeland productivity was poor when assessed on the basis of ecological and palatability merits of the grass layer.

(iv) Results of the correlation analysis of the relationship between all encroaching woody plants combined with the ecological condition index or weighted palatability composition showed the existence of a negative interaction between the density of these woody plants and the botanical composition of the grass layer. In addition, the density of encroaching woody plants was positively correlated with bare ground. The results may indicate that in Borana rangelands, the abundance of these encroaching woody species is more critical to aggravate the deterioration in the grassland productivity than other woody plant species. Therefore, any bush control programme must give priority towards minimizing the abundance of these woody plants.

CHAPTER 9

SOIL SEED BANK CHARACTERISTICS

9.1 INTRODUCTION

Plants establish themselves by the expansion and subsequent fragmentation of vegetative parts such as tillers, rhizomes or runners, or by successful establishment of a soil seed bank or bulbils (Freedman *et al.* 1982). Seeds may have been introduced to the seed bank during the current (i.e. seed rain or transient seeds) or previous years and are removed through germination, predation, senescence and pathogens. It is the balance between these processes that will determine the turnover rate of the seed bank in a particular location (Laura & Brenda 2000).

Seed bank are important in savanna ecosystems where grasses account for a large part of the vegetation and their role is threefold. Firstly, it is a potential pool of propagules for regeneration of grasses after disturbance (Hodgson & Grime 1992; Laura & Brenda 2000). Secondly, the seed bank may reduce the probability of population extinction of desirable or palatable grass species (Venable & Brown 1988). Thirdly, it is also likely to be the major source of establishing aboveground plant communities following environmental changes such as rainfall (Wilson *et al.* 1993; Hyatt 1999).

Recruitment from the seed bank is restricted to periods with favourable condition of the soil parameters that may control germination. One of the most important variables in this regard is soil water (Reynal & Bazzaz 1973), while other factors include soil pH (Thanos & Skordilis 1987; Henig-Sever *et al.* 1996), heat exposure (Thanos & Georghiou 1988) and light (Trabaud & Renard 1999). Storage of germinable seeds and the subsequent establishment are also functions of disturbance factors (Sousa 1984; Thompson 1986). Drought in combination with human activities may adversely affect the seedling recruitment of the seed bank (Skoglund 1992). Heavy grazing by livestock introduces a kind of disturbance to grasslands, which can negatively affect the seed bank size and composition of more desirable/palatable grasses both in space and time (Skoglund 1992). In addition, root destruction through trampling and selective grazing of desirable plant species will reduce their contribution to the seed bank. This may give an opportunity to the less desirable and pioneer plant species to dominate the seed bank.

Several investigations show the relationships between the seed bank and aboveground floral community. Some indicated that grasslands can have a large persistent seed bank; often with a species composition that does not resemble the above ground vegetation (e.g. Thompson & Grime 1979). Others document that the viable seed bank and the surface plant community on a site can be similarly linked, although a few species may be present in one but not in the others (Quinfeng *et al.* 1999).

The importance of soil seed banks is receiving attention in an ever increasing number of studies in the world. In Ethiopia, it seems that there does not exist an economically feasible and viable way of restoring the disturbed extensive communal rangelands other than from the seed bank. Understanding seedling recruitment and composition of the soil seed bank and its relationship with surface plant communities is therefore important because the seed bank may be essential in restoring both availability and genetic diversity of grass population in such degraded communal rangelands. Furthermore, the seed bank may help to promote establishment of grasses in bare rangelands so that they can be protected from loss of nutrients through soil erosion. The evaluation of soil seed banks can also give an idea of the recovery potential of degraded rangeland.

A few studies were conducted in the highland forest areas of Ethiopia to investigate the impact of forest clearing for agriculture on the composition and density of the soil seed bank. Apparently, there has not been any report on soil seed bank investigations in the arid and semi-arid rangelands of Ethiopia.

The objectives of seed bank evaluation were, therefore, to examine:

(i) seedling and floristic density of graminoids and non-graminoids,
- along a distance gradient from the water source (at near, middle and far sites) and
- under three land use systems (communal areas, government ranch and traditional grazing reserve);

(ii) similarities and differences in seed bank composition in terms of floristic composition among distance gradients from water and under the land use systems and

(iii) the similarity of the grass composition between the seed bank and above ground plant community.

9.2 PROCEDURE

9.2.1 Soil sampling

A soil seed bank is defined as seeds at or beneath the soil surface that are capable of germination (Sagar & Mortimer 1976). Soil seed bank samples were collected between 21 September 2001 and 7 October 2001. The upper 30 mm soil layer was removed from a 0.25 m^2 quadrate, using a sharp knife. The samples were then placed in plastic bags before transportation to the glasshouse. For the purpose of this study, soil samples were collected along a distance gradient from water and within three land use systems.

9.2.2 Site selection

To investigate the effect of distance from water on soil seed bank, four watering points from the communal grazing area were selected. Establishment of the gradient, division of the gradient into near, middle and far sub-transects from the water source and location of the main sampling plots within each distance are presented in section 3.2.1.1. A total of 16 soil samples in quadrates ($0.25m^2$) were collected from four plots along each distance from a watering point (4 quadrates per plot). To investigate the effect of the land use systems, 5, 14 and 3 plots were marked at the government ranch, adjacent communal area and at the three adjacent traditional grazing reserve sites, respectively. Sampling plots were marked in the same way as presented in section 3.2.1.1. A total of 20, 56 and 12 quadrate ($0.25\ m^2$) soil samples were taken from all the plots in the ranch, communal land and traditional grazing reserve sites (4 quadrates per grazing reserve), respectively. Unequal sampling was done to ensure proportional distribution of the three land use systems in relation to their total area coverage.

9.2.3 Glasshouse experiment

This experiment was conducted at the Alemaya University located about 1100 km from the collection sites. Prior to commencement, soil samples were stored for three weeks in the glasshouse storage room at room temperature. During this period the soil was checked regularly to see if germination was taking place. None of the samples showed any signs of seed germination. Labeled plastic pots with a depth of 210 mm and a diameter of 240 mm were filled with sterile sand to a depth of approximately 160 mm. Before using the sterile sand, it was checked for possible seed contamination. This was done by keeping the sterile sand moist over a clean flat floor and examining it regularly for germinating seeds over a three week period. No germination of any seed was observed.

Soil sample was spread over the sand in each plastic pot to a depth of 20 mm. Prior to this, the soil was thoroughly mixed after removal of all root and plant fragments. The pots were placed at random in the glasshouse, after which all the seedlings were counted over a six month period. Any plant that could not be identified at the seedling stage was allowed to grow until identification was possible. Each pot was watered regularly and urea fertilizer was added at intervals to ensure continued growth of the seedlings. Ten control pots containing sterile sand were also set up to detect wind blown seeds. Two plant species, registered previously as glasshouse weeds, were identified in both control and experimental pots and were not included in the analysis. The temperature in the glasshouse was kept between 19-22 °C during the day and 10-12 °C during the night throughout the experimental period. Pots were examined every three to four days for the first two months and thereafter weekly until the end of the experiment.

9.2.4 Data collection

The first seedlings started to emerge three weeks after watering. At this stage, it was possible to distinguish the graminoids from the non-graminoids. Seedling data were collected from each group every week until the end of the experiment. Flowering of some plants started after seven weeks of the onset of the experiment. Data on the floristic count was taken from every species as flowering occurred. The flowering plants were removed gently without disturbing the soil after recording. Identification of some of the species was made on the spot of collection in the green house and the rest was done at Alemaya University Herbarium.

9.2.5 Data analysis

A one way ANOVA described by Gomez & Gomez (1984) was used to test the differences between the three distances and the three land use systems in the seedling as well as the floristic densities. Significant differences detected through ANOVA were further tested by pair wise comparison of means, using the LSD test. When comparison between any two independent sample observations was made, the F-test was used to detect the differences. Simple descriptive statistics were employed to describe the floristic composition of the different sites.

Because species richness data (for flowering non-graminoids) was not randomly distributed, a non-parametric analysis was performed to compare the differences using the Mann Whitney U-test. Similarity between seed bank and aboveground grass composition of sites was calculated using Sørensen's similarity index (Greig-Smith 1983). Data on the aboveground grass composition was obtained from the study presented in Chapter 5.

9.3 RESULTS

9.3.1 Seedling density in seed bank

Results of the effect of the three land use systems indicated that graminoid seedling density at the traditional grazing reserve (mean of 798.8 seedlings m^{-2}) was higher ($P<0.01$) by 226.7 % and 200.4 % than the seedling density of the ranch and communal sites, respectively (Table 9.1). There was no significant difference ($P>0.05$) in seedling density of graminoids between the communal and ranch sites. As for the distance gradient from water (Table 9.2), differences in the graminoid seedling density were not statistically significant ($P>0.05$), although the seedling density at the middle site (a mean of 273.5 seedlings m^{-2}) was 29.5 % and 17.3 % higher than the far and near sites, respectively, while the density at the near site (a mean of 233.1 seedlings m^{-2}) was 10.4 % higher than the far site.

Results on non-graminoids revealed that seedling density did not differ ($P>0.05$) among the land use systems. However, the seedling density at the traditional grazing reserve (a mean of 106.1 seedlings m^{-2}) was 37.8 % and 26.6 % lower than that of the ranch and communal sites, respectively (Table 9.1). Statistically significant differences were not obtained in the non-graminoid seedling density between the three distances from the water, but the density at the far site (a mean of 257.9 seedlings m^{-2}) was 100 % and 57.1

% higher than the middle and the near sites, respectively. Seedling density at the near site (a mean of 164.2 seedlings m^{-2}) was 27.3 % higher than the middle site (Table 9.2).

9.3.2 Floristic (flowering) density

Total floristic density of graminoids at the traditional grazing reserve (a mean of 360.9 plants m^{-2}) was significantly higher (P<0.01) by 323.3 % and 290.6 % than the government ranch and communal sites, respectively. There was no marked difference (P>0.05) between the ranch and the communal sites (Table 9.3). Total floristic density of graminoids did not vary prominently among the distance gradients from water (Table 9.4).

Table 9.1 Seed bank seedling density (mean ± SE seedlings m^{-2}) of the graminoids and non-graminoids under the three land use systems.

Land use systems	Graminoids	Non-graminoids
Communal (*n = 56*)	265.94 ± 11.63[a]	134.31 ± 13.25 [a]
Government Ranch (*n = 20*)	244.50 ± 11.54[a]	146.21 ± 9.76 [a]
Traditional grazing reserve (*n = 12*)	798.83 ± 125.7[b] *	106.09 ± 16.66 [a]

*= Significant (P<0.05); [a, b] = Means with different superscripts are significant (P<0.05).

Table 9.2 Seed bank seedling density (mean ± SE seedlings m^{-2}) of the graminoids and non-graminoids along a distance gradient from water.

Distance gradient (*n = 16*)[1]	Graminoids	Non-graminoids
Near	233.18 ± 28.84 [a]	164.19 ± 29.95 [a]
Middle	273.51 ± 35.96 [a]	128.94 ± 14.99 [a]
Far	211.20 ± 17.49 [a]	257.85 ± 80.15 [a]

[1] = communal grazing sites; [a] = Means are not significantly different (P>0.05).

Results on non-graminoides total floristic density (Table 9.3) revealed that mean values were not statistically significant (P>0.05) between the land use systems, although density at the traditional grazing reserve (a mean of 73.7 plants m^{-2}) was 56.7 % and 35.9 % lower than the government ranch and communal sites, respectively. Significant differences were obtained (P<0.05) in non-graminoides total floristic density between the three distances from water (Table 9.4), which indicated that the total non-graminoides floristic density at the far site was 522.3 % and 360.1 % lower than the middle and near sites, respectively. There was no marked variation (P>0.05) between the near and middle sites.

Table 9.3 Mean seed bank floristic density (mean ± SE plants m^{-2}) of the graminoids and non-graminoids under the three land use systems.

Land use systems	Graminoids	Non-graminoids
Communal (*n* = *56*)	92.43 ± 3.61[a]	100.11 ± 6.68 [a]
Government ranch (*n* = *20*)	83.5 ± 6.81[a]	115.43 ± 12.80 [a]
Traditional grazing reserve (*n* = *12*)	360.99 ± 41.89 [c]	73.67 ± 4.28 [a]
	**	

** = Highly Significant (P<0.01), [a, c] = Means with different superscripts are significantly different.

Table 9.4 Mean seed bank floristic density (mean ± SE plants m^{-2}) of the graminoids and non-graminoids along a distance gradient from water.

Distance gradient (*n* = *16*)[1]	Graminoids	Non-graminoids
Near	66.30 ± 10.36 [a]	101.67 ± 25.89 [a]
Middle	99.46 ± 17.18 [a]	137.52 ± 11.10 [a]
Far	81.04 ± 7.24 [a]	22.10 ±2.02 [b]
		*

[1] = communal grazing sites; * = Significant (P<0.05); [a, b] = Means with different superscripts are significantly different.

9.3.3 Seed bank botanical composition

A total of 44 species representing graminoids and non-graminoids flowering plants were identified in this study (Table 9.5). Of these, 25 % were grasses and 75 % were non-grass plant species. The species composition at the near, middle and far sites from the watering points were dominated by the species *Leucas glabrata*, *Verbesina encelioides* and *Lintona nutans*, respectively. In the traditional grazing reserve the species *Lepthotrium senegalensis* made up 67 % of the total botanical composition.

Table 9.5 Botanical composition (%) of soil seed bank under the three land use systems and along distance gradient from water.

	Distance from watering point			Land use systems		
	Near	Middle	Far	Communal	Ranch	Kallo[a]
Graminoids						
Aristida adscensionis , L.	0.72	1.08			2.41	
Dactyloctenium aegyptium, (L.)		6.45	4.00	14.36	6.02	
Digitaria milanjiana, (Rendle)		4.30	4.00	4.79	3.61	
Eragrostis cilianensis Link exlutati			4.00	1.60		
Eragrostis spp		1.08		1.60		
Harpachne shimperi, Hochzt. Ex.	0.72			1.06		
Leptothrium senegalensis, (Kunth)	5.80	5.38	32.00	10.64	15.66	67.80
Lintona nutans, stapf.	2.90	19.35	40.00	11.70	10.84	15.25
Panicum colorata		2.15	4.00	1.34	0.67	
Setaria verticillata, Beauv.	0.01					
Tragus berternianus Schult.	0.72			0.53	1.20	
Non-graminoids						
Acanthus spp					1.20	
Amaranthus graecizans L		9.75	8.00	20.83		
Avena sativa L.						
Bidens pilosa L.		1.08				
Canvolvulus sagittatus	1.44	2.23		4.79	6.61	1.69
Chenopodium album L.		1.00		0.53		
Commellina africana L.				0.53	2.20	
Commellina albescens						
Conyza bonariensis (S. moore) cuf.				6.60		
Euphorbia spp		2.00				
Galinsoga parviflora Cav.				0.53		2.00
Ind*		6.45				
Indigofera amorphoid		1.00			1.20	
Justicia shimperi		1.00			18.46	
Kalanchoe petitiana A. Rich.				2.53	10.82	2.39
Launaea cornuta (oliv. & Hiern)						
Leucas glabrata	23.91			0.53		
Leucas spp						
Medicago laciniata (L.) Mill.				6.72		
Oxygonum sinatum	15.00	2.00	2.00			
Phaseolus vulgaris L. cv.						1.20
Portulaca olerace	8.12					
Pupalia lappacea L	8.91					

Table 9.5 cont'd

Raphanus raphanistrum L.		1.23		5.66	5.61	1.69
Senecio shimperi Schtz-Bip. Ex		1.08			2.41	
Solanum nigrum L.		2.15		5.53		
Solanum shimperiana						
Tagetes minuta L.					7	
Tribulus terrestris L.					9.04	
Verbesina encelioid	31.40	40.28	0.00		1.60	
Vernonia galamensis (Cass.)			2.15			
Vicia sativa L.						

[a] = Traditional grazing reserve
* = Unidentified species

9.3.3.1 Grasses

The species composition of grasses under the land use systems and along the distance gradient from water is presented in Table 9.6. Of the 10 grass species recorded, three were identified as highly desirable, one as desirable and six as less desirable. It is clear from Table 9.6 that in the highly desirable group, *Lepthothrium senegalensis* was found to be common and dominant at the three distances from water (near 53.3 %, middle 13.9 % and far 36.4 %) and under the three land use systems (communal 22.5 %, ranch 38.2 % and traditional grazing reserve 81.6 %). The distribution of *Digitaria milanjiana* was restricted to two distance sites from water: middle (11.1 %) and far (4.5 %) and two land use systems: communal (10.1 %) and ranch (8.8 %), while *Panicum coloratum* was distributed similarly (middle 5.6 %, far 4.5 %, communal 2.3 % and ranch 2.9 %).

In the desirable group, *Lintona nutans* was common and dominant along the distance gradients from water (near 26.7 %, middle 50 % and far 45.5 %) and also under the land use systems (communal 27.7 %, ranch 26.5 % and traditional grazing reserve 18.4 %). Among the less desirable species, *Dactyloctenium aegyptium* was found to be common along the two distance gradients from water: middle (16.7 %) and far (4.5 %) and two land use systems: communal (30.3 %) and ranch (14.7 %). Another less desirable grass, *Tragus berternianus*, occurred only at the near site from water, at communal and ranch sites.

Table 9.6 Floristic composition (%) of seed bank grasses along a distance gradient from water and under the three land use systems.

		Distance gradient from water (communal land)			Land use systems		
Species		Near	Middle	Far	Communal	Ranch	Kallo
Highly desirable							
Digitaria milanjiana	P [b]		11.11	4.46	10.11	8.82	
Leptothrium senegalensis	P	53.33	13.89	36.36	22.47	38.24	81.63
Panicum coloratum	P		5.56	4.46	2.25	2.94	
Desirable							
Lintona nutans	A	26.67	50.00	45.46	27.72	26.47	18.37
Less Desirable							
Eragrostis cilianensis	A			4.46	3.37		
Eragrostis spp	A		2.78		3.37		
Harpachne shimperi	P	6.67			2.25		
Aristida adscensionis	A	6.67	2.78			5.88	
Dactyloctenium aegyptium	A		16.67	4.46	30.34	14.71	
Tragus berternianus	A	6.67			1.12	2.94	

[b] = Life history; P-perennial, A-annual.

Overall proportional distribution of the different groups of desirability discussed above is presented in Figure 9.1. As for the distance gradients from water, the result indicated that at the near site, highly desirable species had the highest proportion (53.3 %) followed by the desirable species (26.7 %), whereas the reverse held true for the middle site (desirable 50 %, highly desirable 30.6 %). The above-mentioned groups were equally proportioned at the far site (45 %). The less desirable species accounted for 20.0 % at the near, 22.2 % at the middle and 8.9 % at the far sites.

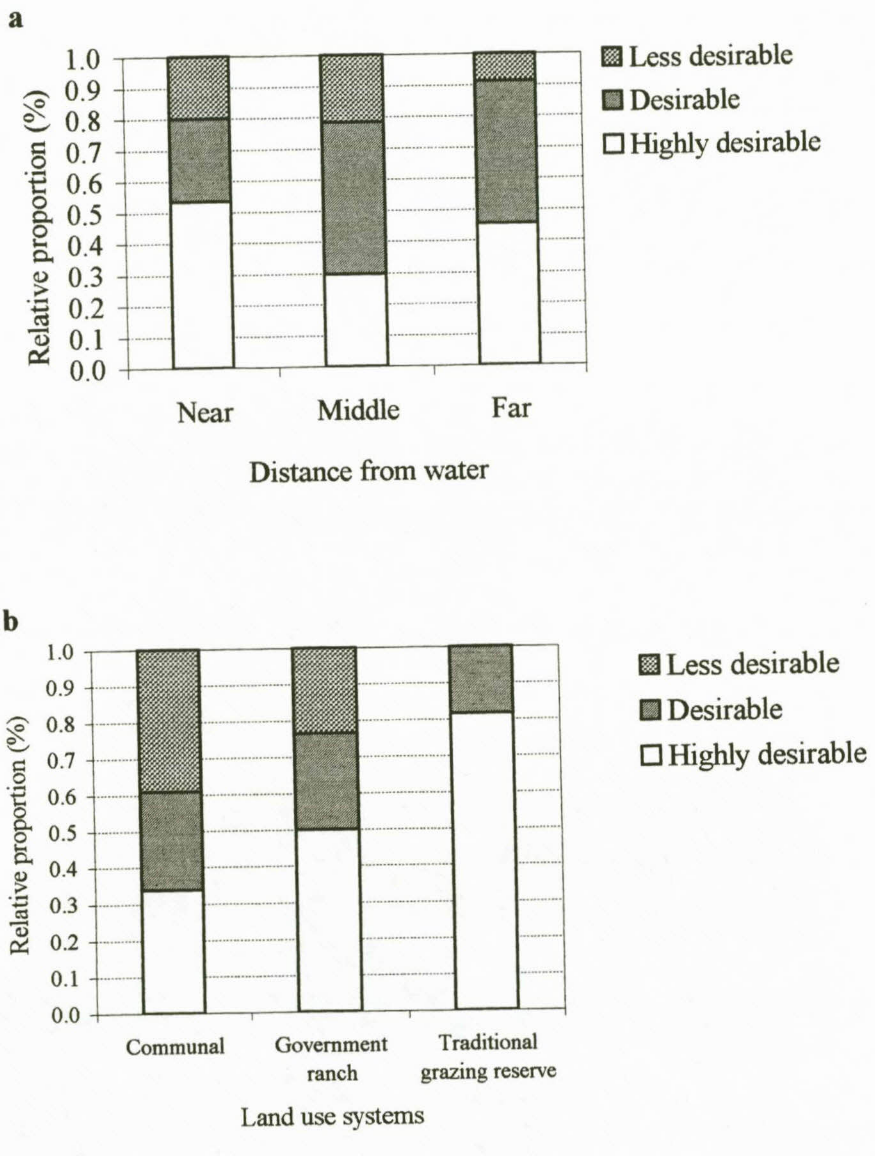


Figure 9.1 Relative proportions of desirability groups of grasses in the soil seed bank along distance gradient from water (a) and under three land use systems (b).

Under the land use systems, the less desirable group had the highest percentage (40.3 %), followed by the highly desirable group (34.8 %) at the communal site. At the government ranch and traditional grazing reserve sites, the highly desirable species had the highest percentage (50.6 % and 81.6 %, respectively), followed by the desirable species (26.5 and 18.4, respectively).

9.3.3.2 Non-grasses

Of the total non-grass species identified, 85 % were herbaceous annuals and 15 % were shrubs. Only one species (*Oxygonum sinatum*) was common to the three distance (near, middle and far) sites from water. *Canvolvulus sagittatus* and *Kalanchoe petitiana* were common to the three land use systems. Results on species richness (Figure 9.2) indicated that the number of non-graminoid species at the middle site (13) was significantly higher (P<0.05) than the near and far sites.

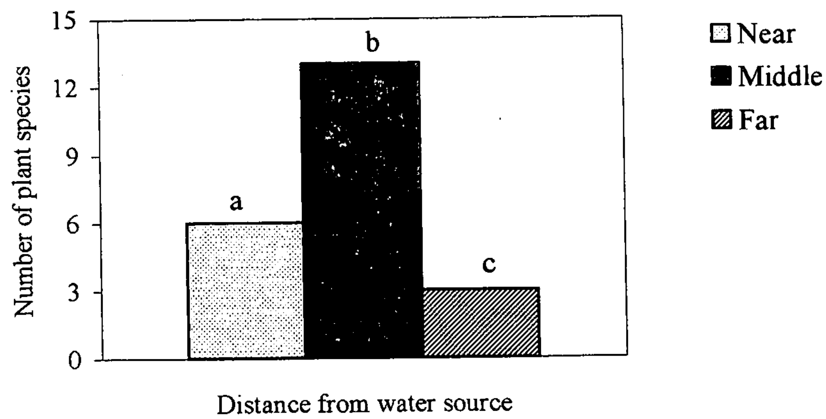
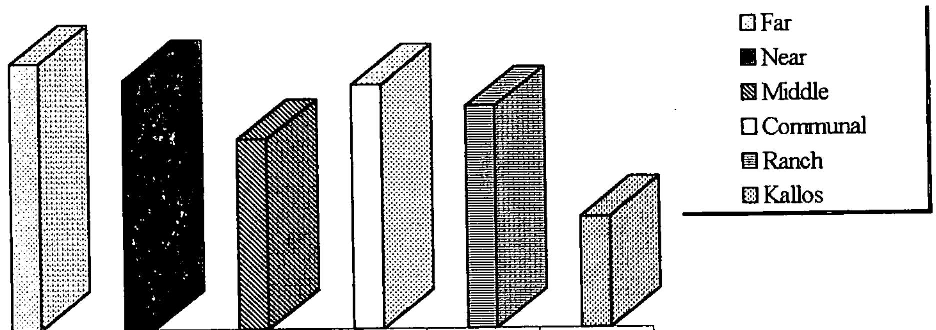


Figure 9.2 Seed bank species richness of flowering non-graminoides in a distance gradient from water.

9.3.4 Grass flora similarity between seed bank and aboveground plant community

Results of the evaluation of the similarity of grass flora between the soil seed bank and established vegetation are illustrated in Figure 9.3. The Sørensen's similarity index along the distance gradients from water indicated that the value was higher at the far than the near and middle sites. Under the land use systems it is clear from the figure that this value was higher at the communal area than the ranch and the traditional grazing reserves.



	Far	Near	Middle	Communal	Ranch	Kallos
Sørensen's index	40.00	37.50	28.57	36.73	33.33	16.67

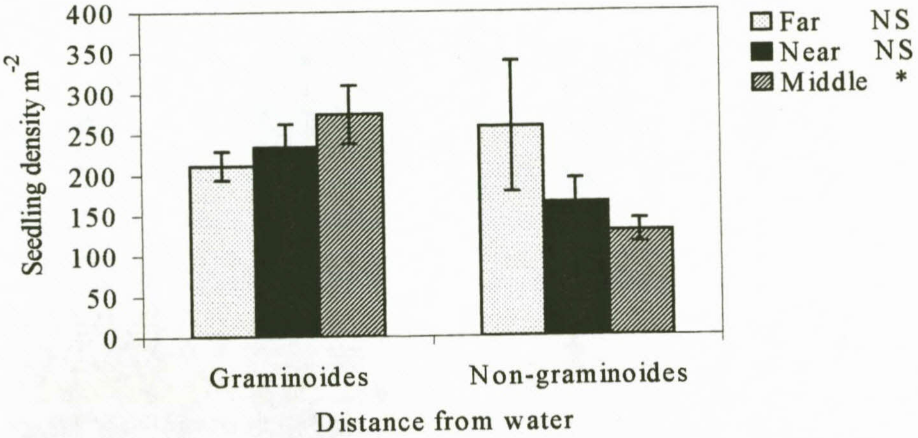
Figure 9.3 Similarity in grass flora between seed bank and aboveground vegetation.

9.3.5 Relationship between graminoides and non-graminoides

9.3.5.1 Seedling density

No statistically significant correlation ($P>0.05$) was observed between the graminoids and non-graminoids seedling density, but there was an indication of a negative trend for the distance gradients from water and the land use systems. Differences between the graminoids and non-graminoids mean seedling density are illustrated in Figure 9.4. It is clear from Figure 9.4a that for the distance gradients from water, the mean seedling density between graminoides and non-graminoides was not significant (P>0.05) at the near and far sites, whereas this difference was statistically prominent at the middle site (P<0.05). For the land use systems, the difference in the mean seedling density between the graminoides and non-graminoides was not apparent at the ranch site, but this was found to be significant at the communal area (P<0.05) and the traditional grazing reserve (P<0.01) sites (Figure 9.4b).

a



b

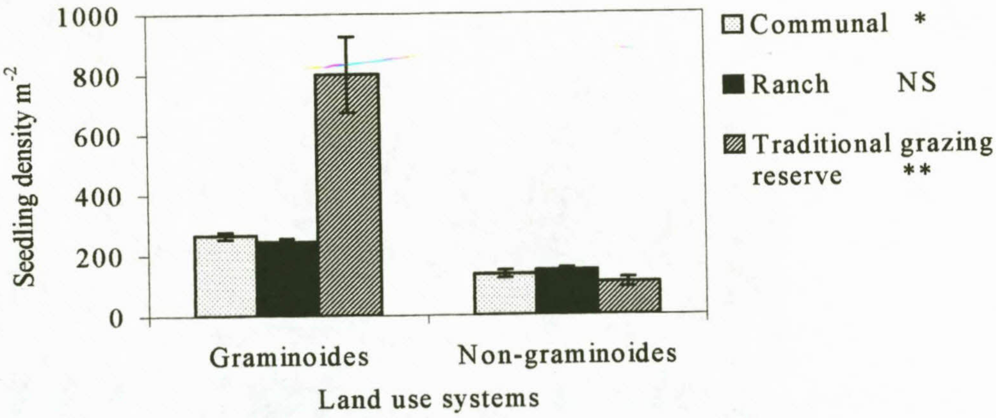


Figure 9.4 Relationship between seed bank seedling density of graminoides and non-graminoides along the distance gradient from water (a), and under three land use systems (b). Y error bars denote SE.

** = Highly significant (P < 0.01), * = Significant (P < 0.05);
NS = Non-significant (P>0.05).

9.3.5.2 Floristic density

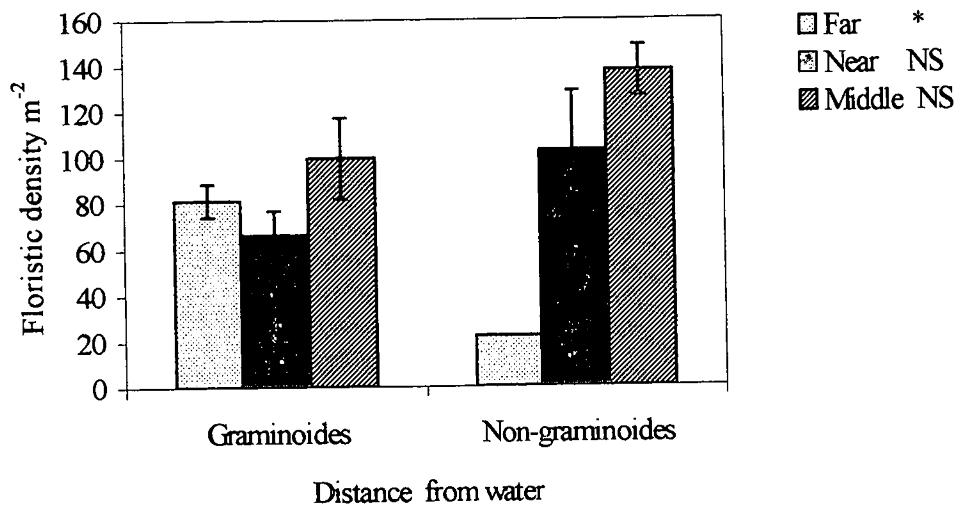
There was no significant relationship (P>0.05) between graminoids and non-graminoides mean total floristic density, but as previously mentioned, an indication of negative trend was noticed along the distance gradient from water and under the land use systems. It is clear from Figure 9.5a that the mean total floristic density between the graminoides and non-graminoides showed significant variation (P<0.05) at the far site of a distance gradient from water, but this did not vary significantly at the near and the middle sites. For the land use systems, there was a marked difference (P<0.01) between mean graminoides and non-graminoides total floristic density at the traditional grazing reserves whereas this difference remained non-significant at the ranch and the communal sites (Figure 9.5b).

9.4 DISCUSSION

9.4.1 Seedling and floristic density

Comparison of the seed bank seedling and floristic density of graminoids among the land use systems suggests that grazing impact is one of the most important causes of variation in seed bank population. This is explained by a significantly higher seed bank seedling and floristic density of graminoids obtained at the traditional grazing reserves than the government ranch and communal grazing sites. It is a common practice in Borana that the traditional grazing reserves have a lower grazing pressure and are used only during critical periods of the year. The government ranch had experienced high grazing pressure of various degrees over many years before the present limitations on stock density came into force only very recently. The communal areas had likewise been subject to heavy grazing, which has been increasing in recent years. From the low graminoids seed bank density measured at the communal grazing areas, it can be deduced that with continuous overgrazing, the proportion of aboveground grass layer has decreased, both because of heavy utilization and destruction of grass roots by trampling livestock Consequently, the production capacity of grasses and their ultimate contribution of seeds to the seed bank is reduced.

a



b

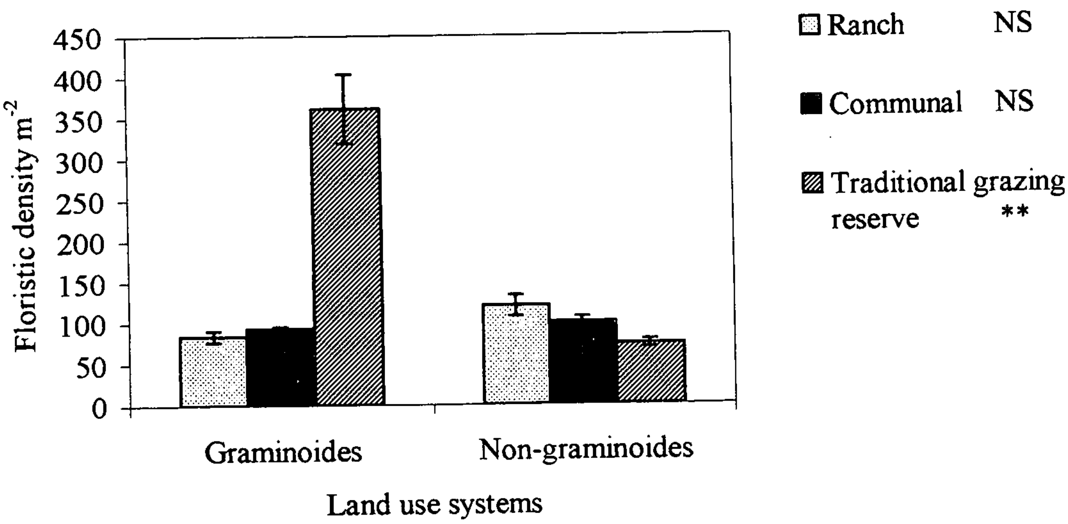


Figure 9.5 Relationship between floristic (flowering) seed bank density of graminoides and non-graminoides along a distance gradient from water (a), and under three land use systems (b). Y-error bars denote SE.
** = Highly significant (P<0.05), * = Significant (P<0.05);
NS = Non-significant (P>0.05).

Other investigations have similarly reported the influence of increased grazing impact on the reduction of the seed bank population (O'Connor & Pickett 1992; Bertiller 1996). The fact that the graminoid seedling and floristic density of the seed bank was significantly higher at the traditional grazing reserve than the communal and ranch sites, emphasizes, the expediency of grazing control to restore and maintain the seed bank population of the semi-arid savanna grasslands.

The non-significant differences in the graminoid seedling and floristic densities along a distance gradient from water can be attributed to similar proportion of grasses and associated seed bank population at the near, middle and far sites. This implies that grazing impacts at the three sites experienced similar levels of impact and disturbance.

On evaluating the non-graminoid seedling and floristic densities, the significantly lower non-graminoid mean total floristic density at the far sites compared to the middle and near sites is difficult to explain. Otherwise values did not show marked differences along the distance gradients from water and under the three land use systems, but again, there is no clear-cut explanation for these results. However, when considering the land use systems, the existence of small variations towards higher values of non-graminoid seedling and floristic density at the ranch and the communal grazing sites than the traditional grazing reserve may suggest that heavy grazing pressure can promote seedling recruitment of forbs. This is because grazing reduces the suppressive effect and seed production of the grass component, thereby allowing forbs to reproduce and contribute an abundance of seeds to the soil seed bank.

9.4.2 Floristic composition

As shown in Table 9.1, most plant species obtained in this study were annual forbs, followed by grasses. No large woody plants were recorded, although they were abundant on the rangeland. Similar results were reported in the Serengeti savanna of Uganda (Skoglund 1992). One reason for this result may be that the germination period of the glasshouse experiment was not long enough (6 months) to further examine seedling recruitment of the woody plants from the soil sample.

By non-statistical inspection it appeared that the highly desirable species, *L. senegalensis* and the desirable species, *L. nutans* were dominant under the three distance gradients from water and under the three land use systems. The remaining two highly desirable species, *D. milangiana* and *P. coloratum* were present at the middle and far sites of the water, and the communal and ranch sites, but the proportional presence of these species was relatively low. From these results, it is clearly seen that regeneration by seed is important for the occurrence and distribution of valuable grass species on the Borana rangeland and the replacement of individuals from the seed bank may have profound effects on the composition and patterns of the grass layer within the community.

When viewed separately, the relative dominant abundance of *L. senegalensis* and *L. nutans* in the seed bank may be attributed firstly, to their ability to persistent seed bank formation and /or secondly, the high turnover of seeds in these species. The persistence of valuable perennial grasses in the seed bank may be indicative of their ability to recover after disturbance. In contrast, the relatively low abundance of *D. milanjiana* and *P. coloratum* may be attributed to their inability to form persistent seed banks and/or their low turn over of seed. The inability to form persistent seed banks may render such perennial grass species vulnerable due to the low level of seedling recruitment. For the species with low persistence may not have a seed bank older than one year, availability of graminoid seeds in the seed bank depends on seed production by the established population in the preceding year (O'Connor & Pickett 1992). The inability to form persistent seed bank, however, is not only associated with agronomic features, but also with a specific set of micro- environmental conditions that must be specifically satisfied before seed germination and establishment can occur (Briske & Wilson 1977). As mentioned above, another overriding constraint of seedling recruitment of these grasses may be the low availability of seeds during rainy seasons (O'Connor 1996).

In the previous section it was shown that the undesirable species, *D. aegyptium*, was present at the middle and far sites of the distance gradient from water, though this species did not constitute a large proportion of the seed bank grass species composition. Similarly, *D. aegyptium* was present at the communal and ranch sites with a relatively high proportion (30.3 and 14.7 % respectively), but this species was not recorded at the traditional grazing sites. As noted earlier, there has been relatively more grazing impact on the ranch and communal grazing areas than the traditional grazing reserves. Therefore, this specific finding may substantiate the assumption that heavy grazing not only alters the aboveground grass species composition towards the abundance of a more, less and undesirable species, but it also changes the species composition of the seed bank in a similar direction.

9.4.2.1 Grass flora similarity between seed bank and aboveground vegetation

The results of this study demonstrate the familiar pattern of low similarity between the grass flora of the aboveground plant community and of associated seed bank at all sites along the distance gradient from water and under the land use systems (Figure 9.3.). Some species as explained in the previous section are well represented in the seed bank. On the other hand, species such as *Chrysopogon aucheri*, *Cenchrus ciliaris*, *Sporobulus nervosus* and *S. pyramidalis*, which are well represented in the vegetation, are absent in the seed bank. These results conform to those of other studies on grassland seed banks (Major & Pyott 1966; Thompson & Grime 1979; Thompson 1986). Some of the reasons were discussed in the previous section. Expectation of such results as ascribed to disturbance was in agreement with the report of Williams (1984). In addition, an extensive set of greenhouse conditions (e.g. Major & Pyott 1966; Roberts 1981) would have been necessary for the germination of more seeds to include expected species.

9.5 CONCLUSION

The following general conclusions can be drawn from this investigation:

(i) Regeneration from seed bank is important for the occurrence and regeneration of valuable grasses and may have a profound effect in maintaining the composition of the grass layer on the Borana rangeland.

(ii) Differences in graminoid seedling and floristic densities among the land use systems were prominent. Both the seedling and floristic densities were significantly higher at the traditional grazing reserve than the government ranch and communal grazing areas. From this result it can be concluded that difference in grazing pressure is one of the most important causes of the variations.

(iii) High grazing pressure, a common occurrence on communal grazing areas, not only changed the botanical composition of the aboveground grass layer towards less desirable and undesirable species, but also negatively affects both the size and composition of grass seeds in the soil seed bank.

(iv) Low grazing pressure and controlled grazing management, as experienced in the traditional protected grazing enclosures, ensured the restoration as well as maintenance of seed bank population of valuable grasses.

(v) The similarity between grass flora of the soil seed bank and aboveground plant community was low.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

As far as promoting the production of livestock from rangelands is concerned, Ethiopia has a large stake in the ecological sustainability of rangeland ecosystems and in maintaining a viable population of pastoral producers. Ethiopian rangelands are differentiated into diverse ecological systems that experience diverse grazing/browsing pressure. One of these is the Borana rangeland. The Borana have traditionally occupied vast and rich rangelands.

The Borana pastoral system until a few decades ago had been considered as among the most successful in east Africa. Over that time, the Borana have developed a conservational ethos for fauna and flora. It was suggested by scientists that the indigenous rangeland management system was efficient, comparable to the results demonstrated by controlled studies (Nicholson 1983; Upton 1986). In the past, comprehensive indigenous knowledge of rangeland management supported by intricate social rules and regulation ensured the sustainable use of the natural resources. The stable political organization of the "Gadda generation class" created a corresponding stability in pastoral production system (Oba 1998).

Other factors that contributed to the success of the pastoral production system in the Borana rangelands include: vast and varied geographical distribution of the rangeland resources, the unity and cohesiveness of the community, management of diverse species of herd and stable indigenous water sources with intricate management institutions.

The current situation in the Borana rangelands is disastrous to the ecosystem and consequently to the livelihood of the Borana society. The deterioration of the Borana rangelands, which may have begun a few decades ago has accelerated over recent years. From this, it can be deduced that the long-held view that the Borana system is an exemplary model of sustainable range-animal production in pastoral Africa has lost credibility. The scenario of the worsening situation of the Borana rangelands may also support the view that the Ethiopian rangelands are in jeopardy and must receive priority attention for rehabilitation or restoration rather than the "luxury" of well planned efforts to promote economic development. It was clear from this study that the deteriorating conditions of the Borana rangelands became obvious by changes in the structure and composition of the grass layer, severe bush encroachment, changes in soil fertility, increased soil erosion (personal observation) and by the status of the soil seed bank of the grass layer.

It was found in this study that there is a tendency of the replacement of most palatable and perennial grass species by less palatable and annual grass species. Some of the most important grass species, such as *Cenchrus ciliaris*, *Panicum maximum*, *Digitaria* spp and *Themeda triandra* are becoming rare, whereas less palatable and annual species (e.g. *Sporobulus pyramidalis* and *S. nervosus*) tend to dominate the grass layer. Basal cover of the grass layer is generally low and bare patchness was abundant on some of the communal grazing sites.

It was also found that, with the exception of the traditional grazing reserves, severe bush encroachment is the most critical problem in the vast communal land and the government ranch. The noxious invader plants were proved to be *Commiphora africana*, *Grewia tembensis*, *Acacia drepanolobium* and *Acacia brevispica*. The change in the grass layer and bush encroachment was much more pronounced on communal grazing land compared to the government ranch and the traditional grazing reserve. In the communal land, studies on the pattern of changes in bush encroachment, structure and composition of the grass layer along a distance gradient from water suggested that the rangeland disturbance reached beyond the threshold of degradation gradient. The current study also showed that not only did the aboveground grass layer of the communal land show deterioration, but the soil seed bank status of the grasses was also poor. The Borana pastoralists also strongly expressed their feelings with regard to the poor and declining trend of the rangeland condition, which to a large extent echoes the results of the current study.

Attributing factors to the degradation of Borana rangeland can generally be categorized into external and internal factors. The external factors include recurrent drought, land alienation, expansion of cultivation and inappropriate interventions. The most important internal factor is the increase of the human population with the concomitant results of increased livestock population. There is no clear evidence to what degree drought in general causes rangeland degradation in Borana. What is more, the effects of climatic drought and man-made drought on the health status of the rangeland are not clearly distinguished.

To this day, the lives of the Borana pastoralists have been shattered by political upheavals in the country. Under the different regimes that came to power, there have been politically associated changes in the natural resources. The rearrangement of local administrative borders and losses of resources following ethnic conflicts in the different Ethiopian states (more serious under the current regime) have caused the Borana to be compressed into only a fraction of the former vast rangelands. Within the reduced grazing/browsing home range, population pressure on the rangeland and water resource has increased. Such pressure on the environment has undoubtly resulted in rangeland degradation.

In spite of the fact that the landscapes of Borana rangelands offer little opportunity for cultivation, the latter is increasing as a result of a chronic threat of famine within the pastoral system. Cultivation could be increasingly difficult to control and its practices on the red upland rangeland soils are expected to be another major cause of rangeland degradation now and in the future. There is speculation that cultivation was introduced by the farmers outside the Borana pastoral system. Today, apart from the threat of famine within the pastoral system, expansion of cultivation is due to the growth of human population in the nearby towns. This increased peri-urban cultivation on fragile soils by immigrant farmers posed a new and growing pressure on the surrounding rangelands, leading to environmental degradation. Cultivation is conquering not only the key grazing areas but also expanding into unsuitable sites. The Borana pastoralists are aware of the fact that extensive cultivation on the rangeland soils is not only far from sustainable, but also competes for the key grazing resource with resulting severe environmental degradation.

Politically driven developmental interventions of the governments in the past and the present regimes have contributed to the degradation of Borana rangeland. In the past, developmental interventions were aimed at commercializing the pastoral production systems through livestock marketing and ranching. In general, government interventions attempted to propagate "modern" and centralized natural resource management systems to replace the traditional and decentralized ones. The chief constraint of the Borana rangeland was argued to be availability of water. The water development was pursued without proper planning, consequently transforming the traditional pattern of resource use pattern, which accelerated the degradation of the rangeland. Water sources (ponds and wells) are the focal points in the management of the rangelands by the Borana. The pastoralists questioned the extensive distribution of water ponds on the rangelands and expressed their preference for water ponds to be developed for human rather than for livestock consumption. The present regime pursued rearrangement of administrative borders and this partly resulted in the alienation of key grazing areas and water resources from the Borana rangeland.

Internal crisis in Borana today is mainly due to a high rate of human population growth in an environment, which is increasingly suffering from a lack of resources. The people have been forced in some parts to relinquish their former nomadic lifestyle in favour of a sedentary (settled) one because a high population density restricts options to move. With continued population growth, a sedentary life style will also increase and if not controlled in one way or another, will soon infiltrate the Borana. The net result of human population growth is a general increase in bush encroachment. This can be explained as follow: Firstly, sedentarization results in recurrent use of grazing lands that formely had been used in rotation. Secondly, although there is still mobility in the remaining parts, high human population is speculated and this has implication on heavy livestock pressure with the consequence of overgrazing. Over time, this will, of course, lead to bush encroachment. The question this issue poses is whether it is possible to reduce the human population to minimize its negative effects on the limited resources over the short term.

The perceived outcomes of rangeland degradation in the Borana pastoral system are many. The efficiency of pastoralism to produce enough to support pastoral livelihood without destabilizing of the natural resource base has declined. The physiological effect of rangeland degradation on the Borana is that they feel trapped and helpless, having no say in their future prospects. They were not willing to discuss freely what to do in future and what they aspired for. They lay the loss of their land directly at the door of the political upheavals in the country. There is an increasing influx of pastoral emigrants into the nearby towns and this has caused an increase in the number of street beggars. Urban dwellers considered this as a good indicator of the worsening of the crisis in the country in general and that of the Borana in particular. They also expressed their views that street begging had become a “no option” profession to the Borana emigrants. They also witnessed that such crisis had dawned very suddenly and unexpectedly on the stable Borana society.

Another consequence of environmental degradation in the Borana rangeland is that, for local urban centers, it is likely that a growing number of unemployed pastoral emigrants would negatively affect the general social welfare. It is also possible that the needs of the nation in terms of animal offtake could be negatively affected.

With respect to the ecosystem, the consequences of the rangeland degradation in the Borana rangelands can be viewed from different perspectives. It is probable that the climatic drought recovery will become a slow process as the resources are dwindling. Important valuable plant species having potential value as medicinal and forage sources have disappeared. The degradation of Borana rangeland has also implication on disrupting the food chain for wildlife. A reduction in the herbaceous layer may for instance, result in decreased population of grazer game species. While this happens, the next consequence may be that the sustainability of those wild animals, which depend on the herbivores, may be in jeopardy. Elder Borana informants reported that there had been a decline in the abundance of large wild animals in the past 40 years. One impression is that the government ranch in this study appears to have served as refuge for some of the wildlife because of a relatively low stocking rate and the exclusion of the pastoralists and their herds. Some of the elders interviewed in the villages near the ranch expressed serious concern for the return of the ranch to the community. This may be an important gesture in the light of severe resource constraints, but may bode unfavourably for the wildlife and conservation of the Borana cattle breed.

10.2 RECOMMENDATIONS

It has been folklore in Ethiopian developmental and rehabilitation circles that pastoralists are very independent and conservative and fiercely resist outside efforts to improve their livelihood. As revealed in this study, there is no evidence, however, that this statement holds true for the Borana rangelands. The Borana are open-minded to appropriate ideas and have in fact pioneered some of their own concepts in resource management. In this, they could be an appropriate model for the introduction of new developmental concepts in semi-arid pastoral Africa (Coppock 1994).

In the past, interventions in the Borana rangelands had not brought changes. Rather such activities had created a large and potentially less stable, regional cattle herd that periodically degrades the environment and are probably responsible in part for the rise in human population that is increasingly dependent on famine relief. Until today, in Ethiopia, the perceived lack of appropriate policy interventions and production technology for the rangeland systems means that the overall rangeland science has been relegated to an inferior status within the agricultural policy and research.

Borana rangeland has become degraded more severely in recent times than was the case in the past. This implies that sustainability of the ecology has to be the primary priority for interventions, followed by poverty alleviation and economic development. Two major options are open: (i) to pursue under the existing pastoral system, and (ii) privatizing the land. The question 'which way forward?' is more debatable today than it was some decades ago.

10.2.1 Ranching (land privatization)

In the past, ranch development on the Borana rangelands failed due to unworkable policies. When considering ranch development (land privatization) as an alternative to the existing pastoral mode of production, the immediate effect that springs to mind is the displacement of the pastoralists, alienation of land, increased pressure on the remaining land and land speculation. Compensation and settlement of the dispossessed are required, but is far beyond the capacity of the government. The net benefit, which is often quoted as the reason for land privatization, is minute over and above the loss of self reliance and increased dependence of the pastoral people on food aid. The process of privatization of the pastoral land will have dire consequence on the entire rangeland systems of Ethiopia.

Oba (1998) considered the Borana rangeland to be in a state of non-equilibrium and under such system, conditions cannot be predicted with certainty. Hence controlled management as envisaged by ranching is not practical. Once the high stocking rate was factored and milk was included as a major product for the pastoral people, the efficiency of the Borana system exceeded that of commercial ranching in a comparable setting in terms of energy yield per person and per unit areas (Coppock 1994). In this case, ranching may be a poor alternative for a subsistence-oriented pastoral society.

Ranching can be viewed, as an alternative, in line with today's most critical problem of the Borana pastoral system. This is the on-going high stocking rate, which further exacerbates the danger of risks for the rangeland degradation and system instability. Under a specialized production system, commercial ranching produces more meat per head than the pastoral system (Coppock 1994). Commercial ranching should not be seen as a threat if the changes improved rather than made them more vulnerable. When weighting the long-term implications of the sustainability of the environment and the socio-economic conditions, ranch development as a policy may have a positive effect on the rangeland resources of Ethiopia at large.

In general, before deciding on ranch development (privatization), it is recommended that policies that acknowledge the uniqueness of the rangelands be applied and the intervention options considered before the communal land is divided. Decisions on the privatization of the communal rangeland must also be conducted with sufficient consultation with the Borana and preceded by a clear policy.

A good alternative to the ranch development (land privatization) can be perceived from the ongoing situation that the Borana system is changing and mobility is gradually declining. One of the internal mechanisms that the Borana have used to counteract the internal exploitation of the rangeland resources is the use of the enclosed traditional grazing reserve (kallo). Kallos can therefore be used for improving rangeland management and controlling land use. If used properly, the kallos may open windows for the application of intensive natural resource management in the Borana rangeland.

10.2.2 Traditional pastoral system

Although the Borana find themselves in a difficult situation today, they do have two major advantages that could help them overcome the crisis and create sustainable wealth, while maintaining the existing pastoral systems. These are: (i) the Borana have an explosive capacity to generate animals, and (ii) they are a very peaceful society and have a high degree of open mindness concerning the adoption of appropriate innovation.

Today, Borana rangelands require greater focus on policy and immediate coordinated action to rehabilitate the severely deteriorated ecosystem. This has to be followed and supported by other interventions. In this study, concepts and interventions that are possibly recommended to the Borana rangeland are indicated below:

(i) Bush encroachment is the critical problem. Therefore, workable control programs need to be devised at policy level and implemented immediately. Interventions directed at bush control include prescribed burning. Burning the encroached Borana rangeland with hot fire any time of the year may be difficult. It is the most effective during a climatic drought recovery period. This is mainly because a smaller cattle population (due to sales and high mortality in the drought period) increases the chance that standing swards can be set aside for burning during dry periods. Adequate fuel loads is essential for hot fire ($\pm$ 2 tons ha^{-1}). Although using fire alone may be the only sustainable management practice, it may not get rid of all young trees and shrubs trees. Thus, it can be followed by arboricides and/or hand felling. Arboricides were shown to be necessary to prohibit woody regrowth of some species, and are very cost effective (Coppock 1994). Hand felling is labour demanding over the vast communal land, but it can be taken as an option.

In the post climatic drought period, control of bush encroachment based on prescribed burning may not be recommended for severely degraded grazing sites (e.g Did Yabello and Did Harra), because heavy cattle grazing would reduce the viability that large standing crops of grass could maintain in this phase.

(ii) The current management of the communal resource using the traditional grazing reserve (kallos) should be promoted. Development of such fodder banks should be integrated into bush encroachment control projects.

(iii) Haphazard and unplanned water development in the Borana rangelands must be stopped.

(iv) Possibilities to use available grazing lands that have not been used before must be investigated. In such a case, water development can be integrated into the use and management of this rangeland resource.

(v) It is vital to develop a clear policy at national level on the use and management of the communal rangeland resources. It is recommendable to formulate the policy on solid scientific and indigenous knowledge systems. The policy should first and foremost safeguard the pastoral people. The policy should also be guided by a comprehensive understanding of the arid and semi-arid parts of the country and their resources.

(vi) Workable systems have to be devised to advice local and traditional institutions, traditional knowledge and skills of natural resource management of the Borana should be applied and functioning systems should be re-instituted (strengthened), which will require strong policy interventions.

(vii) From the past efforts to rehabilitate and develop the Borana it has become clear that dictatorial approaches had been unsuccessful. In this study, it has become more clear that interventions devised on the basis of the grass-roots knowledge of the pastoral people would appear far more appropriate given the cultural attitudes and their reliance on local resources.

(viii) Sustained dialogue needs to be opened between the Borana leadership and development agents to prioritize the up-coming interventions with long term goals in mind.

(ix) Agricultural extension services have to be strengthened. Today, the extension service rendered by the local agricultural offices and a non-governmental organization is weak. This is not because of constraints arising from the indigenous environment *per se*, but because lack of manpower, fuel and vehicles considerably limits the capacity of extension services.

(x) Policies and procedures, which offer young Borana access to education, need urgent attention. In the course of this study, it was perceived that the Borana are very keen to have their youth educated. Some of the existing crises could have been averted if the same attention had been given to education and development of human potential as was given to stimulating marketing and ranching.

10.2.3 Monitoring and research

Efficient implementation of rehabilitation and developmental strategies described above will require research and routine data to be collected through monitoring. For instance, developmental agents need to have a better understanding of cattle population dynamics, status of the grazing reserves and extent of their areas, extent of cultivation, bush encroachment, water resources and pattern of use, the problems of the Borana with regard to water management, grazing resources and relevant matters. Monitoring can be done quantitatively (e.g by aerial survey which may be expensive, driving along the road network at important times of the year), and qualitatively (e.g attending important community meetings and recording perceived needs of the people).

As highlighted in this study, the following future research topics are of primary importance:

(i) As far as socio-economic aspects are concerned, further investigation into how the pastoral population is coping with problems that have arisen from high population growth and perennial climatic drought is needed. Research is needed to determine whether there have been changes in settlement patterns and if so what practical implications they will have on the use of rangeland resources. Research is required into a better understanding of the internal workings of the society, the current ability of the traditional social order (Gada) to cope with social stress (population growth) and its consequence (environmental degradation) and their attitude towards the possibilities of interventions in this regard.

(ii) Research is required to investigate effects of bush encroachment on the herbaceous layer and the extent of soil erosion. Further research is also needed to examine the effects of individual woody plant species (particularly noxious invaders) on the grass layer.

(iii) It was hypothesized in the previous reports (Coppock 1994) that nutrients transferred by cattle from grazing areas to encampments were considered important in encouraging bush encroachment around the encampments. In the current study, there were indications that some of the noxious invader species tended to occur abundantly in the nearby/around water points. Some of these provide a good source of forage to the browsers (camels and goats). The population of these browsers, particularly camels, showed an increasing trend in the Borana rangeland. Therefore, investigation is required whether or not the increased population of these species of animals could positively contribute to the expansion of woody encroachment by dispersal of browse seeds via their faeces.

(iv) The Borana rangeland has a rich flora and fauna, but trends in abundance or diversity of these organisms as affected by human activities are not well documented. Further studies, which could try to assess biodiversity in the Borana rangeland may consider how woody encroachment affects biodiversity at the site and landscape resolution.

(v) Previously in this section, it was recommended that field hay making interventions using traditional grazing reserve must be encouraged. Data is required on how to establish new grass swards for such hay making based on the best local species. One problem with this is, however, that most valuable local grass species are limited in distribution because of overgrazing. This will require further research to examine the soil seed bank dynamics of the Borana rangelands as well as mechanisms of re-establishing these grass species from the seed bank. In addition, effects of local indigenous management and site diversity on the productivity of traditional reserves deserve attention.

(vi) Further research is required to identify herbaceous and browse plants that have good forage value. This is because, for improvement of the Borana rangeland, the best option is to concentrate on the most promising native species of grasses and browse plants, which have the advantage of proven persistence in an environment constrained by low rainfall and/or high ambient temperature.

(vii) Further research is needed to investigate the effects of water development on native biodiversity in addition to the effects on the Borana production system as a whole.

There has been a debate regarding an appropriate mix of "upstream" (high-technology) versus "down stream" research activities in sub-Saharan Africa (Winrock international 1992). Whether it involves developing appropriate technology or gaining key insights for the interdisciplinary systems approach, the current study advocates the value of down stream research in Borana rather than upstream research. This encourages the Borana themselves to play a significant role in the process. In addition, collaboration between grass-roots development agents (including local agricultural offices), researchers and stake holders (pastoralists) is of paramount importance. The development agents should complete the loop between the Borana and the researchers to create a more participatory systems research approach. Both development agents and the pastoralists can help provide the eyes and ears of the research. Collaboration between researchers, development workers and the stake holders can be mutually beneficial in terms of helping understand the real problems, extending appropriate technology more rapidly and spread research results in scientific literature.

SUMMARY

The study was conducted in the Borana rangeland of southern Ethiopia. The landscape is gently undulating across an elevation of 1000 to 1600 m above sea level, except for a few mountain ranges, scattered volcanic cones and craters. The Borana plateau is dominated by a semi-arid climate. The average annual rainfall ranges between 111mm and 858 mm, with mean annual temperatures varying from 15 °C to 24 °C. Vegetation is predominantly a savanna type. Soil studies on an area of 15 475 km^2 suggested that the geology is 40 % quaternary deposits, 38 % basement complex formations and 20 % volcanics. Vertisols occur more in the valley bottoms, while upland soil is found everywhere.

A study on the pastoralists' perceptions and cattle rangeland management practices was conducted on 40 households and 128 elders (7 per group). The respondents were selected from 20 villages in the five peasant associations. Data on the characteristics and performance of individual livestock holding were obtained by a combination of formal discussion and structural interviews of individual households. Further formal discussions were conducted to gather information on the opinions and perceptions of the elders towards rangeland condition.

Studies on the grass layer, woody vegetation structure, soil characteristics and rangeland condition were conducted in four communal grazing areas and one government ranch. A total of eight watering points from the communal grazing areas and two from the government ranch were selected. Four traditional grazing reserves were also selected in the four communal grazing areas (Did Yabello, Did Harra, Dubuluk and Melbana). The selected sites had similar soil (red type), landscape, altitude and climate, but differed in the historical pastoral use. The same criteria were used to select the watering points, but additionally, water holding capacity and age were considered. One transect (3 to 12 km in length) was established along each watering point. Each transect was divided into three sub-transects to cover relatively nearby, middle and further away distances from

the water source. Approximately in the middle of each sub-transect and in the traditional grazing reserves, a plot of 20 x 50 m was marked, which was used for the vegetation and soil surveys.

The species composition of the grass layer was estimated using frequency of occurrence with the wheel point apparatus. The nearest plant and basal strikes were recorded from 300 point observations. The strike was recorded as bare ground when the nearest plant was > 400 mm from the marked wheel point. Surveys were carried out late in the long rainy season of the year 2001 (April to May).

For the study of the woody vegetation, three 10 x 10 m sub-transects were marked within each main plot. All rooted live woody plants were recorded by species, their height measured and counted for the analysis of density and species composition. Woody plant data were standardized to tree equivalent ha^{-1} (1 TE = 1 tree, 1.5 m high) for some comparisons.

Ten soil samples per plot were collected from the topsoil (to a depth of 200 mm) for the chemical and physical analysis. Each set of 10 samples was bulked and processed. Analysis was done for texture, pH, percentage total nitrogen (N), percentage organic C, available phosphorus (P) and exchangeable cations. Data on soil bulk density and soil compaction were also collected.

Study on soil seed bank characteristics was conducted by collecting soil samples along a distance gradient from water source (near, middle and far) and from the three land use systems. The upper 30 mm soil layer was removed from 0.25 m^2 quadrate. To investigate the distance effect, four of the total eight watering points identified for the vegetation and soil studies were used. Establishment of transect, sub-transects and plots followed the same procedure as mentioned previously. Concerning the land use systems, the government ranch, adjacent communal land and the traditional grazing reserve were used.

The glasshouse experiment was conducted at Alemaya University located 1 100 km away from the collection sites. Plastic pots were filled with sterile sand. Soil sample was spread over each plastic pot with a depth of up to 20 mm. Seedling and flowering dats were collected over a six month period.

Results on the pastoral survey indicated that the average household size for the study areas was 7.23. The percentage of male and female children who attended primary school were 21.8 % and 9.3 %, respectively, while that of secondary school and higher institution in total were 4.2 % and zero, respectively. The pastoralists relied on both livestock production and cultivation. Livestock holding per household in the study areas was estimated to be 14 cattle, 10 goats, 6 sheep and 2 camels. Total livestock population per household has declined over the past years. With regard to the population of all animal species, except camels showed a decrease in population. Camel population showed a large positive change over time in some of the areas. The growing interest in camel keeping and small ruminant production was emergency strategy to achieve food security.

Surveys in the study areas revealed the wide distribution of cultivation in the rangelands. The type of land encroached by cultivation seems to be a big threat to livestock and the traditional resource management. The competition between cultivation and livestock production for the key grazing resource was high. Elder pastoralists in the current study were concerned about the expansion of cultivation into the rangeland.

Major constraints of livestock production on the rangelands were in order of importance: recurrent drought, feed shortage, water scarcity, animal diseases and predators and communal land tenure. Interviews with pastoral elders indicated that the rangeland condition in Borana had declined. The main attributing factors to the rangeland deterioration were in order of importance: drought, increased human and livestock population, expansion of cultivation, ban on the use of fire and water development. Elder respondents also mentioned the bush encroachment problem in Borana rangeland.

Most respondents were of the opinion that it was difficult to predetermine the future prospects of the rangeland condition.

A total of 49 grass species were identified in this study. Results on the proportion of life forms among the land use systems showed the communal land had higher and lower percentages of annuals and perennials ($P<0.05$), respectively, than the government ranch and traditional grazing reserve. Both life forms did not show marked differences ($P>0.05$) between the communal grazing sites and along the distance gradient from water source.

Of the most common grass species, *Chrysopogon aucheri* differed significantly ($P<0.05$) between communal land (14.0 %) versus the government ranch and traditional grazing reserve. *Leptothrium senegalensis, Cenchrus ciliaris* and *Chloris myriostachya* did not differ significantly ($P>0.05$) between the land use systems. *Sporobulus nervosus* was higher ($P<0.05$) in the communal land (13.3 %) than in the other land use systems. There were no significant differences ($P>0.05$) in the occurrence of *S. pyramidalis* between the land use systems (average 32.1 %).

Herbaceous basal cover was generally low and did not differ significantly ($P>0.05$) between the land use systems, whereas bare patchness was higher ($P<0.05$) in the communal land (5 %) than in the other two (average = 0.4 %). Most of other studied variables showed significant differences between the communal area and other land use systems. This suggested that grazing pressure and hence intensity of use, may be the primary cause for the difference. Results on the life forms may show the existence of some replacement of perennials with annuals in the communal land that experienced a relatively higher grazing pressure than the two land uses. The frequency of both life forms, most common grass species, basal cover and bare patchness did not differ ($P>0.05$) along a distance gradient from water source. This is probably because the grazing disturbance has already exceeded a threshold of degradation over the complete distances around the watering points. Considering the communal grazing sites, key increaser species (*S. nervosus* and *S. pyramidalis*) and bare ground had the greatest values in the grazing sites experiencing a relative external interventions in the form of water development and rehabilitation (Did Harra), competition for and alienation of grazing lands (Did Yabello).

Total woody plant density was far higher ($P<0.001$) in the communal area (1083 TE ha^{-1}) and government ranch (1 188 TE ha^{-1}) than in the traditional grazing reserve. Within the communal area, Did Yabello (1 318 TE ha^{-1}), Did Harra (1 088 TE ha^{-1}) and Melbana (1 178 TE ha^{-1}) had greater ($P<0.05$) densities than Dubuluk. Differences along a distance gradient from water source were not significant ($P>0.05$) (average = 1 150 TE ha^{-1}).

The hypothesized number of woody plant in the semi-arid Borana rangeland above which it was regarded as representative of severe encroachment was 1 100 TE ha^{-1}. Therefore, with the exception of the traditional grazing reserve, the current study showed the advancement of woody encroachment into the study areas. The absence of significant variations along a distance gradient from water source may explain the occurrence of severe disturbance beyond the threshold of severe degradation.

The most important encroaching species identified in this study were *Commiphora africana*, *Grewia tembensis*, *Acacia drepanolobium* and *A. brevispica*. *Acacia drepanolobium* differed significantly between the land use systems. Density at the grazing reserve (1 TE ha^{-1}) was 95 % and 99 % less than ($P<0.001$) that of the government ranch and the communal land, respectively. Density at the communal land was 280 % higher ($P<0.01$) than that of the government ranch. In a distance gradient from water source, density of *A. drepanolobium* in the middle site (10 TE ha^{-1}) was 94 % and 81 % less than that of the near and far sites, respectively. The density at the near site (177 TE ha^{-1}) was 219 % higher than the far site. In respect of the communal grazing sites, Did Yabello and Did Harra have significantly higher density ($P<0.05$) than Melbana. The significant difference ($P<0.05$) for *C. africana* revealed that the communal area had a 282 % and 222 % higher TE density than the government ranch and the traditional grazing reserve, respectively. Along the distance gradient from water, the TE density of *C. africana* showed an increasing trend away from water, with the far site (mean of 371 TE ha^{-1}) having 122 % and 133 % higher density than the near and middle sites, respectively. Tree equivalent density of *C. africana* in Did Harra was 224 %, 114 % and 186 % higher ($P<0.05$) than Did Yabello, Dubuluk and Melbana sites, respectively.

Tree equivalent density of *Grewia tembensis* did not differ between the land use systems and along a distance gradient from water ($P>0.05$). In the communal grazing areas, TE density of *G. tembensis* was the highest in Did Yabello (110 TE ha^{-1}) and lowest in Melbana (29 TE ha^{-1}). There was no significant difference ($P>0.05$) in the TE density of *A. brevispica* between the communal land and the government ranch. Tree equivalent density of *A. brevispica* differed significantly between the near and middle ($P<0.05$), middle and far ($P<0.01$) and near and far ($P<0.01$) sites from the water source. In the communal grazing sites, *A. brevispica* was recorded only at Did Yabello and Dubuluk sites, with extremely higher density being obtained at the former (266 TE ha^{-1}) than the later (3 TE ha^{-1}) site.

Data on the content of soil nutrients indicated that no marked differences ($P>0.05$) occurred between the three land use systems, four communal grazing sites and along the distance gradient from water. Sand, silt and clay were similar to the three land use systems (average = 69.8 %, 22 % and 8.1 %) and in a distance gradient from water source and communal grazing sites (average = 71.8 %, 21 % and 7.5 %, respectively). Similar results were also obtained on bulk density and soil compaction. Overall results on the soil nutrients suggested that the values are low. This may suggest that the studied areas are not suitable for sustained and intensified cultivation without fertilization. In addition, as evident from the sandier and shallower nature of the soil, the Borana rangelands are ill-equipped to store nutrients and water, hence the greater vulnerability of the system to the current expanding practice of opportunistic cultivation.

Assessment of rangeland condition indicated that the total ecological condition index (ECI) in the government ranch (711) was 21.7 % and 26 % higher than at the traditional grazing reserve and the communal land, respectively. Likewise, the weighted palatability composition (WPC) at the government ranch (55 %) was 83.3 % and 48.6 % higher than at the communal and traditional grazing reserve, respectively. Differences in ECI and WPC between the three distances from water source were low (average = 533 and 26 %, respectively). As for the grazing sites within the communal area, Dubuluk and Melbana had higher ECI (602 and 520, respectively) and WPC (37 % and 36 %, respectively) than the other two sites. On the whole, the rangeland conditions in the study areas were poor.

A total of 44 plant species representing graminoid and non-graminoid flowering plants were identified in the seed bank study. Of these, 25 % were grasses and 75 % were non-grass plant species. Seedling and floristic density of the graminoids in the traditional grazing reserve (798 seedlings m^{-2} and 361 plants m^{-2}, respectively) were higher ($P<0.01$) than at the government ranch and communal grazing area. There were no significant differences ($P>0.05$) along the distance gradients from water. Similarity between the grass flora of the seed bank and that of aboveground plant community was low. As for the land use systems, results on the density of the graminoids suggested that grazing impact is one of the causes for the variations in the seed bank population. The non significant differences in the graminoids seedling and floristic density along the distance gradient from the water indicated that the grazing impacts already exceeded the threshold of severe degradation around the watering points. In general, regeneration of grasses from the soil seed bank can be an important means of re-establishing the valuable grasses and may have a profound effect in maintaining the composition of the grass layer in degraded Borana rangeland.

In this study, it is concluded that the current situation in the Borana rangelands is disastrous to the ecosystem as well as the livelihood of the pastoralists. Some of the most palatable grass species are becoming rare, whereas less palatable annual grass species tend to dominate the grass layer. Bush encroachment is a critical problem. There is a loss of soil fertility and increased soil erosion. Therefore, it is recommended that the Borana rangeland should receive strong focus on policy and immediate coordinated action to rehabilitate the severely deteriorated ecosystem.

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APPENDICES

Appendix 1. Pastoral households selected for the study of cattle-rangeland management practices and their perceptions towards rangeland degradation.

Name of households	Peasant association	Name of villages
Galma Halake	Did Yabello	Roba Boru
Roba Boru		
Duba Dabassa		Dabassa
Jateni Duba		
Boru Nura		Nura Tuke
Nura Tuke		
Kalicha Bagaio		Kalicha Bagaio
Adi Tuna		
Shoba Boru	Did Harra	Guvo Kavu
Garbicha Duba		
Tadhole Halake		
Jilo Dulacha		Dulacha
Dimtu Wako		
Guvo iateni		Guvo iateni
Galicha Jateni		
Nura Chach		Cachu Hallake
Diramo Gorbu	Movatte	Tadicha Warvo
Tadicha Warvo		
Abiduba Dabas		Warvo Jilo
Warvo Jilo		
Dahngne Huka		Huka Lemma
Garbele Huka		
Danbala Dida		Dida Dahgne
Gufur Dida		
Malich Jilo	Dubuluk	Jilo Boru
Jilo Boru		
Dulacha Alaka		Barki Ako
Jilo barchi		
Galmo Kivo		Dabassa
Elema Dabassa		
Boru Warvo		Boru Warvo
Malicha Boru		
Dida Boru	Melbana	Dida Boru
Boru Mulu		
Tukunu Kana		Dida Warvo
Jatani Abato		
Sake Dida		
Wato Dabaso		Liben Gofu
Kalicha Dabaso		
Jarso Agali		Jarso agali

Appendix 2 Questionnaires for the household survey

1 Livestock production (house hold)
1.1 Mention major farm activities

A. Livestock only ☐

B. Crop only ☐

C. Livestock and crop ☐

D. Other activities done by the family to support their livelihood other than farming

____

____

E. Additional Information in similar topics

____

____

1.2 The relative importance of each farm activity

1.2.1 Crop production

A. Major crops produced

B. Area under cultivation (in ha)

C. Do You observe expansion of crop production? Yes ☐ No ☐

1.2.2 Livestock production

A. Cattle ☐

B. Sheep and goat ☐

C. Camel ☐

D. Others, Specify ☐

1.3 Purpose of keeping cattle in order of importance

A. Cattle
A.1. ______________________
A.2. ______________________

A.3. ______________________
A.4. ______________________
A.5. ______________________
A.6. ______________________

B. Sheep
B.1. ______________________
B.2. ______________________
B.3. ______________________
B.4. ______________________
B.5. ______________________
B.6. ______________________

C. Goats
C.1. ______________________
C.2 ______________________
C.3. ______________________
C.4. ______________________
C.5. ______________________
C.6. ______________________

D. Camel
D.1. ______________________
D.2. ______________________
D. 3. ______________________
D.4. ______________________
D.5. ______________________
D.6. ______________________

1.4 Herd size, composition and structure

1.4.1 How is the composition of livestock species? Give rank **1 to 5** in terms of their number distribution.

A. cattle ☐

B. camel ☐

C. sheep ☐

D. Goats ☐

D. Other ☐

1.4.1.1 Do you think the species composition in terms of number has changed over time (15-20 years a go)? (elder groups will have more experience than the other family members and preferably need to be interrogated).

Yes ☐ no ☐

If the answer is yes,
1.4.1.2 What was the previous species composition? **Rank 1-5**

A. Cattle ☐

B. Camel ☐

C. Sheep ☐

D. Goats ☐

E. Others ☐

1.4.2 How is the trend in each species in terms of No (15-20 years ago)?

	Decrease	Increase	No significant change
1. Cattle			
2. Sheep			
3. Goats			
4. Camel			

1.4.3 How is livestock change over time 10 years a go in terms total species population? (Elders of the family group will be interviewed).

A. Decrease ☐

B. Increase ☐

C. No significant change ☐

D. Others ☐

1.4.4 Major constraints to livestock production (keen informants with a good understanding and ability to respond need to be interrogated)

A. Availability of grazing/feed resources ☐
B. Water availability ☐
C. Labor scarcity ☐
D. Communal land tenure
E. Management practice, stock wealth and production goals ☐

F. Animal diseases ☐

G. Recurrent drought ☐

H. Predators ☐

I. Others

1.4.5 Livestock inventory

A. Cattle

	Local name	No	Age	male	female
Calves					
young stock (<3 years old)					
Cows					
oxen/bulls					

B. Sheep

	Local name	No	Age	male	female
lamb					
adult					

C. Goats

	Local name	No	Age	male	female
Young					
mature					

D. Camel

	Local name	No	Age	male	female
Calves					
young stock					
milked camel					
bulls					

2. Household structure and educational background

2.1 House hold size

	Total
Male	
Female	

2.2 Age distribution (to be answered by the Father and mother)

Sex	Children under the age of 10 years old	Between 10-14 years old	Between 15-50 years old	Adults older than 50
Male				
Female				
Total				

2.3 Major activities done in crop production

A. By Male (Answered by male group of the family)

Major activities	Age group
	Under 10 years old
	Between 10-14 years
	Between 15-50 years
	>50 years

B. By Female (to be answered by females)

Major activities	Age group
	Under 10 years old
	Between 10-14 years
	Between 15-50 years
	>50 years

2.4 Major tasks in livestock production (labor available to livestock production activity)

A. By Male (answered by male)

Major activities	Age group
	Under 10 years old
	Between 10-14 years
	Between 15-50 years
	>50 years

B. By Female (answered by female)

Major activities	Age group
	Under 10 years old
	Between 10-14 years
	Between 15-50 years
	>50 years

2.5 Educational background

A. Do you think education is important? yes ☐ No ☐
B. How many persons in your household

	Male	Female
- Attend school? A.1. Elementary	☐	☐

A.2. Secondary ☐ ☐

A.3. Higher institutes ☐ ☐

A.4. Do not attend ☐ ☐

3. Cattle-range management practices

3.1 How do you graze/browse your animals (to be answered by house hold groups/shepherds)

A. All together (regardless of age, species, and sex) ☐

B. Grouping only by sex ☐

C. Grouping by sex and age ☐

D. Grouping only by species ☐

E. Others ☐

3.2 Answer to 3.1. Discuss briefly how it works?

____

____

3.3 Do you rotate your animals? yes/no
A. If yes, why?

____

____

____

____

____

____

3.4 When? i.e. from which season to which season
from which place to which place?

____

____

____

____

____

3.5 Do you use feed resource other than grazing/browsing? Yes ☐ No ☐
(to be answered by house hold groups)

If yes, Mention them

Type | Methods of utilization
A. ____________ | ______________________

B. ______________ ______________________________

C. ______________ ______________________________

D. ______________ ______________________________

E. ______________ ______________________________

F. Other opinion
____
____

3.5.1 Which animal group is fed (majority of the case) (to be answered by the house hold group)

A. Mature animals/adult bulls/oxen ☐

B. Young stock/calves ☐

C. Cows ☐

3.5.2 Do you feed them seasonally? Yes ☐ No ☐
(House hold group)

If the answer is yes, when is the season?
____
____
____

3.6 Do you have grazing/browsing shortage? Yes ☐ No ☐
(Elder Shepherds from the house hold groups and Elders/ leaders-key informants)

If yes,

A. What is the critical period (Season) of shortage? ☐

A.1. Ganna (March to May) ☐

A.2. Adolessa (June -August) ☐

A.3. Hagaya (September-November) ☐

A.4. Bonna (December-February) ☐

B. Strategy to minimize the risk of feed shortage? (Elder Shepherds from the house hold groups and Elders/ leaders-key informants)

- Supplementation ☐
-Mobility ☐
-No strategy ☐
-Others ☐

3.7 Do you have grazing/browsing land shortage? Yes/No (Elder Shepherds from the household groups and Elders/ leaders-key informants)

3.7.1 If No, Do you use all the available land for grazing/browsing? Yes ☐ No ☐

3.7.1.1 If No, Why (in order of importance)

A. Lack of access (road and the like) ☐

B. Fear of wild animals ☐

C. Not suitable i.e. Hilly and mountainous ☐

D. Too far to be reached ☐

E. Lack of watering point in the vicinity ☐

F. Others specify ☐
____
____
____
____

3.8 In the past, what practice did you employ to manage your grazing lands to keep the ecological balance of the range resource? (range feed resource) (in order of importance)
(to be answered by the elders/leaders and relatively adult members of the family)

A. Burning ☐
B. Mechanical bush clearing ☐
C. Rotational grazing ☐
D. Others ☐

3.8.1 Explain each practice **(to be answered by the elders/leaders and relatively adult members of the family)**

A. Burning

-What is the frequency of burning? (Burning interval)

- When did you burn? (Time of burning)

-What is the rest period after burning? (grazing protected)

3.8.2 Do you use it currently? Yes ☐ No ☐

3.8.3 If the answer is no, why?

A. Government ban ☐

B. Unmanageable to do it currently ☐
-No enough ground cover
-Trees already mature

C. Others ☐

3.8.4 Were you satisfied with this practice? Yes ☐ No ☐

3.8.4.1 Explain how you get satisfaction i.e. in what sense?

3.8.4.2 How long is it since the burning practice is banned by the government?

B. Mechanical clearing

B.1. Explain briefly the mechanism of mechanical bush clearing

- Was it practiced in the past? Yes ☐ No ☐

- Currently? Yes ☐ No ☐

-Is/Was it done frequently? Yes ☐ No ☐

-How is/was coordinating

The community themselves ☐

Government ☐

Other NGOs ☐

C. Other management option

4. Perceptions of pastoralists to range deterioration

4.1 Range condition

4.1.1 How is the range condition (say as compared to 15 years a go)? (to be answered by the elders/leaders)

A. No significant deterioration

B. Moderate deterioration

C. Very significant deterioration

4.1.2 How do you explain such change in range condition? (to be answered by the elders/leaders)

____

____

____

4.1.3 Do you observe change in grass species composition? Yes ☐ No ☐
if yes, How is the trend?

-towards the abundance of less palatable and disappearance of more desirable and palatable ☐

- towards the abundance of intermediate palatable and disappearance of more desirable and palatable ☐

-towards the abundance of less and intermediate palatable and disappearance of more palatable.

4.14. Are there species ☐ which were not found before and which appears in recent time?

Yes ☐ No ☐

If yes, give their names

____
____
____
____
____
____
____
____

4. 1.5 What do you think the reasons for the change (in order of importance)

A. Increased livestock production ☐

B. Increased Human population ☐

C. Recurrent drought ☐

D. Increased number of watering point ☐

E. Introduction of cultivation ☐

G. Others ☐

____
____

4.1.6 Do you observe change in bush density (15 years a go)? yes ☐ No ☐
If yes,

A. very significant

B. Moderate encroachment

C. No significant change

4.1.7 Do you think there is change in bush species composition? Yes ☐ No ☐
4.1.8 Is the change process in bush density and species composition (within 15 years)

A. Slow ☐

B. Moderate ☐

C. Very fast ☐

4.1.9 Why is such change taking place?

A. Increased livestock production ☐

B. Increased Human population ☐

C. Recurrent drought ☐
D. Increased number of watering point

E. Introduction of cultivation ☐ ☐

G. Ban of fire ☐
H. Other

____
____
____

4.1.10 Do you think bush encroachment affect livestock production? Yes ☐ No ☐

How?

____
____
____

Which species is more affected?(In order)

A ____________
B ____________
C __________
d. ___________

Which species of wood/shrub show heavy expansion?

____
____
____
____
____
____
____

4.2 Prospects and opinions to improve the range condition

4.2.1. What do you forecast the condition of the range to be for the coming years, say 10 years a head to come?

A. Will not change ☐

B. Will deteriorate slowly ☐

C. Will deteriorate very much progressively ☐

D. Very difficult to forecast ☐

E. Other opinion ☐

4.2.2 What do you think its effect on livestock production?

____
____
____
____
____
____
____

4.2.3. On the existence of the society?

4.2.4 Your general opinion what will happen if the deterioration progress?

4.2.5 What is your opinion for such deterioration to take place (in order of importance)?

A. Livestock population increment ☐

B. Recurrent drought ☐

C. Human population growth ☐

D. traditional management ☐

E. little attention from the government ☐

F. others ☐

4.2.5.1 Explain each how it contributes?

____
____
____
____

4.2.6 Your opinion to improve the range degradation (in order of importance)

A. Reduction of livestock population ☐

B. Burning ☐

C. Bush clearing ☐

D. Development of marketing infrastructure ☐

E. Other opinion

Appendix 3 Ecological groups, botanical composition and condition scores under the three land use systems.

Species category (Relative index value)	Traditional grazing reserve	score	Communal	score	ranch	score
Decreasers (10)						
Andropogon canaliculatus, Schumacher	0.00	0.00	0.00	0.00	0.20	2.03
Bothrichloa insculpta(Hochst.) A. Camus	0.00	0.00	0.07	0.72	0.00	0.00
Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	0.00	0.00	0.11	1.09	0.00	0.00
Cenchrus ciliaris, L.	3.34	33.40	4.67	46.68	4.77	47.73
Chloris myriostachya, Horst.	1.12	11.20	1.98	19.78	0.88	8.82
Chrysopogon aucheri, (Boss) Stapf.	27.66	276.6	14.01	140.05	23.01	230.10
Digitaria erantha	0.00	0.00	0.02	0.17	0.00	0.00
Digitaria milanjiana, (Rendle) Stapf.	5.79	57.85	2.81	28.06	1.86	18.60
Eustachys paspaloides, (Vahl.) Lanza Mattei	0.00	0.00	0.00	0.00	0.00	0.00
Leptothrium senegalensis, (Kunth) Clayton	4.31	43.13	4.24	42.41	3.39	33.85
Panicum coloratum	0.00	0.00	0.10	1.02	0.74	7.417
Panicum maximum, Jacq.	2.01	20.05	2.03	20.35	0.50	4.98
Panicum sp. Aff. turgidum, Forsk	0.10	1.00	0.30	3.03	2.85	28.50
Setaria ustilata	0.20	2.00	0.08	0.83	0.00	0.00
Themeda triandra, Forsk.	0.71	7.08	0.39	3.94	12.19	121.90
Andropogon abyssinicus fresen.	1.91	19.08	0.08	0.82	0.07	0.68
Andropogon sp	0.00	0.00	0.27	2.68	2.18	21.83
Sub total		**471.39**		**311.61**		**526.47**
Increasers IIa (7)						
Cynodon dactylon, (L) pers.	0.90	6.30	4.22	29.54	0.00	0.00
Hayparrhenia hirta, (L.) stapf.	0.00	0.00	0.00	0.00	0.54	3.76
Heteropogon contortus, (L.) Beauv. ex. R. Sch.	1.20	8.40	0.65	4.54	4.90	34.32
Lintonia nutans, stapf.	0.20	1.40	0.09	0.63	0.20	1.38
Lintona spp	0.00	0.00	0.02	0.11	0.00	0.00
Enteropogon simplex (schum) A. ehevalier.	0.00	0.00	0.00	0.00	0.07	0.47
Sub total		**16.10**		**34.82**		**39.96**
Increasers IIb (4)						
Oropetium capense Stapf	0.90	3.61	0.43	1.72	0.00	0.00
Erichloa fatmensis (Hochst Stead.) A. Camus	0.00	0.00	0.13	0.52	0.00	0.00
Bothriochloa radicans, A. camus	0.70	2.80	0.78	3.12	0.41	1.62
Elusine jaegeri, pilger	0.00	0.00	0.40	1.59	0.28	1.10
Elyonurus muticus	0.00	0.00	0.02	0.07	0.07	0.26
Sporobulus nervosus Hochst.	3.32	13.29	13.28	53.12	1.89	7.56
Eragrostis cilianensis Link exlutati.	0.30	1.21	0.58	2.33	0.07	0.27
Harpachne shimperi, Hochzt. Ex. A. Rich.	0.10	0.40	0.15	0.59	0.46	1.84
Tetrapogon villosus Desf.	0.00	0.00	0.03	0.13	0.00	0.00
Pennisetum mezianum, (Vahl.) Lanza Mattei	2.37	9.49	2.01	8.02	0.00	0.00
Pennisetum stramineum, peter	0.21	0.82	0.42	1.67	0.07	0.27
Digitaria velutina (Forssk.) P.Beauv.	0.00	0.00	0.22	0.88	0.00	0.00

Appendix 3 cont'd

Species category (Relative index value)	Traditional grazing reserve	score	Communal	score	ranch	score
Sporobulus festivus Hochst. ex. A.Rich.	0.90	3.60	0.36	1.43	0.00	0.00
Setaria verticillata, Beauv	0.00	0.00	0.02	0.07	0.07	0.27
Sporobulus pyramidalis, Beauv.	31.82	127.29	32.97	131.86	31.80	127.20
Loudetia flavida (Stapf.) C.E. Hubb.	0.00	0.00	0.07	0.27	0.00	0
Sub total		**162.51**		**207.39**		**140.41**
Increasers IIc						
Aristida adoensis, Hochst.	0.40	0.40	0.22	0.22	1.59	1.58
Aristida adscensionis, L.	0.70	0.70	0.30	0.30	1.05	1.05
Aristida congesta	0.00	0.00	0.02	0.02	0.00	0.00
Dactyloctenium aegyptium, (L.) Pers	0.00	0.00	1.09	1.09	0.35	0.34
Eragrostis senni, Chiov	0.10	0.10	0.38	0.38	0.40	0.39
Microchloa kunthii, Desv.	8.23	8.23	4.26	4.26	1.67	1.66
Tetrapogon cenchriformis(A.Rich)W.D.Clayton	0.00	0.00	0.02	0.02	0.00	0.00
Tragus berternianus Schult.	0.30	0.30	0.69	0.69	0.07	0.06
Dinebra retroflexa (vahl) panzer	0.00	0.00	0.02	0.02	0.00	0.00
sub total		**9.74**		**6.99**		**5.12**
Total		**584.87**		**560.81**		**711.95**

Appendix 4 Ecological groups, botanical composition and condition scores in a distance gradient from water source.

Species category (Relative index value)	Near	score	middle	Score	far	score
Decreasers (10)						
Andropogon canaliculatus, Schumacher	0.00	0.00	0.00	0.00	0.00	0.00
Bothrichloa insculpta(Hochst.) A. Camus	0.12	1.23	0.05	0.54	0.11	1.08
Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	0.32	3.17	0.05	0.50	0.28	2.78
Cenchrus ciliaris, L.	3.65	36.50	4.59	45.88	4.29	42.91
Chloris myriostachya, Horst.	2.46	24.63	1.75	17.53	2.16	21.55
Chrysopogon aucheri, (Boss) Stapf.	8.97	89.70	12.73	127.30	13.62	136.21
Digitaria erantha	0.00	0.00	0.05	0.50	0.00	0.00
Digitaria milanjiana, (Rendle) Stapf.	2.27	22.66	3.61	36.14	1.98	19.83
Leptothrium senegalensis, (Kunth) Clayton	2.22	22.20	2.25	22.54	2.32	23.24
Panicum coloratum	0.35	3.50	0.00	0.00	0.31	3.06
Panicum maximum, Jacq.	2.11	21.09	2.23	22.30	1.85	18.45
Panicum sp. Aff. turgidum, Forsk	0.00	0.00	0.00	0.00	0.05	0.48
Setaria ustilata	0.23	2.26	0.00	0.00	0.20	1.98
Themeda triandra, Forsk.	0.06	0.59	0.15	1.48	0.15	1.46
Andropogon abyssinicus fresen.	0.00	0.00	0.25	2.46	0.00	0.00
Andropogon sp	0.00	0.00	0.00	0.00	0.29	2.86
sub total		**227.51**		**277.15**		**275.88**
Increasers IIa (7)						
Cynodon dactylon, (L) pers.	1.55	10.85	9.47	66.32	1.36	9.49
Heteropogon contortus, (L.) Beauv. ex. R. Sch.	0.31	2.19	0.10	0.70	1.30	9.09
Lintonia nutans, stapf.	0.06	0.43	0.15	1.05	0.05	0.38
Lintona spp	0.06	0.39	0.00	0.00	0.05	0.34
sub total		**13.86**		**68.07**		**19.30**
Increasers IIb						
Oropetium capense Stapf	1.36	5.43	0.05	0.22	1.19	4.75
Erichloa fatmensis (Hochst Stead.) A. Camus	0.45	1.78	0.00	0.00	0.39	1.56
Bothriochloa radicans, A. camus	0.74	2.96	0.16	0.62	1.27	5.07
Elusine jaegeri, pilger	0.19	0.75	1.03	4.12	0.16	0.66
Sporobulus nervosus Hochst.	14.18	56.73	15.25	60.99	12.79	51.16
Eragrostis cilianensis Link exlutati.	0.06	0.25	1.34	5.34	0.05	0.22
Harpachne shimperi, Hochzt. Ex. A. Rich.	0.07	0.27	0.05	0.20	0.06	0.24
Tetrapogon villosus Desf.	0.11	0.45	0.00	0.00	0.10	0.40
Pennisetum mezianum, (Vahl.) Lanza Mattei	6.36	25.42	0.41	1.62	5.56	22.25
Pennisetum stramineum, peter	0.00	0.00	0.89	3.55	0.00	0.00
Digitaria velutina (Forssk.) P.Beauv.	0.17	0.66	0.47	1.87	0.15	0.58
Sporobulus festivus Hochst. ex. A.Rich.	0.19	0.75	0.00	0.00	0.16	0.66
Setaria verticillata, Beauv	0.06	0.22	0.00	0.00	0.05	0.20
Sporobulus pyramidalis, Beauv.	40.21	160.84	33.21	132.86	35.71	142.84
sub total		**256.51**		**211.37**		**230.55**

Appendix 4 cont'd

Species category (Relative index value)	Near	score	middle	score	far	score
Increasers IIc						
Aristida adoensis, Hochst.	0.00	0.00	0.00	0.00	0.29	0.29
Aristida adscensionis, L.	0.57	0.57	0.15	0.15	0.50	0.50
Aristida congesta	0.06	0.06	0.00	0.00	0.05	0.05
Dactyloctenium aegyptium, (L.) Pers	2.90	2.90	0.63	0.63	2.54	2.54
Eragrostis senni, Chiov	0.05	0.05	0.77	0.77	0.10	0.10
Microchloa kunthii, Desv.	2.78	2.78	4.44	4.44	3.10	3.10
Tetrapogon cenchriformis(A.Rich)W.D.Clayton	0.06	0.06	0.00	0.00	0.05	0.05
Tragus berternianus Schult.	0.43	0.43	0.75	0.75	0.76	0.76
Dinebra retroflexa (vahl) panzer	0.06	0.06	0.00	0.00	0.05	0.05
sub total	**6.91**	**6.91**	**6.74**	**6.74**	**7.43**	**7.43**
Total score		**504.79**		**563.32**		**533.16**

Appendix 5 Ecological groups, botanical composition and condition scores under four communal grazing areas.

Species category (Relative index value)	Communal grazing sites							
Decreasers (10)	Did Yabello	score	Did Harra	score	Dudbuluk	score	Melbana	score
Bothrichloa insculpta(Hochst.) A. Camus	0.00	0.00	0.14	1.43	0.14	1.43	0.00	0.00
Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	0.00	0.00	0.00	0.00	0.07	0.67	0.37	3.70
Cenchrus ciliaris, L.	2.91	29.13	4.52	45.15	6.98	69.80	4.26	42.63
Chloris myriostachya, Horst.	0.74	7.35	1.54	15.40	1.12	11.20	4.52	45.15
Chrysopogon aucheri, (Boss) Stapf.	12.98	129.83	12.93	129.30	15.92	159.18	14.19	141.88
Digitaria erantha	0.00	0.00	0.07	0.67	0.00	0.00	0.00	0.00
Digitaria milanjiana, (Rendle) Stapf.	2.30	23.02	0.07	0.72	2.78	27.77	6.07	60.73
Leptothrium senegalensis, (Kunth) Clayton	2.84	28.38	2.27	22.67	6.48	64.80	5.38	53.80
Panicum coloratum	0.00	0.00	0.41	4.08	0.00	0.00	0.00	0.00
Panicum maximum, Jacq.	0.00	0.00	2.09	20.87	2.44	24.38	3.61	36.13
Panicum sp. Aff. Turgidum, Forsk	0.96	9.58	0.13	1.32	0.00	0.00	0.12	1.23
Setaria ustilata	0.00	0.00	0.07	0.67	0.00	0.00	0.26	2.63
Themeda triandra, Forsk.	0.26	2.63	1.12	11.15	0.20	1.97	0.00	0.00
Andropogon abyssinicus fresen.	0.00	0.00	0.00	0.00	0.33	3.28	0.00	0.00
Andropogon sp	1.07	10.70	0.00	0.00	0.00	0.00	0.00	0.00
sub total		**240.63**	**25.34**	**253.42**	**36.45**	**364.48**		**387.90**
Increasers IIa								
Cynodon dactylon, (L) pers.	10.64	74.48	3.76	26.34	1.70	11.90	0.78	5.45
Heteropogon contortus, (L.) Beauv. Ex. R. Sch.	1.44	10.05	0.80	5.59	0.29	2.04	0.07	0.47
Lintonia nutans, stapf.	0.07	0.50	0.29	2.01	0.00	0.00	0.00	0.00
Lintona spp	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.46
sub total		**85.03**		**33.94**		**13.94**		**6.37**
Increasers IIb								
Oropetium capense Stapf	0.00	0.00	0.00	0.00	1.52	6.09	0.20	0.79
Erichloa fatmensis (Hochst Stead.) A. Camus	0.00	0.00	0.00	0.00	0.00	0.00	0.52	2.08
Bothriochloa radicans, A. camus	1.65	6.61	0.48	1.91	0.34	1.36	0.64	2.57
Elusine jaegeri, pilger	0.98	3.93	0.61	2.43	0.00	0.00	0.00	0.00
Elyonurus muticus	0.07	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Sporobulus nervosus Hochst.	22.76	91.03	6.69	26.75	12.82	51.27	10.86	43.43
Eragrostis cilianensis Link exlutati.	0.79	3.15	0.28	1.13	0.79	3.17	0.47	1.88
Harpachne shimperi, Hochzt. Ex. A. Rich.	0.07	0.27	0.24	0.96	0.28	1.13	0.00	0.00
Tetrapogon villosus Desf.	0.00	0.00	0.00	0.00	0.13	0.53	0.00	0.00
Pennisetum mezianum, (Vahl.) Lanza Mattei	0.15	0.59	0.00	0.00	0.46	1.84	7.42	29.66
Pennisetum stramineum, peter	0.00	0.00	0.27	1.06	1.41	5.63	0.00	0.00
Digitaria velutina (Forssk.) P.Beauv.	0.00	0.00	0.00	0.00	0.07	0.27	0.82	3.26
Sporobulus festivus Hochst. Ex. A.Rich.	1.22	4.86	0.14	0.56	0.08	0.31	0.00	0.00
Setaria verticillata, Beauv	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.26
Sporobulus pyramidalis, Beauv.	21.50	85.98	45.12	180.47	36.80	147.19	28.45	113.80

Appendix 5 cont'd

Sub toatal		**197.24**		**215.80**		**218.78**		**197.74**
Increasers IIc								
Loudetia flavida (Stapf.) C.E. Hubb.	0.14	0.55	0.13	0.53	0.00	0.00	0.00	0.00
Aristida adoensis, Hochst.	0.45	0.45	0.35	0.35	0.07	0.07	0.00	0.00
Aristida adscensionis, L.	0.00	0.00	0.50	0.50	0.64	0.64	0.07	0.07
Aristida congesta	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
Dactyloctenium aegyptium, (L.) Pers	0.87	0.87	0.07	0.07	0.20	0.20	3.22	3.22
Eragrostis senni, Chiov	0.75	0.75	0.42	0.42	0.20	0.20	0.13	0.13
Microchloa kunthii, Desv.	2.36	2.36	7.13	7.13	4.56	4.56	3.00	3.00
Tetrapogon cenchriformis(A.Rich)W.D.Clayton	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
Tragus berternianus Schult.	1.33	1.33	0.07	0.07	0.39	0.39	0.97	0.97
Dinebra retroflexa (vahl) panzer	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Sub total		**5.75**		**8.69**		**6.06**		**7.46**
Total score		**528.65**		**511.84**		**603.27**		**599.47**

Appendix 6 Palatability classes, Frequency (%) composition and palatability scores of grasses under three land use systems.

Palatability classes (weighing value)	Traditional grazing reserve	score	Communal	score	ranch	score
Highly palatable (3)						
Andropogon canaliculatus, Schumacher	0.00	0.00	0.00	0.00	0.20	0.61
Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	0.00	0.00	0.11	0.33	0.00	0.00
Cenchrus ciliaris, L.	3.34	10.02	4.67	14.00	4.77	14.32
Chrysopogon aucheri, (Boss) Stapf.	20.18	60.53	14.01	42.02	23.01	69.03
Digitaria erantha	0.00	0.00	0.02	0.05	0.00	0.00
Digitaria milanjiana, (Rendle) Stapf.	5.79	17.36	2.81	8.42	1.86	5.58
Eustachys paspaloides, (Vahl.) Lanza Mattei	0.00	0.00	0.00	0.00	0.00	0.00
Leptothrium senegalensis, (Kunth) Clayton	4.31	12.94	4.24	12.72	3.39	10.16
Panicum coloratum	0.00	0.00	0.10	0.31	0.74	2.23
Panicum maximum, Jacq.	2.01	6.02	2.03	6.10	0.50	1.50
Panicum sp. Aff. turgidum, Forsk	0.10	0.30	0.30	0.91	2.85	8.55
Setaria ustilata	0.20	0.60	0.08	0.25	0.00	0.00
Themeda triandra, Forsk.	0.71	2.12	0.39	1.18	12.19	36.57
Digitaria abyssinica (Hochst. ex A.Rich.) Stapf	0.00	0.00	0.00	0.00	0.00	0.00
Andropogon abyssinicus fresen.	1.91	5.72	0.08	0.25	0.07	0.21
Andropogon sp	0.00	0.00	0.27	0.80	2.18	6.55
Enteropogon simplex (schum) A. ehevalier.	0.00	0.00	0.00	0.00	0.07	0.21
Digitaria velutina (Forssk.) P.Beauv.	0.00	0.00	0.22	0.66	0.00	0.00
Sub total	**38.53**	**115.60**	**29.33**	**88.00**	**51.83**	**155.50**
Intermediately palatable (2)						
Bothrichloa insculpta(Hochst.) A. Camus	0.00	0.00	0.07	0.14	0.00	0.00
Chloris myriostachya, Horst.	1.12	2.24	1.98	3.96	0.88	1.76
Cynodon dactylon, (L) pers.	0.90	1.80	4.22	8.44	0.00	0.00
Hayparrhenia hirta, (L.) stapf.	0.00	0.00	0.00	0.00	0.54	1.08
Heteropogon contortus, (L.) Beauv. ex. R. Sch.	1.20	2.40	0.65	1.30	4.90	9.81
Lintonia nutans, stapf.	0.20	0.40	0.09	0.18	0.20	0.40
Lintona spp	0.00	0.00	0.02	0.03	0.00	0.00
Harpachne shimperi, Hochzt. Ex. A. Rich.	0.10	0.20	0.15	0.30	0.46	0.92
Sub total	**3.52**	**7.04**	**7.17**	**14.34**	**6.98**	**13.97**
Less palatable (1)						
Oropetium capense Stapf	0.90	0.90	0.43	0.43	0.00	0.00
Erichloa fatmensis (Hochst Stead.) A. Camus	0.00	0.00	0.13	0.13	0.00	0.00
Elusine jaegeri, pilger	0.00	0.00	0.40	0.40	0.28	0.28
Sporobulus nervosus Hochst.	3.32	3.32	13.28	13.28	1.89	1.89
Eragrostis cilianensis Link exlutati.	0.30	0.30	0.58	0.58	0.07	0.07
Tetrapogon villosus Desf.	0.00	0.00	0.03	0.03	0.00	0.00
Pennisetum mezianum, (Vahl.) Lanza Mattei	2.37	2.37	2.01	2.01	0.00	0.00
Pennisetum stramineum, peter	0.21	0.21	0.42	0.42	0.07	0.07

Appendix 6 cont'd

Sporobulus festivus Hochst. ex. A.Rich.		0.90	0.90	0.36	0.36	0.00	0.00
Setaria verticillata, Beauv		0.00	0.00	0.02	0.02	0.07	0.07
Sporobulus pyramidalis, Beauv.		31.82	31.82	32.97	32.97	31.80	31.80
Loudetia flavida (Stapf.) C.E. Hubb.		0.00	0.00	0.07	0.07	0.00	0.00
Aristida adscensionis, L.		0.70	0.70	0.30	0.30	1.05	1.05
Aristida congesta		0.00	0.00	0.02	0.02	0.00	0.00
Dactyloctenium aegyptium, (L.) Pers		0.00	0.00	1.09	1.09	0.35	0.35
Eragrostis senni, Chiov		0.10	0.10	0.38	0.38	0.40	0.40
Tetrapogon cenchriformis(A.Rich)W.D.Clayton		0.00	0.00	0.02	0.02	0.00	0.00
Dinebra retroflexa (vahl) panzer		0.00	0.00	0.02	0.02	0.00	0.00
Sub total		**40.63**	**40.63**	**52.50**	**52.50**	**35.96**	**35.96**
Unpalatable (1)							
Bothriochloa radicans, A. camus		0.70	0.70	0.78	0.78	0.41	0.41
Elyonurus muticus		0.00	0.00	0.02	0.02	0.07	0.07
Aristida adoensis, Hochst.		0.40	0.40	0.22	0.22	1.59	1.59
Microchloa kunthii, Desv.		8.23	8.23	4.26	4.26	1.67	1.67
Tragus berternianus Schult.		0.30	0.30	0.69	0.69	0.07	0.07
Sub total		**9.63**	**9.63**	**5.97**	**5.97**	**3.79**	**3.79**
	Pc		**172.90**		**160.81**		**209.22**
	VCI		**57.63**		**53.60**		**69.74**
	WPC		**36.48**		**30.43**		**54.57**

VCI = Pc X 100 ÷300

Appendix 7 Palatability classes, frequency (%) composition and palatability scores of grasses in three distances around water point.

Palatability classes (weighing value)						
Highly palatable (3)	Near	Score	middle	score	far	score
Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	0.32	0.95	0.05	0.15	0.28	0.83
Cenchrus ciliaris, L.	3.65	10.95	4.59	13.76	4.29	12.87
Chrysopogon aucheri, (Boss) Stapf.	8.97	26.91	12.73	38.19	13.62	40.86
Digitaria erantha	0.00	0.00	0.05	0.15	0.00	0.00
Digitaria milanjiana, (Rendle) Stapf.	2.27	6.80	3.61	10.84	1.98	5.95
Leptothrium senegalensis, (Kunth) Clayton	2.22	6.66	2.25	6.76	2.32	6.97
Panicum coloratum	0.35	1.05	0.00	0.00	0.31	0.92
Panicum maximum, Jacq.	2.11	6.33	2.23	6.69	1.85	5.54
Panicum sp. Aff. turgidum, Forsk	0.00	0.00	0.00	0.00	0.05	0.14
Setaria ustilata	0.23	0.68	0.00	0.00	0.20	0.59
Themeda triandra, Forsk.	0.06	0.18	0.15	0.44	0.15	0.44
Andropogon abyssinicus fresen.	0.00	0.00	0.25	0.74	0.00	0.00
Andropogon sp	0.00	0.00	0.00	0.00	0.29	0.86
Digitaria velutina (Forssk.) P.Beauv.	0.17	0.50	0.47	1.40	0.15	0.44
Sub total	**20.33**	**60.99**	**26.38**	**79.13**	**25.47**	**76.41**
Intermediately palatable (2)						
Bothrichloa insculpta(Hochst.) A. Camus	0.12	0.25	0.05	0.11	0.11	0.22
Chloris myriostachya, Horst.	2.46	4.93	1.75	3.51	2.16	4.31
Cynodon dactylon, (L) pers.	1.55	3.10	9.47	18.95	1.36	2.71
Heteropogon contortus, (L.) Beauv. ex. R. Sch.	0.31	0.63	0.10	0.20	1.30	2.60
Lintonia nutans, stapf.	0.06	0.12	0.15	0.30	0.05	0.11
Lintona spp	0.06	0.11	0.00	0.00	0.05	0.10
Harpachne shimperi, Hochzt. Ex. A. Rich.	0.07	0.13	0.05	0.10	0.06	0.12
Sub total	**4.63**	**9.27**	**11.58**	**23.16**	**5.08**	**10.16**
Less palatable (1)						
Oropetium capense Stapf	1.36	1.36	0.05	0.05	1.19	1.19
Erichloa fatmensis (Hochst Stead.) A. Camus	0.45	0.45	0.00	0.00	0.39	0.39
Elusine jaegeri, pilger	0.19	0.19	1.03	1.03	0.16	0.16
Sporobulus nervosus Hochst.	14.18	14.18	15.25	15.25	12.79	12.79
Eragrostis cilianensis Link exlutati.	0.06	0.06	1.34	1.34	0.05	0.05
Tetrapogon villosus Desf.	0.11	0.11	0.00	0.00	0.10	0.10
Pennisetum mezianum, (Vahl.) Lanza Mattei	6.36	6.36	0.41	0.41	5.56	5.56
Pennisetum stramineum, peter	0.00	0.00	0.89	0.89	0.00	0.00
Sporobulus festivus Hochst. ex. A.Rich.	0.19	0.19	0.00	0.00	0.16	0.16
Setaria verticillata, Beauv	0.06	0.06	0.00	0.00	0.05	0.05
Sporobulus pyramidalis, Beauv.	40.21	40.21	33.21	33.21	35.71	35.71
Aristida adscensionis, L.	0.57	0.57	0.15	0.15	0.50	0.50
Aristida congesta	0.06	0.06	0.00	0.00	0.05	0.05
Dactyloctenium aegyptium, (L.) Pers	2.90	2.90	0.63	0.63	2.54	2.54

Appendix 7 cont'd

Eragrostis senni, Chiov	0.05	0.05	0.77	0.77	0.10	0.10
Tetrapogon cenchriformis(A.Rich)W.D.Clayton	0.06	0.06	0.00	0.00	0.05	0.05
Dinebra retroflexa (vahl) panzer	0.06	0.06	0.00	0.00	0.05	0.05
Sub total	**66.85**	**66.85**	**53.72**	**53.72**	**59.45**	**59.45**
Unpalatable (1)						
Bothriochloa radicans, A. camus	0.74	0.74	0.16	0.16	1.27	1.27
Aristida adoensis, Hochst.	0.00	0.00	0.00	0.00	0.29	0.29
Microchloa kunthii, Desv.	2.78	2.78	4.44	4.44	3.10	3.10
Tragus berternianus Schult.	0.43	0.43	0.75	0.75	0.76	0.76
Sub total	3.95	3.95	5.35	5.35	5.42	5.42
	Pc	**141.06**		**161.35**		**151.43**
	VCI	**47.021**		**53.78375**		**50.47625**
	WPC	**20.57**		**30.71**		**25.75**

VCI = PcX100 ÷300

Appendix 8 Palatability classes, Frequency (%) composition and palatability scores of grasses in four communal grazing sites.

Palatability classes (weighing value)	Communal grazing sites							
Highly palatable (3)	Did Yabello	score	Did Harra	score	Dudbul uk	score	Melb ana	score
Erichloa nubica Hack & Scheweinf (Hochst Stead.) clayton	0.00	0.00	0.00	0.00	0.07	0.20	0.37	1.11
Cenchrus ciliaris, L.	2.91	8.74	4.52	13.55	6.98	20.94	4.26	12.79
Chrysopogon aucheri, (Boss) Stapf.	12.98	38.95	12.93	38.79	15.92	47.76	14.19	42.57
Digitaria erantha	0.00	0.00	0.07	0.20	0.00	0.00	0.00	0.00
Digitaria milanjiana, (Rendle) Stapf.	2.30	6.91	0.07	0.22	2.78	8.33	6.07	18.22
Leptothrium senegalensis, (Kunth) Clayton	2.84	8.52	2.27	6.80	6.48	19.44	5.38	16.14
Panicum coloratum	0.00	0.00	0.41	1.23	0.00	0.00	0.00	0.00
Panicum maximum, Jacq.	0.00	0.00	2.09	6.26	2.44	7.32	3.61	10.84
Panicum sp. Aff. turgidum, Forsk	0.96	2.88	0.13	0.40	0.00	0.00	0.12	0.37
Setaria ustilata	0.00	0.00	0.07	0.20	0.00	0.00	0.26	0.79
Themeda triandra, Forsk.	0.26	0.79	1.12	3.35	0.20	0.59	0.00	0.00
Andropogon abyssinicus fresen.	0.00	0.00	0.00	0.00	0.33	0.99	0.00	0.00
Andropogon sp	1.07	3.21	0.00	0.00	0.00	0.00	0.00	0.00
Digitaria velutina (Forssk.) P.Beauv.	0.00	0.00	0.00	0.00	0.07	0.21	0.82	2.45
sub total	**23.33**	**69.99**	**23.66**	**70.98**	**35.25**	**105.76**	**35.09**	**105.27**
Intermediately palatable (2)								
Bothrichloa insculpta(Hochst.) A. Camus	0.00	0.00	0.14	0.29	0.14	0.29	0.00	0.00
Chloris myriostachya, Horst.	0.74	1.47	1.54	3.08	1.12	2.24	4.52	9.03
Cynodon dactylon, (L) pers.	10.64	21.28	3.76	7.53	1.70	3.40	0.78	1.56
Heteropogon contortus, (L.) Beauv. ex. R. Sch.	1.44	2.87	0.80	1.60	0.29	0.58	0.07	0.13
Lintonia nutans, stapf.	0.07	0.14	0.29	0.57	0.00	0.00	0.00	0.00
Lintona spp	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.13
Harpachne shimperi, Hochzt. Ex. A. Rich.	0.07	0.14	0.24	0.48	0.28	0.56	0.00	0.00
sub total	**12.95**	**25.90**	**6.77**	**13.54**	**3.54**	**7.07**	**5.43**	**10.85**
Less paltable (1)								
Oropetium capense Stapf	0.00	0.00	0.00	0.00	1.52	1.52	0.20	0.20
Erichloa fatmensis (Hochst Stead.) A. Camus	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.52
Elusine jaegeri, pilger	0.98	0.98	0.61	0.61	0.00	0.00	0.00	0.00
Sporobulus nervosus Hochst.	22.76	22.76	6.69	6.69	12.82	12.82	10.86	10.86
Eragrostis cilianensis Link exlutati.	0.79	0.79	0.28	0.28	0.79	0.79	0.47	0.47
Tetrapogon villosus Desf.	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00
Pennisetum mezianum, (Vahl.) Lanza Mattei	0.15	0.15	0.00	0.00	0.46	0.46	7.42	7.42
Pennisetum stramineum, peter	0.00	0.00	0.27	0.27	1.41	1.41	0.00	0.00
Sporobulus festivus Hochst. ex. A.Rich.	1.22	1.22	0.14	0.14	0.08	0.08	0.00	0.00
Setaria verticillata, Beauv	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Sporobulus pyramidalis, Beauv.	21.50	21.50	45.12	45.12	36.80	36.80	28.45	28.45

Appendix 8 cont'd

Loudetia flavida (Stapf.) C.E. Hubb.	0.14	0.14	0.13	0.13	0.00	0.00	0.00	0.00
Aristida adscensionis, L.	0.00	0.00	0.50	0.50	0.64	0.64	0.07	0.07
Aristida congesta	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
Dactyloctenium aegyptium, (L.) Pers	0.87	0.87	0.07	0.07	0.20	0.20	3.22	3.22
Eragrostis senni, Chiov	0.75	0.75	0.42	0.42	0.20	0.20	0.13	0.13
Tetrapogon cenchriformis(A.Rich)W.D.Clayton	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
Dinebra retroflexa (vahl) panzer	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Sub total	49.14	49.14	54.37	54.37	55.05	55.05	51.46	51.46
Unpalatable (1)								
Bothriochloa radicans, A. camus	1.65	1.65	0.48	0.48	0.34	0.34	0.64	0.64
Elyonurus muticus	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Aristida adoensis, Hochst.	0.45	0.45	0.35	0.35	0.07	0.07	0.00	0.00
Microchloa kunthii, Desv.	2.36	2.36	7.13	7.13	4.56	4.56	3.00	3.00
Tragus berternianus Schult.	1.33	1.33	0.07	0.07	0.39	0.39	0.97	0.97
Sub total	5.86	5.86	8.03	8.03	5.36	5.36	4.61	4.61
	Pc	**150.88**		**146.92**		**173.24**		**172.20**
	VCI	**50.29**		**48.97**		**57.75**		**57.40**
	WPC	**25.48**		**23.50**		**36.65**		**36.13**

VCI = PcX100 ÷300