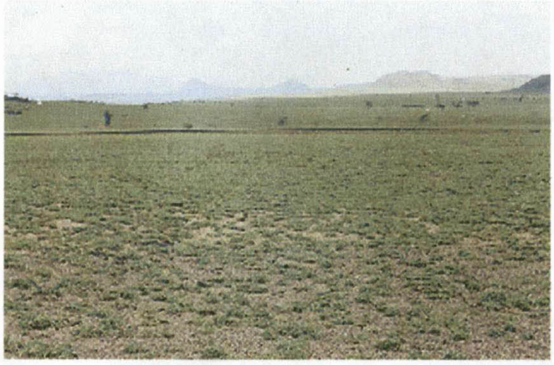
RANGELAND EVALUATION IN RELATION TO PASTORALISTS PERCEPTIONS IN THE MIDDLE AWASH VALLEY OF ETHIOPIA



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RANGELAND EVALUATION IN RELATION TO PASTORALISTS PERCEPTIONS IN THE MIDDLE AWASH VALLEY OF ETHIOPIA

By

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Submitted in partial fulfilment of the requirements for The degree of

DOCTOR OF PHILOSOPHY

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(Grassland Science)
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DEDICATION

This thesis is dedicated to the memory of my mother, Askale Yigelatu, who had been fully committed to my success with strong prayer for the betterment and success of my life as a whole.

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RANGELAND EVALUATION IN RELATION TO PASTORALISTS PERCEPTIONS IN THE MIDDLE AWASH VALLEY OF ETHIOPIA

By

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DEPARTMENT: Animal, Wildlife and Grassland Sciences

Degree: Doctor of Philosophy

ABSTRACT

Pastoralism is the most dominant land use form in the arid rangelands of Sub-Saharan Africa in which Ethiopia is not an exception. However, in Ethiopia and elsewhere, rangeland-based life-styles are in difficulty with the rangeland environment under threat because of both external and internal constraints. The spatial variability of the annual rainfall in these areas also has an affect on the pastoralists livelihood. Accordingly, four studies were undertaken in two neighbouring districts occupied by pastoralists of different ethnic groups living in the middle Awash valley of Ethiopia with the objective of evaluating the condition of the rangelands, which was related to the perception of the pastoralists in order to come up with possible recommendations to minimize further degradation.

The pastoralists perceptions of the rangeland resource were studied through group discussions and by using a structured questionnaire where each household was taken as a unit of analysis (90 households from Oromo living in Kereyu-Fantale district and 55 households from Afar living in Awash-Fantale district). The data was analysed using Statistical Package for the Social Sciences (SPSS). The result showed that the average family size per household was about 6.74, with nearly 80% of the people without any kind of education. The main source of income for both pastoral

groups was from the sale of animals. The second source of income to the Oromo and Afar pastoralists was from the sale of crops and milk and milk by-products, respectively. Both pastoral groups reported that woody species like *Cryptostegia grandiflora*, *Capparis fascicularis*, *Erythrina abyssinica* and *Flueggea virosa*) and herbaceous species like *Tribulus terrestris*, *Tephrosia subtriflora* and *Cynodo* are sources of poisons which affect their livestock production. Ninety seven and 3% of the Oromo respondents use *Cymbopogon commutatus* and *Chrysopogon plumulosus* for house roofing respectively, while 38.1%, 23.0%, 10.6% and 28.3% of the Afar pastoralists use *C. commutatus*, *C. exacavatus*, *Enterpogon* and *Sporobolus ioclados*, respectively for a similar purpose. Seventy six percent of the Oromo and 77 % of the Afar respondents do not harvest grasses from the rangelands and the primary use of woody plants in both pastoral groups was for livestock feeding. It was indicated that the grazing lands were bush encroached notably with *Acacia senegal*, *A. nubica* and *Prosopis juliflora* (Awash-Fantale district only) and the condition of the rangeland to be in poor condition. None of the Afars and only 12% of the Oromo pastoralists had private grazing lands. The majority of the respondents chose to continue with communal type of ownership in the grazing lands and a shortage of water was a critical constraint to the Oromo pastoralists. There is a critical shortage of livestock feed during the dry season and the first measure taken to solve feed shortage is migration. Unfortunately, 90% of the Oromo and 60% of the Afar respondents replied that migration is a bad practise. The Afar pastoralists (cattle = 20; sheep = 12; goats = 26; Camels = 15) had a higher number of livestock owned per household than the Oromo pastoralis (cattle = 10; sheep = 8; Goats = 11; Camels = 5).

Rangeland condition in terms of grass, browse and soil parameter was studied at 11 sites in Awash-Fantale district and 10 sites in Kereyu-Fantale district using techniques and/or methods mostly developed in South Africa. Grazing and browsing capacities were also calculated for each of the rangeland sites. The most dominant grass species in the study districts was *Chrysopogon plumulosus* followed by different species of *Sporobolus*. The percentage bare ground as estimated by the point method varied from 0.33 to 10.79 with a mean value of 5.27. The basal cover in both districts was low, averaging 3.35%. The DM yield of the grass ranged between 168.52 kg ha^{-1} to 832 kg ha^{-1}. The grazing capacity varied from as low as 54.14 ha LSU^{-1} to as high as 7.06 ha LSU^{-1}. The results of the evapotranspiration tree equivalent (ETTE ha^{-1}) showed that the study districts were bush encroached with *A. senegal*, *A. nubica* and *P. juliflora*. In both districts, the browse production (total leaf DM) ranged from as low as 194 kg ha^{-1} to 3 311 kg ha^{-1}, with most of the leaf dry mass found above the height of 1.5 m. In both districts, the highest browsing capacity (ha BU^{-1}) was contributed by *A. senegal* and *A. nubica*.

The condition of the communal grazing lands was also assessed in relation to benchmark sites. Basal cover and the DM yield of grasses was higher in the benchmark sites (basal cover= 5.3% and DM yield of grasses = 985.7 kg ha^{-1}) than the sample sites (basal cover = 3.3% and DM yield of grasses = 447.2 kg ha^{-1}), which indicated that given proper management, there is ample room to improve the grazing capacity of the rangelands.

With the objective of studying the effects of tree species on grass species composition, yield and some soil parameters under different grazing gradients (light, medium and heavy) in two sub-habitats (under canopy and open grassland), two tree species (*Acacia tortilis* and *Balanites aegyptica*) were identified. The data was analysed using DECORANA and SAS (Statistical Analysis System). The results showed that the grass species found at the heavily grazed sites were mostly annuals and less desirable species. The major difference between the medium and lightly grazed site in grass species composition was the presence of *Panicum maximum* under the canopy of trees in lightly grazed condition. The DM yield of grass improved substantially as the grazing intensity decreased (heavy = 311.9 kg ha^{-1}, medium = 1 607 kg ha^{-1} and light = 2 737.5 kg ha^{-1}). At the medium and lightly grazed sites, the DM yield of grass was higher ($P<0.001$) under tree canopies than the corresponding open grasslands. Soil nutrient status increased as the grazing pressure decreased from heavy to light grazing. Electrical conductance, percentage nitrogen and organic carbon increased ($P<0.01$) under tree canopies compared to the corresponding open grasslands whereas they decreased with an increase in the depth of soil.

In conclusion, all studies with different objectives and arguments clearly indicate that the condition of the rangelands is poor, requiring careful and participatory interventions. Future studies need to distinguish between climate and man-made droughts although droughts are a normal phenomenon in these drier areas. Rangelands in poor condition increase the intensity and frequency of climatic droughts.

DECLARATION

I declare the dissertation hereby submitted by me for the partial fulfilment of the requirement of the degree Doctor of Philosophy (Grassland Science) at the university of the Free State is my own independent work and has not previously been submitted by me at another university/Faculty. I furthermore cede copyright of the dissertation in favour of the University of the Free State.

Abule Ebro Gedda

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ABBREVIATIONS

ADB	African Development Bank
ANP	Awash National Park
BTE	Browse tree equivalent (g, kg ha^{-1})
BU	Browsing unit
CANVOL	Canopy volume
DM	Dry matter
EARO	Ethiopian Agricultural Research Organization
ETTE	Evapotranspiration tree equivalent (500 cm^3 , ha^{-1})
EWCO	Ethiopian wildlife conservation organization
FAO	Food and Agricultural Organization of the United Nations
IFAD	International Foundation for Agricultural Development
LMAS	Leaf dry mass (g, kg ha^{-1})
masl	Meters above sea level
MOA	Ministry of Agriculture
TE	Tree equivalent
UNESCO	United Nations Educational, Scientific and Cultural Organization

CHAPTER 1

INTRODUCTION

Ethiopia's ruminant livestock population is the largest in Africa and tenth in the world. Economically, the livestock sub-sector accounts for about 40% of Ethiopia's Agricultural Gross Domestic Product (GDP), 16% to the total GDP and has generated an estimated 31% of the total agricultural employment (Mengistu 1996). Hides and skins accounted for between 12% and 16% of the total export value during 1984-1988 (Addis 1992). In addition, more than 90% of the croplands are cultivated with the aid of 6 million draft animals (Gryseels & Anderson 1983). Annually, a total of 0.74 million tonnes of milk and 0.23 million tonnes of beef are produced (FAO 1995). In the pastoral areas, livestock is the sole source of livelihood and accounts for more than 60% of the household revenue (Zinash *et al.* 1998). Despite the huge livestock population, productivity per animal is low for all classes of livestock. This low level of productivity is caused by poor husbandry and management systems, as well as the prevalence of diseases and malnutrition (AAMC 1984).

Livestock production in Ethiopia is mainly based on grazing and/or browsing by cattle, sheep, goats and camels. In the highlands, crop residues and agro-industrial by-products augment natural pasture. In the pastoral system, livestock production is almost totally dependent on native pasture and woody plants (Daniel & Tesfaye 1996; Zinash *et al.* 1998). This can be ascribed to insufficient rainfall to sustain arable production and the practice of nomadic grazing. The pastoralists have been able to survive in the harsh conditions of the dry land for centuries because of their traditional coping mechanisms and development of risk management strategies.

Pastoralism is the most dominant land use form in the dry lands of Sub-Saharan Africa (SSA) in which Ethiopia is not an exception. There are more than 25 million people in the SSA to whom pastoralism is not only a system of livestock production, but also a way of life (Lane 1998). The majority of the pastoralists in Ethiopia consist of the Somalia's, Borana and Afar living in the southeast, southern and northeast rangelands, respectively. In addition, other ethnic groups include the Hamors, Arbores, Dannans, Neurs and the Kereyus (EARO 2001). In Ethiopia, pastoralists and agro-pastoralists inhabit a significant portion of the more arid areas. An estimate by FAO (1992) put the area covered by the rangelands at 78.1 million hectares or some 70% of Ethiopia's land area. Of the total livestock population of the country, the Ethiopian lowlands is estimated to raise 40% cattle, 75% goats, 25% sheep and 100% camels. The rangelands are not only known for livestock, but there are many wildlife parks, sanctuaries and reserves (Schloeder & Jacobs 1993; Beruk & Tafesse 2000; Dawit 2000; MOA 2000; EARO 2001).

The condition of the rangeland areas of Ethiopia and present productivity as compared to the potential is variable but generally low. The low condition in productivity resulting from mismanagement is generally manifested by ecological deterioration of vegetation, soil erosion, lowered fertility, reduced soil water availability for plant growth and decreased nutritive value of available forages (MOA 1996). The loss of biological productivity is largely due to over-use of shrinking rangelands by a growing number of pastoralists. Their potential impact can be more severe than that of farmers because the ecological impact of a 2% increase in pastoral population is equivalent to a 4% increase of farmers (Williams & Balling 1996; Lusigi & Acquay 1999). In addition, the spread of cropping, particularly in areas critical to dry season grazing, uncontrolled grazing around water points and near villages, as well as cutting of trees for fuel are leading to rangeland degradation. Despite the vast area of rangeland in Ethiopia, rangeland research and development are limited only to that of the Borena rangelands (Daniel & Tesfaye 1996). Accordingly, large-scale development projects related to the pastoral societies were carried out by government and non-government organizations in southern (mainly), south-eastern and north-eastern rangeland development units. On the other hand, some of the areas of the country including the study districts, which are predominately pastoral, remained without any large-scale pastoral development projects (Alemayehu 1998). Even in areas with development projects, where millions of dollars have been spent by international institutions, the general impression is rather negative. Very little seems to have been achieved as production has not increased, natural resources continue to deteriorate, the social structures have broken down and livelihoods have declined (MOA 1996).

The failures in pastoral development projects, be they in Ethiopia or Africa, are partly attributed to ignorance of the indigenous knowledge of the pastoralists. However, traditional experiences, skills and strategies accumulated by pastoralists over the centuries should instead complement modern scientific knowledge rather than be ignored (MOA 1996; Haan 1999; Muller 1999; Tsundle 1999). Based on an overview by Haan (1999), it is stated that driven by the political objectives of providing cheap meat to the urban areas, earlier range livestock development concentrated on increasing meat output from the pastoral systems. As this was often contrary to the objectives of the pastoral population, adoption of those technologies to promote increased meat production almost always failed. Understanding the production objectives of a particular system also explains the different supply response to price changes, i.e., whether a system is mostly trade or mostly subsistence oriented (Pratt *et al.* 1997) and is thus a critical element in determining the economic feasibility of any investment.

In comparison with the rangeland resource base of the country, studies with regard to the condition of the rangeland ecosystem have not received the attention they deserve. In addition, previous studies have focused mainly on the Borena rangelands (e.g., Oba 1998; Ayana & Baars 2000) and very few in the others. Furthermore, numerous advancements have been made in the area of both rangeland assessment techniques and factors to be used in the assessment, which better aid in the understanding of changes in rangeland ecosystem dynamics. In any assessment of a rangeland ecosystem composed of different vegetation components, rangeland monitoring must incorporate three tiers of assessments i.e., the soil, herbaceous layer and the tree-shrub layer (Friedel 1991). Despite the significant contribution of woody vegetation both as a source of feed for domestic and game animals, most of the assessments fail to consider the contribution of the woody vegetation, not only in terms of feed resources but also their role in general ecosystem stability. Unfortunately, there is no detailed rangeland condition assessment considering the tiers of the rangeland resource for grazing lands commonly grazed by the animals of the pastoralists living in Awash-Fantale and Kereyu-Fantale districts identified for this study.

Based on a conference held in Ethiopia on pastoralism (Ali 1993; Desta 1993) and studies conducted by Tibabu (1997); Mudris (1998); Sharon (2000) and a review of the strategy prepared by EARO (2001) the following points characterise the study area. The rangeland is mainly used for livestock, wildlife, crop production and government owned development activities. Accordingly, formerly open access rangelands have gradually become the focus of conflict between the different forms of land use. With the added pressure of population growth decreasing the available land for grazing, losses of useful fodder/pasture species and herbs is quite evident. There is no adequate database with respect to the vegetation cover, composition of plant community and their current status particularly for those of the commonly grazed rangelands by the pastoralist`s livestock. To this is added the competition for scarce resources by different pastoral groups. With increasing human and livestock populations and the growth in resources being relatively static, the problems associated with the carrying capacity of the Awash basin are likely to become more serious, further aggravating the problems of the survival of the different pastoral groups and the other development activities. Studies undertaken elsewhere (e.g., Ellis & Swift 1988; William *et al.* 1990; Behnke *et al.* 1993; Ekaya *et al.* 2001) and long term studies in Ethiopia (Coppock 1994) have clearly indicated that household use of rangeland resources and associated constraints vary between years and between seasons of the same year depending on the spatial variability of rainfall.

The main objectives of this study were, therefore, to evaluate the condition of the rangelands and assess the perceptions of the pastoralists with regard to rangeland resources, their utilization, constraints and possible solutions in two neighbouring districts (Awash-Fantale and Kereyu-Fantale districts) inhabited by different pastoral groups (Afar and Oromo pastoralists) living in the middle Awash valley of Ethiopia and to investigate possible solutions to minimize further degradation of the rangeland ecosystem.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Rangelands are defined as those areas of the world, which by reasons of physical limitation, low and erratic precipitation, rough topography, poor drainage, or cold temperatures are unsuited for cultivation and which are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife. This definition includes grassland as well as savanna and forest areas often used by grazing animals (Stoddart *et al.* 1975). Almost half of the land area in the world, covering about 6.7 billion ha can be classified as pastures and rangelands (Singh & Ghosh 1993). If all the uncultivated land of the world with potential to support grazing or browsing animals is taken into account, 70% of the world's land area can be classified as rangeland (Holechek *et al.* 1989). More than 200 million people use rangelands worldwide for some form of pastoral production. About 30-40 million nomadic people in developing countries are wholly dependent on livestock (WRI, IIER 1989). African rangeland, extending over 3 million km^2 support a pastoral population of 16-20 million (Widstrad 1975) and nearly 500 million head of livestock (FAO 1975). The majority of the world's pastoralists are in Africa (55%), Asia (29%), the Americas (15%) and Australia (10%) (Child *et al.* 1984).

Rangelands are an important renewable resource, in addition to performing a number of ecological and economical functions, which include provision of humans with consumable products such as red meat, fibre and water and non-consumptive services such as recreation and wildlife viewing (Batabyal & Godfrey 2002). Of these, extensive livestock production is the major land use on rangelands with large areas of land required per head of livestock (Zhou *et al.* 1998). Furthermore, rangelands provide habitats for a wealth of wild and domesticated plant species. Many plants are of medicinal value and other species may provide important genetic material for future economic use. The genetic pool of species found, may hold important keys for improving livestock, developing new crop varieties, curing disease and numerous other benefits to mankind as yet undiscovered. Thus, conserving the rich biological diversity of these rangelands is crucial for sustainable economic development (Miller 1997).

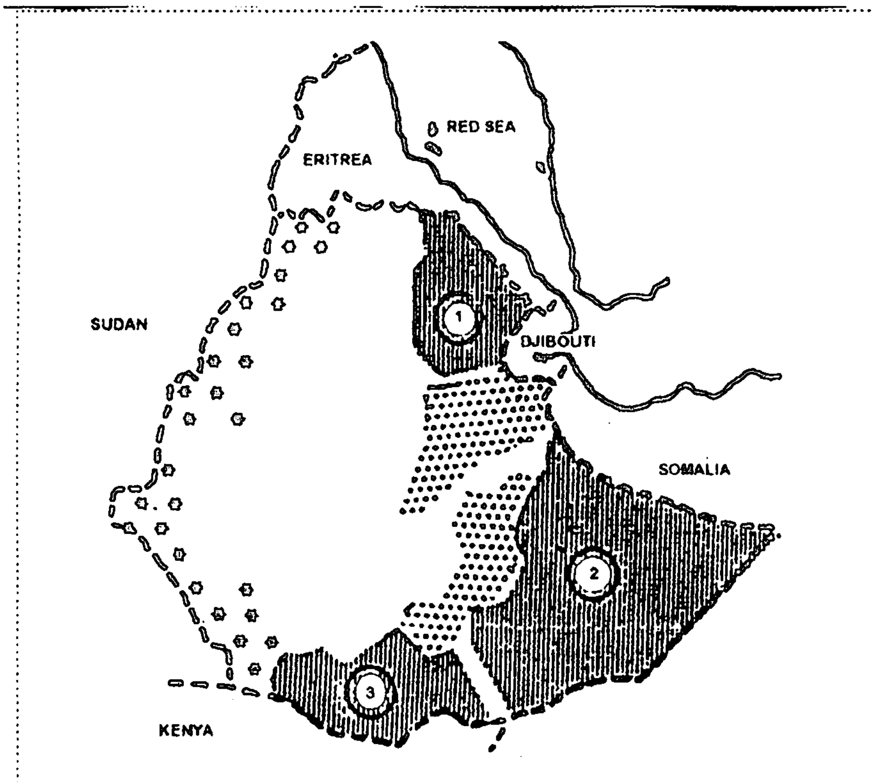
Based on the above facts, this chapter gives a description of the rangelands and pastoralism in Ethiopia, major production constraints, development interventions undertaken in the middle Awash Valley of Ethiopia, pastoralism and the different arguments revolving around their livelihood. Furthermore, a review of literature is also done on rangeland condition assessment techniques for both herbaceous and woody vegetation; browse production, the importance of woody vegetation in ecosystem functioning and their role in rangeland condition and bush encroachment.

2.2. RANGELAND AND PASTORALISM IN ETHIOPIA

2.2.1. The resource base

There is no accurate and reliable data indicating the area coverage, human and livestock population of the pastoral and agro-pastoral production systems in Ethiopia. However, extensive review works by Coppock (1994); Beruk & Tafesse (2000); Dawit (2000); MOA (2000); Tafesse (2000); EARO (2001); Getachew (2001) indicated that it is estimated to cover 61% to 67 % of the country usually below 1 500 meters above sea level (m.a.s.l.) The pastoral areas of the country are divided into five, i.e., the northeast, eastern, southern, southeast and extreme southern part of the country (**Figure 2.1**). Recent estimates by the same reviewers indicated that the human population is in the range of 7 to 8 million, which is about 13% of the human population in the country and are composed of 29 Nilotic and Cushitic ethnic groups. Of this, it is estimated that 93% are considered to be pastoralists or agropastoralists, while the remaining are either hunter-cultivators or pure cultivators (Beruk & Tafesse 2000). Furthermore, the density of people km^{-2} in the lowlands is about 10 as opposed to 90 for the highlands (EPA 1998), indicating the potential for future development. Using rainfall and temperature regime, the climate is divided into arid (64%), semi-arid (21%) and the remaining dry sub-humid (EPA 1998).

The estimates of the CSA (1996) indicates that there are 32 million cattle, 13 million sheep, 10 million goats, 4 million equines, 1.0 million camels and 33 million poultry in Ethiopia.



Limited pastoral use due to trypanosomiasis

Predominantly pastoral but without large scale pastoral development

Predominantly pastoral including large scale development programmes

1. NERDU (Northeastern Rangelands Development Unit)
2. SERP (Southeastern Rangelands Project)
3. SORDU (Southern Rangelands Development Unit)

Figure 2.1. The pastoral areas of Ethiopia.

Gadamu (1990) estimated that of the total livestock population in Ethiopia, the share of pastoral and agro-pastoral people is about 40%, 25%, 75%, 100% and 20% of the cattle, sheep, goats, camels and equine population, respectively. Recent review work by MOA (2000) indicated that the share of pastoral and agro-pastoral areas in terms of livestock ownership changed to 28% for cattle, 26% for sheep, 66% for goats and 100% for camels. According to this estimate, the lowlands carry about 26% of the total livestock population of Ethiopia. Although, the lowlands have lower number of livestock than the highlands, the most important breeds of livestock like the Borana cattle are found in the lowlands and lowland breeds of cattle and sheep made up over 90% of legal export of live animals (Coppock 1994).

Not only livestock, but also the presence of more national parks and wildlife sanctuaries in the lowlands is a clear indication of the potential of the rangelands for conservation activities. Review work by Beruk and Tafesse (2000); MOA (2000); Tafesse (2000); EARO (2001) indicated that, except for the Bale and Simen mountains, the rest of the national parks are situated in the lowlands. Out of the 24 endemic bird species, the lowlands share 19 species with the highlands. In addition, the same review indicated that, in terms of plant biodiversity, the rangelands are well known for their diverse plant species. For example, Ogaden region is one of the richest areas considered for endemic flora, characterized by a high diversity in *Acacia*, *Baswellia* and *Commiphora* species. The area has about 25% of the plant species in the country. There are actual or potential mineral resources, such as gold in the Adola of Borena, natural gas in the Ogaden, salt mines in Afar and Soda ash in the rift valley. The rangelands are also rich in surface, underground water and large perennial rivers. The rich deposit of natural gas, geothermal energy is a clear indication of the rich wealth potential of the pastoral areas. These areas are also of prime interest for archaeological and socio- anthropological studies (Getachew 2001; Yacob 2001).

2.2.2. Past development interventions

Many projects were undertaken in the pastoral areas beginning with the 1960's. They are the Arero rangeland pilot project and the second, third and fourth livestock development projects. A brief review of the projects is presented in this section.

The Arero Rangeland Pilot Project was initiated in 1965 with the aim of improving rangeland use efficiency through pond construction and controlled grazing. The project area covered about 2 400 km^2 of the rangelands near Yavello. This project attracted settlement around the new water points, resulting in severe overgrazing. On top of this, a subsequent drought in northern Kenya led to the migration of Kenyan Borana pastoralists into the project area and the collapse of the rotational grazing program. Furthermore, there was little local support for the project (Solomon 1993; Tafesse 2001; World Bank 2001).

The World Bank as of 1973 funded the second livestock development project (SLDP). It was initiated to develop an integrated market and stock route system in order to improve livestock off-take rate. The SLDP created some infrastructure that contributed to the opening up of pastoral areas and facilitated the expansion of livestock marketing. Most project-constructed slaughterhouses are still in use and have been recently privatised. Most terminal markets are also in use, but under municipal management. However, the stock routes have not been used. In addition, many of the facilities were destroyed in the Ethio-Somalia war of 1977. This project did not take into account the traditional stock routes, which would have been successful otherwise (Solomon 1993; Tafesse 2001; World Bank 2001).

The third livestock development project (TLDP) was established in 1975 with a blend of World Bank, International Foundation for Agricultural Development (IFAD) and African Development Bank (ADB) funding. It was the first large-scale development project and sponsored studies in the Borena, Afar and Somalia rangelands, implemented by the International Livestock Center for Africa (ILCA), which was also contracted to monitor project impacts (World Bank 2001). The project was meant to rehabilitate and develop the three areas through its sub-units namely, North East Rangeland Development Unit (NERDU), Jijiga Rangeland Development Unit (JIRDU) and Southern Rangelands Development Unit (SORDU) (**Figure 2.1**). The project aimed to raise the standard of living of pastoral people through the restructuring of the traditional system of extensive livestock production. The project provided, among other things, veterinary services, water and infrastructural development. It continued to provide services with funding from the Ethiopian Government until 1996. It was abandoned due to the government's decentralization and regionalization policy.

The fourth livestock development project (FLDP) funded by the World Bank and IFAD, was focused on upland livestock systems, but included linkages to the pastoral areas. It was started in 1988 and the project included a comprehensive forage testing and seed multiplication program, a livestock credit program, vaccine production, drug supply and epidemiology program and substantive capacity building activities. It differed from the previous projects in that it took into account the traditional organizations and indigenous knowledge of the pastoralists. The FLDP, though promising, collapsed as a result of Ethiopian political turmoil in 1990.

In conclusion, despite these development interventions, human life in the pastoral areas still continues to be full of uncertainties. The benefit generated has not justified the investment (Solomon 1993).

2.2.3. Constraints related to the pastoral production system

The major constraints facing the pastoral production systems have been reviewed by different authors (e.g., Coppock 1994; Alemayehu 1998; Oba 1998; Beruk & Tafesse 2000; MOA 2000; Zinash *et al.* 2000; EARO 2001; Getachew 2001; Yacob 2001). Some of the constraints indicated by the different reviewers are presented in the following paragraphs.

Periodic drought is a characteristic of the lowland pastoral production systems. Even in normal rainfall years, there are localized parts of the lowlands, which suffer from drought. As a result of increasing human and livestock population pressure, the capacity to cope with drought has declined to the point that there is a growing threat to the survival of viable pastoral production system (World Bank 2001).

The pastoralists living in the rangelands are also threatened by bush encroachment. Bush encroachment is the process of open grassland savannas being transformed into thick bush (Barnes 1979) and is one of the major problems threatening the rangelands (Coppock 1994; Alemayehu 1998; Beruk & Tafesse 2000; EARO 2001). According to Coppock (1994) cited from Hacker (1990) roughly 15 species of woody plants are thought to be encroachers in the Borena plateau. Of these, *Acacia drepanolobium* and *A. brevispica* are the most important. The lack of prescribed burning, accompanied by severe overgrazing and the expansion of farming in the dryland were among the main problems associated with bush encroachment. According to Oba (1998), 40% of the Borena rangelands were estimated to be bush encroached. Beruk & Tafesse (2000) with reference to the Afar region indicated that an increase of *Acacia seyal*, *A. mellifera*, *A. senegal*, and *Prosopis juliflora* are of major concern.

Because of the diverse culture of the people, the abundance of wildlife and plant resources, scenic value and the existence of archaeological sites, pastoral areas are well known as tourist attractions. Accordingly, a total land area of 0.47 million ha of the rangeland has been converted to wildlife sanctuaries, i.e., 0.35 million ha (Afar region), 0.06 million ha (Southern region), 0.051 million ha (Gambella Region) (Beruk & Tafesse 2000). Studies in other countries have clearly indicated that, depending on marketing arrangements; wildlife can generate greater wealth at lower economic and environmental costs than livestock and arable agriculture and thus be profitable to rural sectors (Kiss 1990; Cumming & Bond 1991; Jansen 1992). Furthermore, Cole (1990) indicated that wildlife can increase the revenue earned per kg of animal in the rangeland and wildlife ranches in dry regions can earn three times more per ha than cattle ranches. Research shows that wild animals gain weight more quickly than domestic stock, breed faster and have leaner meat. Unfortunately, because of poor tourism development, wildlife conservation capability, the lack of the involvement of the pastoralists and the absence of benefit sharing from conservation activities, the wildlife enterprise is blamed for not benefiting the pastoralists living nearby the conservation areas. The resultant effect being severe ecological deterioration affecting both livestock and wildlife development activities.

In addition to the above reasons, the expansion of large-scale commercial farms without due consideration to the benefits of the local pastoralist is considered a threat to the livestock production system. These interventions can help the country in many ways. However, great concern must also be given to the pastoralist's welfare and the ecology of the rangelands.

Livestock are the principal and most productive investments of the pastoralists with few alternative investment opportunities. However, the difficulties of access to markets and the high costs of marketing and other related problems have hindered proper livestock marketing in the pastoral system (Sintayehu 1993; World Bank 2001). Moreover, inadequate delivery of veterinary services both in terms of area covered and supplies is among the major problems of the pastoralists (Wario 1993; Tefesse 2001).

Inter and intra clan conflict over the rangeland resources, mainly grazing land and water points especially during the dry season, has contributed to the decline of the resources. This is a common feature of the pastoralists of the Afar, Somalia, Boran, Neurs, Kereyu and ethnic groups in the South Omo. Human and livestock losses are inevitable. In most cases, the ultimate result will be a reduction in the overall size of the traditional pastoral territory (Desta 1993; Tibabu 1997; Mudris 1998; Beruk & Tafesse 2000; Getachew 2001; Yacob 2001).

2.2.4. Current attitude towards pastoralism

In the past, Ethiopian government policy towards pastoralists had never been spelt out clearly in any pastoral or arid-land policy document or strategy. It was only implicit in the kinds of projects that were implemented in pastoral areas (Tafesse 2000). Currently, the government is taking measures that indicate the concern towards the welfare of the pastoralists, like the establishment of national pastoral extension team, the emphasis given in the research system to pastoral areas and the issues of proclamations regarding pastoral welfare (Beruk & Tafesse 2000).

2.2.5. Development interventions undertaken in the Awash Valley

Natural resources of the rangelands of the study districts are subject to three competing claims: development to generate revenue for the state, conservation of wildlife and wilderness areas as well as use for local production. Furthermore, the expansion in the size of Lake Beseka is further decreasing available land in the area. In the following sections, the development interventions undertaken are reviewed.

2.2.5.1. Large scale irrigated agriculture

The history of large scale irrigated agriculture in Ethiopia dates back to the beginning of the 1960's when the potential of the Awash River for irrigated agriculture was realised. In order to speed up the development of irrigation agriculture, the Imperial Ethiopian Government established the Awash Valley Authority (AVA), which had little concern for the need of the pastoralists (UNDP/RRC 1984). The Awash river basin is the most developed part of Ethiopia in terms of commercial agriculture, having 0.07 million ha of land already under cultivation and an estimated potentially irrigable land close to 0.21 million ha (Halcrow 1989). The valley is divided into uplands, upper, middle and lower basins. Of the basins, it is the upper and part of the middle Awash that is of concern to this study. The dominant perennial crop in the upper valley is sugar cane while fruits, vegetables and cotton are produced in the middle valley. Past irrigation developments in both the upper and the middle basin have been responsible for the loss of the Kereyu and Afar peoples most critical dry season grazing habitat, which forced the pastoralists to move their settlements to the outer margins of the irrigation schemes, in those areas that were once seasonally exploited (Schloeder & Jacobs 1993). The state owned farms that are operating in the study area are Methara Sugar Estate, Nura Era State Farm, Awara Melka Agricultural Development and Middle Awash Agricultural Development Enterprises (MAADE).

The Methara Estate Sugar was established based on the agreement of the Ethiopian government and a Dutch company called H.V.A. (Handels Vereniging Amsterdam). It covers an area of 11 000 hectares of land (Waktola & Micheall 1999). Studies by

Tibabu (1997) and Mudris (1998) indicated that of the total 11 000 employees in 1996 the contribution of Methara Sugar Estate in terms of employing the local pastoralists is 11% and they are mainly guards. Admission to the school is only allowed to the children of the employees. Irrigation by the Methara sugar plantation has denied the Kereyu and Ittu pastoralists access to critical watering points along the river banks and has almost eliminated all traditional dry season forage sites (Schloeder & Jacobs 1993).

The other farm operating in the area is the Nura Era State Farm. This farm is located in the vicinity of the Kereyu and Ittu pastoralists. Nura Era fruit and vegetable farm covers a total land area of 3 277 ha of which 2 900 ha are in actual production (Waktola & Micheal 1999). Studies by Tibabu (1997) and Mudris (1998) indicated that of the 4 141 workers employed in the farm in 1996, the Oromo pastoralists were 3.6%.

The two farms operating in the Afar area are the Awara Melka Agricultural Development Unit and the Middle Awash agricultural development enterprises. The Awara Melka agricultural development is a fruit and vegetable farm occupying 1 200 ha of which 820 ha is under cultivation. Tibabu (1997) studied the number of people employed in this farm in 1996 and indicated that of the total employee, 13% were Afars, which are working mainly in guarding, cotton picking, weeding and some other activities (Waktola & Micheal 1999). In addition, the same authors indicated that the relationship between the farm and the local communities appeared to be better than that with other state farms. Communities benefit from the farm through social and technical services and they get free health care at the clinic. According to Lane *et al.* (1993), the middle Awash development enterprise has a land area of 30 400 ha which is a major loss of dry season grazing lands. Moreover, it has denied pastoralists access to about 30 km of the Awash River.

2.2.5.2. Nationally protected areas and conservation

In Ethiopia, awareness of wildlife as a valuable resource began as early as 1940's (Negarit Gazeta 1944). With the growing awareness on the importance of wildlife, there came a need to manage wildlife on a sustainable basis. Wildlife conservation in the "modern sense" and as a state owned enterprise started during the regime of His Imperial Majesty Haile Selassie I. The United Nations Educational, Science and Cultural Organisation (UNESCO) supported the idea of the government and assisted in the identification of those areas with potential for wildlife development. One of these, the Awash conservation area is located at the point where the Ethiopian Rift Valley joins the Afar triangle.

The Awash National Park (ANP), which is located in the centre of the conservation area, is approximately 756 km^2 in size (EWCO 2000). According to UNESCO (1964) the justifications for the choice of Awash as a national park rested on its extra ordinary interesting feature from both the physiographic and geological point of view. Its proximity to the capital city of Ethiopia (Addis Ababa) also strengthens the justification. Furthermore, the area had already been protected as a private hunting reserve for His Majesty Emperor Haile Sellasie I and there was an abundance of game in the area (Petrides 1961).

The establishment of the park placed it within the classification of a "strict conservation area" defined as excluding all kinds of human use of the area like settlement, exploitation of natural resources and grazing" (Moore 1982). Currently, in the park there are more than 81 species of mammals, 453 species of birds (6 of them endemic), some reptiles and invertebrates. In addition, the existence of wild animal species such as Beisa oryx, Soemmerring's Gazelle, Greater Kudu, Lesser Kudu, Salts dikdik, Deferssa waterbuck, Warthog, Mountain reedbuck, Klipspringer, Grevy's zebra, Bushbuck and others add a beauty to the park (EWCO 2000).

The establishment of the park required the resettlement of the people and their livestock from their original places and it also coincided with the establishment of the sugar cane plantation leaving little alternative to the local community (Schloeder & Jacobs 1993). Some efforts to resettle the people were unable to solve the problem. The attempts made were primarily to buy 1 500 ha of land in the Borchata area, which was out of the traditional territory of the pastoralists. His Imperial

Majesty also granted 31.1 ha of land from the king's private reserve of land along the Kesem River, which was in the traditional boundary of other tribes. Tribal conflicts accompanied by the lack of water in the new sites blocked the use of the land given to the Kereyu pastoralists. In general, the efforts made were short lived and there was no compensation made there after (Schloeder & Jacobs 1993; Tibubu 1997; Mudris 1998).

With the subsequent changes of government in Ethiopia, conservation activities have been affected. Accordingly, in 1975 following the change in government, the pastoralists challenged the management policies of the Awash National Park (ANP). The reasons for this were primarily in response to the settlement and grazing exclusion practices, which the ANP staffs were trying to put into effect. The absence of rainfall for two consecutive years resulted in the permission of access to the different sections of land occupied by the park (Schloeder & Jacobs 1993). The challenge from the side of the pastoralists continued further with 67% of the park`s land being effectively settled on or used by the various pastoralist groups, either seasonally or permanently. Furthermore, several of the conservation areas were overrun and the wild animals poached. Such changes and challenges have seriously affected the development of the wildlife industry in the area.

Throughout this long period negotiations have been undergoing between the pastoralists and the management of the park at different times to solve the problems of the conservation activities and the pastoralists livelihood (particularly on issue of grazing lands). At times, the issues move to Central Government both directions presenting their problems. A new management plan is now under revision as former plans (Robertson 1970; Jacobs & Schloeder 1993) have proved inappropriate and it is hoped that it will be ready within three years. It is likely that zonation of the park will occur in a similar manner that was suggested in the 1993 management plan (Sharon 2000). Furthermore, efforts to solve the problems of the pastoralists as well as the conservation activities are being made by non-government organizations notably the Awash Conservation and Development Project (CARE Awash).

In general, state intervention to create exclusive wildlife reserves without the pastoralists obtaining viable alternatives has been the greatest failure in the development of the wildlife industry. Furthermore, the lack of participation of the local community in the conservation process and its further development just served to further isolate the communities and has resulted in negative impacts to both human society and the conservation areas (Schoelder & Jacobs 1993; Tibabu 1997; Mudris 1998). The studies undertaken by Tibabu (1997) and Mudris (1998) showed that government owned interventions caused a change in land use practices of the pastoralists from pastoralism to crop farming, charcoal and firewood selling and others forms of living.

2.2.6. Lake Beseka

In the study area, land is further decreased due to expansion of lake Beseka. It occupies a small rift between two opposing sets of faults and as a result, water is able to percolate up through the porous lava blocks to form a large standing body of saline water rendering its use as a source of water for livestock and human beings (Schloeder & Jacobs 1993). Moreover, due to poor irrigation infrastructure, practices and over grazing in the catchments area in the last 20 years, the lake has increased from 3.3 km^2 to 35 km^2, with an average annual increase in height of 0.12 m (EVDSA 1990). The effect of this being a decrease in the grazing land of the Kereyu pastoralists. Currently, the government has planned and budgeted to let the lake flow into the Awash River.

In general, there is a lack of accurate and reliable data on the size of the land occupied by the different enterprises and the reports are also contradicting. The available information is shown in **Table 2.1.**

Table 2.1. Land use practices in the study districts.

Existing land use	**Area (ha)**
Methara sugar plantation (Waktola & Micheal 1999)	11 000
Nura Era state farm (Waktola & Micheal 1999)	3 277
Awara Melka state farm (Waktola & Micheal 1999)	1 200
Middle Awash agricultural development enterprise (Lane *et al.* 1993)	30 400
Lake Beseka (Schloeder & Jacobs 1993)	3 500
Awash National Park (Schloeder & Jacobs 1993)	75 600

2.2.7. Livestock, feed and rangeland resource base of the study area

Animal production plays a major role in the economy of pastoral society (Singh & Ghosh 1993). Unlike the other pastoral areas, there are a number of additional factors that affect the livestock, feed and rangeland resource base of the area and the associated use of these resources. Even in a normal pastoral production system, there are several changes in management practices between the different seasons of the same year and between different years because of change in the amount of precipitation (Ellis & Swift 1988; Behnke *et al.* 1993; Coppock 1994).

When raising the issue of livestock in the study districts, it is not only the pastoral groups that are the utilizers of the rangeland resources, but also people living in the town and the different plantations own a considerable amount of livestock that heavily depend on the rangeland and feed resource of the area. With an increase in human population, both in the town and in the different plantations, there is an accompanied increase in the need for more land for crop production and forage resources, which in turn, have created severe competition even among the pastoralists of the same ethnic group, which at times result in heavy dispute and conflict. The rangeland resource is also shared between the various components of the ecosystem including both livestock and wild animals. Added to the different interacting factors operating in the study districts, over the last 5 years there was a general decline in the amount of rainfall, which might affect the rangeland resource base of the area (Methara Estate Sugar, meteorological data, 1966-2001). The influence of rainfall on herbaceous production in semi-arid areas is well documented (Shiflet & Dietz 1974; Warren *et al.* 1984; O'Connor 1994; Ekaya *et al.* 2001; O'Connor *et al.* 2001). Based on this account, the livestock feed and rangeland resource base of the area need to be assessed to indicate the changes in space and time.

The pastoralists in the study area are transhumants keeping cattle, sheep, goat and camels like the rest of the pastoral society in Ethiopia. A transhumant pastoral are those types of pastoralists which are not nomadic, but instead maintain permanent settlements. They do, however, move their livestock seasonally in order to exploit areas away from the permanent settlement sites. The entire village rarely moves with the herders in these instances (Halcrow 1989). Like all pastoral areas in Ethiopia, the animals owned are used for milking, slaughtered for meat, sold for cash or bartered for other commodities.

Similar to the general situation in Ethiopia, there is no accurate and reliable data regarding the livestock population of the area. The available information is also limited in time to indicate changes that can occur under the conflicting resource use pattern of the study area and a decline in the amount of precipitation in consecutive years. Livestock populations for the Afar, Kereyu and Ittu pastoralists living in and around the park were 35 139 cattle, 61 804 sheep and goats, 8 282 camels and 1 076 donkeys (Schloeder & Jacobs 1993). This when converted to Tropical Livestock Unit (TLU) equals 24 597 for cattle, 6 180 for sheep and goats, 8 282 for camels and 538 for donkeys. This conversion is based on the TLU conversion for Sub-Saharan Africa, which is shown in **Table 2.2**. A Tropical Livestock Unit is the equivalent of one bovine animal of 250 kg live weight. In the rest of the thesis this conversion factor is used unless specified.

Mudris (1998) showed a livestock ownership of 13, 10, 10, 3 and 1 for cattle, sheep, goat, camel and equines per Kereyu and Ittu household, respectively. For the Afars living in Awash- Fantale district, Tibabu (1997), reported an average livestock ownership per household of 23.4 for cattle, 47 for sheep and goats,19.0 for camels and 0.23 for donkeys.

Table 2. 2. Tropical livestock unit (TLU) equivalents for Sub-Saharan Africa (ILCA 1990).

Species	Average biomass (kg)	TLU equivalents
Camels	250	1.0
Cattle	175	0.7
Sheep and goats	25	0.1
Horses and mules	200	0.8
Donkeys	125	0.5

To the pastoralist, his domestic animals are considered family and are also an important medium of social exchange. A pastoralist with many animals can be generous to his friends and relatives giving them animals during ceremonies, when they are ill, or purely as a sign of friendship. He can help poorer households by giving or lending them animals. A man with many animals can afford to marry more wives and have more children. He can also take in impoverished friends or relatives as dependants, adding to his prestige and his labour force. The Maasai say a successful man is like a tree on a hot sunny day, he shelters many people under his shade (Solomon *et al.* 1991). Thus, the study of livestock ownership in pastoral communities is very important, though the pastoralists are relactant to tell the exact number of their livestock.

Poor nutrition caused by inadequate amounts and poor quality of feed is one of the major causes of low livestock productivity in tropical areas (Kaitho 1997). Subsequently, a detailed assessment of the available feed resources, their extent of usage by the categories of users, season of usage, constraints that are faced in the usage and alternative measures taken during feed shortage need to be clearly known in such a way that it can assist in solving the problems associated with the degradation of the rangeland. To this effect, there is a limitation of information regarding the utilisation of the different feed resources in the area. The Methara Estate Sugar produces annually a total of 0.37 million sacks of fine molasses and some other by-products, which could have helped much in alleviating the further degradation of the available rangeland (Mathara Estate Sugar 2001). Unfortunately, most of the molasses is used for export, ethanol production and for the production of alcoholic drinks. It is also used for cattle feeding but mainly by enterprises outside of the study districts.

2.2.8. Migration and rangeland management in the study districts

Intact relationships exist between the pastoralist and his environment based on the availability of rainfall and the resulting availability of grazing. The seasonal availability of green pasture and its rapid exhaustion owing to heavy grazing are the main reasons for the migratory movements of the pastoralists in the study area. The timing, direction and the extent of their movement are primarily dictated by rainfall. Although previous studies indicated the existence of migration in the study districts (Desta 1993; Tibabu 1997; Mudris 1998) there is no detailed information to describe the problems associated with migration, livestock disease problems linked with migration and pastoralists perceptions on migration which are key elements in rangeland resource use pattern and decisions regarding their future situation.

Land in Ethiopia was formally brought under State ownership in 1975. However, most state owned rangeland is in practice managed as common property and is usually controlled by an ethnic group, clan or other social units. They in turn apply rules and traditional social control, which regulate the access and coordinate, the action of individual managers in the utilization of the natural resources (Simonsen & Mitiku 1998). In both pastoral groups, kinship is concerned with rights over property and succession in a local community. Like the rest of pastoralists in Ethiopia, these pastoralists have their traditionally set social organization that is involved in rangeland management. In both cases, village heads, sub clan leaders and clan representatives, elders (Gada leaders in the Oromo groups) play a major role in the protection and utilization of the rangeland (Desta 1993; Tibabu 1997; Mudris 1998).

2.3. WILDLIFE CONSERVATION AND PASTORALISM

The problem associated with state owned conservation and pastoralism is not unique to Ethiopia. Although the problem is not wide spread globally, it exists in a much smaller area in Africa, namely part of the rangelands of eastern and southern Africa. Therefore, a brief review of the situations in these countries will be important in order to have a wider outlook of the problem and the interventions undertaken to solve the problem.

Livestock and wildlife co-existence means the joint occupation and utilization of the same general land area for any period during the course of the year (Bourn & Blench 1999). On the basis of this definition, pastoralists and their livestock have probably co-existed with wildlife in Africa for some 7000 years. It may be difficult to perfectly establish the relation between wildlife and human beings at that time, yet it is likely that few of the tensions evident today were present.

In East Africa, nationally protected areas cover some 193 000 km^2 or 12.7% of the region with the largest owned by Tanzania, followed by Kenya and Uganda. Wildlife is a major tourist attraction and foreign exchange earnings of countries such as Botswana, Kenya, South Africa, Tanzania, Zambia and Zimbabwe (Pearce 1997). Hence, extensive land areas have been set-aside in these countries for some form of conservation management (e.g., as much as 25% of Tanzania, 30% of Zambia, 12% of Zimbabwe and 10% of South Africa). In South Africa, private reserves and integrated livestock-wildlife ranches are common, accounting for almost half the total conservation areas. Game ranching is also rapidly increasing in Zimbabwe and Nambia (Cumming 1990a,b,c; Cumming & Bond 1991; Winrock international 1992; Child B. 1995; Child G. 1995a, b).

Extensive reviews of the problems currently facing pastoralism and conservation were made by various researchers (Schulz & Skonhoft 1996; Bourn & Blench 1999). They indicated that human population growth, agricultural expansion, deforestation, hunting and the ramification of economic development have had profound, cumulative impacts on the environment, natural habitats and wildlife population all over the world. For example, the wildlife population of Kenya has fallen by a third over the last two decades and wildlife has also been eliminated from much of the Uganda, including many protected areas.

The establishment of national parks and game reserves excludes and has often directly displaced rural communities from their land, which traditionally was theirs. It is argued that, due to implicit notions of nomadic pastoralism as uneconomic and environmentally destructive deeply founded in Western agricultural mentality, the pastoral people have been caught in an accelerating poverty process (Johnsen 1998). Similar problems have been noted in Kenya and Tanzania (Lane & Swift 1989; Coe & Goudie 1990; Enghoff 1990; Homewood & Rodgers 1991; Prins 1992; Kamugisha & Stahl 1993; Lane & Moorehead 1994; Mustafa 1997).

The general trend over much of the East African regions has been for livestock and game to be managed separately. Pastoral livestock are excluded from the great majority of such areas in Africa today, although multiple uses are allowed in some protected areas, such as Amboseli National Park and Ngorongoro Conservation areas.

Conservationists argue that livestock tends to displace wildlife from grazing areas and convert habitat to less productive and biologically diverse states (Coe *et al.* 1976). Contrary to this idea, eliminating livestock grazing and pastoral management practices, such as burning, from areas in Ngorongoro Conservation area, has detrimentally altered vegetation for wildlife, favouring less nutritious and less palatable species (Homewood & Rodgers 1987, 1991). Livestock and wildlife exploit different (but overlapping) ecological niches in time and space and have evolved different physiological and behavioural strategies to reduce competition (Infield 1996). At the same time, there has also been a realisation that relying solely on protected areas to conserve biodiversity is insufficient. Wildlife is a fugitive resource, with some species migrating seasonally, ignoring boundaries delimited by protected areas. For example, in Kenya three-quarters of all large mammals are found outside protected areas for at least part of the year. Conservation and wildlife management must, therefore, be extended beyond the protected areas.

In order to solve the above-mentioned problem many countries have tried different methods. Strategies for the integration of livestock and wildlife rely on the benefits of diversifying livelihood through non-consumptive and consumptive sustainable use. Among them are commercial game ranching, sharing resources with the local communities around national parks and community based wildlife management practices such as the communal areas management programme for indigenous resources (CAMPFIRE) in Zimbabwe. Although many problems are associated with the programme it is now being used as a model for similar programmes in a number of other countries in SSA (Bourn & Blench 1999).

2.4. PASTORALISM AND OPPORTUNISTIC MANAGEMENT

Recent research works undertaken in communal grazing lands, has shown that fluctuation in yield of natural forage in drylands areas is affected far more by variability in rainfall than by grazing pressure (Warren & Khogali 1992; Behnke *et al.* 1993). Thus, the marginal nature of pastoral environments has imposed certain constraints to livestock production and settlement patterns. Livestock are bred for their resilience to drought and disease rather than their productivity. Human and livestock movement is a response to seasonal variations in forage availability. Herd diversification is common, with many herd owners herding a variety of different stock in different areas. Not only do different animals have different niche specialisations, but also have different vulnerabilities to drought. Such diversification helps reduce overall vulnerability to drought and disease and herd growth tends to be opportunistic rather than conservative. Thus, communal ownership of the rangeland is an adaptation to variability (Hogg 1997; UNDP 1997).

Movement of animals in response to spatial and temporal variation in resource availability is perhaps the most classic of all the tracking strategies (Swallow 1994). It is used as a means to adjust local imbalances in stock numbers and to make use of the seasonal availability of pasture and water (Smith 1992; Behnke *et al.* 1993), thus indicating that pastoralists are strategists (Dyson-Hudson 1980). Rather than manipulating herd numbers in response to climatic variability, as would a rancher operating in an enclosed area, pastoralists move and so shift their resource endowments (Oba 1998). In addition, pastoralists almost invariably have some access to crop residues and other agricultural by-products. Catch cropping by pastoralists often results in more fodder than grain. In addition, grazing arrangements between pasoralists and agriculturalists have long been a route for pastoralists to gain access to farm resources (Toulmin 1992; Powell & Williams 1993).

International development agencies and African governments have devoted considerable effort to the suppression of pastoral techniques of land and livestock management. These programmes were undertaken on the presumption that pastoralism was inherently irrational, ignorant, unproductive, ecologically destructive and largely or solely responsible for poverty, overgrazing and the general degradation of the land. It is also associated closely with the failure of development schemes (Hardin 1968; Picardi & Seifert 1976; Livingstone 1977; Sandford 1983). The main reasons associated with these ideas are that communal farming inevitably results in over-grazing because it is totally unregulated free-for all which Hardin (1968) named the "tragedy of the commons". There are no controls to ensure the continued viability of land held in communal ownership. In addition, according to Sandford (1983) decisions are motivated by tradition, rather than rationale or scientific knowledge.

Contrary to the above assumptions, with regard to herd productivity, comparative studies of ranch and pastoral herd output in West Africa (Breman & De Wit 1983), Southern Africa (De Ridder & Wagenaar 1984) and East Africa (Western 1982; Cossins 1985) demonstrate that pastoralism either equals or exceeds the productivity per unit land area of commercial ranching in comparable ecological environments. Furthermore, many studies of traditional communal farming do not support the free-for-all assumption (Netting 1976; Gilles & Jamtgaard 1981; Sinclair & Fryxell 1985). The existence of complex social mechanisms, as well as ecologically based management strategies which regulate the use and distribution of resources by the pastoralists is well documented (Schapera 1943; Bodley 1985; Ellis & Swift 1988). In fact it has been shown that many pastoral groups have through their indigenous organization, been able to control access to rangeland and that some of the longest-used areas are least degraded. A wealth of anthropological studies over the past few decades have convincingly demonstrated that most such practices are part of an internal rationality or logic which permit people to optimally utilize available resources. Perhaps more importantly, they support social systems of reciprocity, which have become adapted to the local conditions over time (Bodley 1985).

2.5. EQUILIBRIUM VERSES NON-EQUILIBRIUM DYNAMICS IN PASTORAL PRODUCTION SYSTEM

The terms equilibrium and non-equilibrium as used in rangelands, are points of strong debate among scientists working in rangeland ecology, particularly when applied to African pastoral ecology. The central aspect of this debate is the definition of the degree to which climate or consumers influence environmental trends. One view is that consumers reach densities that degrade environments from a previous condition of equilibrium (Lamprey 1983) and the other side is that the dynamics of pastoral systems are non-equilibrium and primarily dictated by variability in rainfall (Ellis & Swift 1988).

Based upon a review (Scoones 1995b) indicated that the equilibrium system assumes that range-livestock systems operate in environments that are stable or equilibrium in nature, where climate variability is not important, i.e., plant-growing conditions are relatively invariant over time. Moreover, vegetation change is gradual, following the classical climax concept of Clementsian succession (Clements 1916; Stoddart *et al.* 1975). Livestock populations are in turn limited by available forage in a density-dependent manner, so that excessive animal numbers, above a carrying capacity level, result in negative effects on the vegetation (Miller 1997). The concept of an equilibrium system first developed and applied in North America became the basis for planning livestock use on rangelands in pastoral systems (Miller 1997). Lamprey

(1983) from the long-term studies in Tanzania, Coppock (1994) from Ehtiopia and Meadows & White (1979); Evangelou (1984); Grandin (1987) from Kenya Maasai land support the concept of equilibrium ecosystem dynamics.

The concept of equilibrium has been challenged both from a theoretical and practical point of view (Hyder *et al.* 1966; Glieck 1987; Horowitz & Little 1987; Ellis & Swift 1988; Nicolis & Prigogine 1989). Ecological research in the last decade in semi-arid rangelands, where climatic variability is high and ecosystem functions very dynamic, suggests that most arid and semi-arid rangeland ecosystems function as non-equilibrium systems. In these areas, plant growth and rangeland productivity were found to be more functions of climate than of livestock stocking rates, and the effect of livestock on rangeland vegetation being more sporadic than continuous. Given the array of publications in widely circulated literature, the new science is rapidly being established as a dogma and could subsequently be incorporated into policy decisions (Cousins 1996; Dikeni *et al.* 1996). However, recently Campbell *et al.* (2000) from Zimbabwe examined one tenet of the new science that pastoral systems give higher economic returns than other systems. They compared the economics of four cattle management practices. They reported that strategies based on conservative stocking rates would have higher net present values than strategies based on opportunistic stocking rates or management. They further identified several serious flaws in the papers that elevate opportunistic pastoral systems as giving higher economic returns than other systems, opening more room for continuation of further research in equilibrium and disequilibria concepts as related to the pastoral production system.

Researchers differ in terms of opinion regarding as where the non-equilibrium dynamics occur. Some relate it to the coefficient of variation (CV) of annual rainfall, i.e., when the CV is greater than 35%, the ecosystem tends to be non-equilibrium. Others, on the other hand, suggest that areas that receive less than 300-400 mm of rainfall annually will operate as non-equilibrium systems (Miller 1997).

2.6. RANGELAND CONDITION ASSESSMENT

2.6.1. Herbaceous vegetation

2.6.1.1. Significance and historical development of rangeland condition assessment

Since the inception of the word rangeland condition, different people have tried to give different kinds of definitions. However, it is usually concerned with the "state of the health" of the vegetation, i.e., what the vegetation should look like under normal climate and optimum management. In a more complete sense, it includes the direct and indirect changes in vegetation composition land productivity and land stability over time under various regimes of livestock production (Bailey 1945; Parker 1951; Short & Woolfolk 1956; Tueller & Blackburn 1974; Pratt & Gwynne 1977; Tainton 1981; Wilson & Tupper 1982; Trollope *et al.* 1990; NRC 1994; Tainton 1999).

Rangeland condition and trend are perhaps the most important concepts in the management of renewable resources in arid and semi-arid lands. There are three objectives in rangeland condition assessment namely; evaluation of rangeland condition relative to its potential in that ecological zone (Tainton 1999); evaluation of the effects of current management on rangeland condition and monitoring changes over time (Hacker 1974; Trollope 1990; Tainton 1999) and classification of the different vegetation types on the farm and quantification of their condition (Tainton 1999). This is mainly done based on a concern for the long-term productivity and stability of the rangelands (Wilson & Tupper 1982). As pointed out by Tainton (1988) and Stuart-Hill & Hobson (1991) interpretation of the condition and grazing capacity assessments allows the user to define possible management options to improve the condition and therefore grazing capacity of the rangeland. It is, therefore, not surprising that a lot of effort has been put in the ways of developing appropriate techniques for rangeland condition assessment.

It is widely believed that overgrazing is the most important cause of rangeland degradation (Fourie & Fouche 1985; Fourie *et al.* 1985; Danckwerts & Tainton 1996; David *et al.* 2000). When the production potential of rangeland is over-estimated the resultant overgrazing will cause a decrease of the palatable perennial plants in favour of the less palatable, undesirable vegetation. Such changes will also influence the hydrological status (Snyman & Fouche 1991, 1993), stability (Snyman 1998), quality (Potgieter 1991), productivity (Kirkman & Moore 1995a; O'Connor & Bredenkamp 1997; Snyman 1997), and utilization potential of the rangeland. This can have major economic implications (Van der Westhuizen 1994; Snyman 1998; Van der Westhuizen *et al.* 1999) and therefore to ensure sustainable utilization and production of the grassland ecosystem, the determination of rangeland condition and trend is essential.

Smith (1895), Griffith (1903) and Wooten (1908) were some of the first authors to recognize the need for rangeland assessments as an input for management decisions (Foran 1976). In the early 1900's, Clements (1916) proposed that vegetation was dynamic and is constantly changing. This theory contrasted to the then-prevalent view that vegetation was static and unchanging (McIntosh 1985). Clements (1916) successional theory rested upon the assumption that vegetation could be classified into "formations" representing a group of plant species acting as an organic entity. This theory of vegetation dynamics has been referred to as the mono-climax theory. While Clements (1916) theorized that climate alone controlled the climax vegetation, other scientists questioned the narrowness of this mono-climax description of a stable community. Clements (1916) identified livestock grazing as a factor initiating plant invasion and the processes of plant succession. In the late 1930's Stoddart used the term "vegetative condition class" to describe successional stage (Spence 1938). Attempts to officially define methods to determine rangeland condition were made by the Interagency Range Survey Committee in 1937.

Dyksterhuis (1949) described a quantative approach for assessing rangeland condition. The standard for comparison was developed by establishing 3 classes of plant species (decreasers, increasers and invaders) based on their response to grazing. Relative coverage of plant species within these 3 classes was estimated in the field and compared to standard cover values for that location. He broadened the idea of climax beyond that of Clements (1916) to include edaphic or physiographic climaxes. Publications after 1949 and into the late 1960's explored the relationship between rangeland condition and insects (Nerney 1958), runoff (Leithead 1959), plant vigour (Goebel & Cook 1960), livestock production (Cook *et al.* 1962), grazing management (Valentine 1967) and wildlife management (Berg 1966).

The first International Rangeland congress, which was held in 1978, paved the way for enhanced communication between international scientists and presented a general critique of the rangeland condition concept. Since then, critiques have attacked 3 assumptions that were outlined by Smith (1989) as (1) climax is pristine vegetation in equilibrium with climate and soil; (2) climax is the only vegetation furnishing adequate soil protection and, therefore, is the most productive species composition for a given site, and (3) retrogression due to grazing stress and succession after removal of that stress are viewed as opposing and reversible linear responses. Scientists presented anomalies in very arid areas with highly erratic precipitation (Westoby 1980), areas dominated by exotic species (Westoby 1980), annual grasslands (Dyksterhuis 1949; Laycock 1991), forested lands (Dyksterhuis 1949; Hall 1978), areas having a long history of use where "climax" vegetation is not known (Westoby *et al.* 1989), and areas which do not revert to climax when management is removed (Slayter 1975). In addition, scientists faulted the rangeland condition concept for its total dependency on botanical composition (Wilson & Tupper 1982). Foran *et al.* (1986) described the ecological theory underlying the rangeland condition concept as inadequate. Since then, non-equilibrium community dynamics, alternative steady states and transition thresholds have been offered as components in alternative theoretical models for rangeland vegetation dynamics (Archer & Smeins 1991; Friedel 1991; Laycock 1991).

2.6.1.2. Criteria used in rangeland condition assessment

Wilson & Tupper (1982) extensively reviewed and categorised the factors involved in the concept of rangeland condition into three. Accordingly, changes in vegetation such as the botanical composition of the herbage, its total quantity or cover and its invasion or emergence from a dominance by inedible shrubs or trees are considered as primary attributes, whereas the secondary changes may occur to soil attributes, such as infiltration rate, nutrient content or soil stability. Changes that may occur in production characteristics of the land, such as animal production, water yield, wildlife habitat and amenity value are taken as the last stage. The common factor in these is that in all cases a change in condition refers to a change in status, relative to the potential of each parameter within a particular land class. Therefore, a number of factors have been used in singly or combination and the most common once are discussed below.

2.6.1.2.1. Botanical composition

Rangeland condition is measured in terms of vegetation because a change in vegetation is most easily measured and it is the primary factor which leads to a change in other attributes such as erosion or reduced secondary productivity (Wilson & Tupper 1982). Furthermore, grass species composition 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. These are all determinants of habitat, which is especially important in the case of multi-species ecosystems (Smit 1994).

2.6.1.2.2. Basal cover

Basal cover is the proportion of the soil surface covered by vegetation and it is mostly used for herbaceous vegetation. This might be near to 0 % in deserts or in an unplanted cultivated field and greater than 12% in dense grassland (Baars *et al.* 1997). Limitations to the use of basal cover were indicated by Wilson & Tupper (1982), as it is a relative measure used to determine mainly the density and composition of perennial grass species. Mentis (1983) further added that, it is difficult to measure basal cover accurately, precisely and cheaply and it is not an input in common models of soil losses or rangeland production. Despite these limitations, basal cover is still used in determining rangeland condition even in recent years (Shackleton *et al.* 1994; Baars *et al.* 1997; Amsalu 2000; Ayana & Baars 2000; Dahlberg 2000).

2.6.1.2.3. Plant vigour

Grass vigour can be defined as the potential or ability of a grass plant to regrow during the season following defoliation. This measure has direct bearing on management, as it gives an indication of management effects on the production of grazing during the following year and it also serves as a short-term measure of the effect of grazing on the health of the individual species (Kirkman 1995). In general, many researchers have observed the influence of grazing on plant vigour and plant vigour as one important parameter (Johnson *et al.* 1992; O'Reagain & Turner 1992; Morris & Tainton 1993; Kirkman 1995; Kirkman & Moore 1995a,b,c; Peddie *et al.* 1995; Lutge *et al.* 1996; Mckenzie 1996; Muir & Abrao 1999).

2.6.1.2.4. Biomass

From a grazing viewpoint, production or yield is one of the most important measures in assessing rangeland. Biomass or standing crop usually refers to the weight of organisms present at one time (Pieper 1978). Most estimates of plant biomass or standing crop include only that above the soil surfaces. This material is commonly available to large herbivores. Below ground biomass is very important for plant functions, but is difficult to measure and generally not included in inventory or monitoring procedures (Jerry *et al.* 1989). Direct harvesting is considered the most reliable method of determining aboveground biomass. Furthermore, the use of equations and models are also developed (e.g., Deshmukh 1984; De Leeuw *et al* 1991; Snyman & Fouche 1993).

2.6.1.2.5. Bush encroachment

The encroachment of inedible shrubs and trees into semi-arid rangelands represents a community change that may be viewed either as a change in the botanical composition or as a separate vegetation attribute; the herbaceous –woody species balance. Such indices of shrub encroachment may be an incomplete measure of the situation, particularly when the shrubs are not fully established and represent an incipient rather than a current problem. Separate measure of shrub seedling density may be required and those would be considered as an assessment of the trend in condition, rather than condition itself (Wilson & Tupper 1982).

2.6.1.2.6. Soil erosion

Soil erosion is a natural process but the quantity and the rate of surface runoff and sediment yield may be altered through land use and management practices (Gifford & Hawkins 1978; Blackburn *et al.* 1982; Thurow *et al.* 1986; Weltz & Wood 1986; Snyman 1999a). Physical erosion or more frequently, a decline in the physical characteristics of the soil surface, is the most serious manifestation of a decline in rangeland condition because of its long lasting and progressive impact on production attributes (Wilson & Tupper 1982). Ellison *et al.* (1951) noted that condition should be based primarily on soil stability and secondarily on forage value. He indicated that condition is always unsatisfactory unless the soil is stable and that the forage value is only considered when the stability is assured.

2.6.1.2.7. Soil compaction

Compaction is the most complex soil feature having significant inter-relationships with most of the recognized physical, chemical and biological properties of soils as well as with environmental factors such as climate (Mckibben 1971). Compaction of the soil leads to physical soil degradation and modification of the pore structure. Examination of the soil matrix reveals a reduction in size and number of macropores and a change of shape and continuity of pores. Associated with these changes is increased soil strength and bulk density and a reduction of conductivity, permeability and diffusivity of water and air through the soil pore system that all have an important bearing on plant growth (Soane *et al.* 1981).

2.6.1.2.8. Soil parameters

Research on rangelands has historically focused on the effects of various management practices on forage production and animal response. Little attention has been given to the impact of grazing on the nutrient dynamics of the soils. Recent interest in soil health or soil quality has directed attention to grazing impacts on soil parameters that make up soil health/quality (Du Preez & Snyman 1993; Manley *et al.* 1995; Lavado *et al.* 1996; Derner *et al.* 1997).

2.6.1.3. Techniques used in rangeland condition assessment and their limitations

An extensive review on the assessment of rangeland condition and trend was made by many researchers (Wilson & Tupper 1982; Lauenroth & Laylock 1989; Hardy & Hurt 1989; Friedel 1991; Hurt & Bosch 1991). They indicated that it remained a source of controversy despite its use for a long period. The limitations refer both to the concept of rangeland condition and its assessment. Moreover, there is confusion in determining which factors are of particular importance for meaningful rangeland condition assessment and how these factors should be collected or determined whilst the interpretation of the results often varies from one researcher to another, depending on the person's original objective.

In general, the data collected and the production simulation models (stochastic) are exceptionally limited, localized and in most cases derived somewhat subjectively (Mentis 1983; Bosch & Booysen 1992). The extrapolation potential of the techniques is, therefore, limited and in most cases a particular technique can only be of real value in the area where it was developed. These anomalies indicate that there is a mismatch between the advance in the understanding of ecological processes and the developments in the theory and practise of rangeland assessment. Procedures therefore differ considerably in their objectivity. The method to be used in rangeland condition assessment should be simple, inexpensive, efficient and adopted over a wide area within a minimum of time. Moreover, the method should be objective (Wilson & Tupper 1982; Mentis 1983; Heard *et al.* 1986).

There are a number of steps involved in the development of any method of rangeland condition. These include the choice of vegetation measure, the species to be included and their classification as well as the type of index to be constructed. At each step, the choice made from the available methods and systems is dependant on the current land use and the attribute of condition to be assessed.

In general, there are two basic approaches to rangeland condition rating, i.e., ecological and the other is based on production. Both approaches depend on assessment in relation to the potential or capability of the ecological site and on the amount and composition of the vegetation (Smith 1988). Moreover, the techniques have a common factor, namely the creation of a basis from which grazing capacity can be calculated (Heard *et al.* 1986; Hardy & Hurt 1989) and attempt to provide a measure of monitoring condition trends with time (Heard *et al.* 1986). The available techniques are reviewed in more detail, as well as their shortcomings.

2.6.1.3.1. Subjective

The method developed by Roberts (1970) used plant density, species composition, vigour, surface soil condition and insect or rodent damage on a 3-point scale to index rangeland condition. Such ratings were combined to form a single numerical rating for the site whereby rangeland could be described in one of the four condition classes (very poor to good). The technique only tells the state of health of the rangeland and it cannot be used as a basis to estimate grazing capacity. Later, Van Zyl (1986) used a method based on a complete survey of the species composition and linked that with rainfall. The same was done by Snyman (1993) for a semi-arid rangeland. Jordaan *et al.* (1997) indicated that the subjective technique is most frequently used by both extension staffs and farmers.

2.6.1.3.2. Quantative

In the quantative approach there are two general methods, i.e., agronomic (production) and ecological. In the agronomic approach, it is important to obtain measures of rangeland composition, at least in terms of palatabity classes, which are representative of the rangeland being grazed (Barnes *et al.* 1984). This approach has been widely used in the United States (Humphrey 1945, 1946, 1949, 1962) and South Africa (Edwards & Coetsee 1971; Barnes *et al.* 1984). Species are allocated palatability ratings, which signify their forage production potential. Three palatability classes were developed for the purposes of classifying grassland species: class I - highly palatable, class II - intermediate and class III - unpalatable (Barnes *et al.* 1985, 1987; Rethman & Kotze 1986). Multipliers, i.e., weightings of 3, 2 and 1 are used for classes I, II and III respectively, to derive a palatability composition rating for each sample site. It is calculated as the sum of the products of the relative abundance of each species and its weightings, and is expressed as a percentage of the maximum palatability composition (viz 300) to produce a scale ranging from 33.3 (all species in class III) to 100 (all species in class I). These palatability composition (PC) values are converted to weighted palatability composition (WPC) values by means of the formula developed by (Barnes *et al.* 1984), namely:

$$WPC = (PC - 33.3) \times 100 \div 66.7$$

Under the ecological group, there are many methods such as the benchmark, ecological index method, the key species, weighted key species and the degradation gradient techniques.

A benchmark is an example of vegetation that is considered to provide the highest possible sustainable animal production for the rangeland type under consideration (Danckwerts 1982). Benchmarks provide a baseline against which the benefits and harmful effects of domestic grazing can be evaluated and a standard against which the effects of man's intervention in the natural environment can be assessed. A benchmark will not necessarily be the climax vegetation for an area and is often some form of sub-climax. However, limitations to the benchmark method have been suggested by Mentis (1983), Barnes *et al.* (1984) and Martens *et al.* (1996). Benchmarks may be in atypically favoured locations, they may experience different rainfall or have a different fire history, or they may simply not exist and must be theoretically constructed. Differences due to variability within a site may be inappropriately attributed to management. Multiple benchmarks have been proposed (Wilson 1984; Bosch *et al.* 1987) to represent the variability within a rangeland site or land unit. However, recent works indicated that the benchmark does not provide an estimate of the botanical composition over relatively large areas. For successful rangeland condition assessment, the technique must be simple and fast to execute, ecologically meaningful and scientifically sound. The commonly used rangeland benchmark technique does not fulfil these requirements (Martens *et al.* 1996). Therefore, efforts continued for more refined techniques.

The ecological index method was developed by Vorster (1982) for the Karoo biome and is based on the principle that rangeland, in a reasonably homogenous farming area, is compared with a reference point (benchmark), which has the same topography and occurs in the same area as the survey site. The method combines cover with botanical composition to provide a single indicator of veld condition that is quick and easy to measure. The plant species are divided into a decreaser group, three increaser groups and an invader group, based on specialist knowledge. Relative index values of 10, 7, 4,1 and 1 are allocated to the five groups, respectively. A rangeland condition index is obtained by the sum of the respective groups. The latter is obtained by multiplying the sum of the frequency of the species, within each group, with the relative index value. The derived rangeland condition index is used to calculate grazing capacity or to monitor rangeland condition trends. A major shortcoming of this approach is the subjective allocation of species to categories and the assumption that all species are equally sensitive to utilisation.

In an attempt to develop a more rapid and simplified technique for use in large scale field surveys (Tainton 1988) and the apparent insensitivity of the benchmark and the ecological index method (Hardy & Hurt 1989), a number of attempts have been made to develop an assessment technique based on the relative abundance of only a limited number of key species within any ecological region. Foran (1976) compared indices developed from the abundance of only *Themeda triandra* with those derived from the full proportional species composition of a site and found such indices to provide a relatively precise indication of the condition of the community.

Heard *et al.* (1986) used an adaptation of the key species technique to deduce rangeland condition indexes from weighted species occurrences. Hardy & Hurt

(1989) and Hurt & Hardy (1989) make use of an ordination technique to identify those species, which react to grazing. Species weights are based on the positioning of these key species on the grazing gradient. The sum of the key species and their associated weights only are used to calculate the rangeland condition index. Since all the key species react to this grazing impact, the final score is thus an exact indication of the site's position on the grazing gradient (Hurt & Bosch 1991).

The lack of sensitivity in monitoring rangeland condition changes in the above methods paved the way for the development of the degradation gradient technique (DGT). The DGT was developed in the climatic climax grasslands using a multi-variate procedure (Bosch 1989: Bosch *et al.* 1987; Bosch & Gauch 1991; Bosch & Kellner 1991). Degradation gradients represent a suite of sample sites in deteriorating ecological condition along a grazing gradient, and were constructed for certain relatively homogenous grazing areas in the climatic climax grasslands. These gradients were then used as a basis for objective and quantative condition assessments of new sites by incorporating the new sites into the old ordinations (Bosch & Gauch 1991). Interpretation of the rangeland condition index is conducted in conjunction with a description model derived from the ordination studies (Bosch & Kellner 1991).

The use of ordination to objectively identify species responses to grazing has received considerable attention in recent years (Mentis 1983; Bosch 1989; Hardy & Hurt 1989; Hurt & Hardy 1989; Bosch *et al.* 1992; Hurt *et al.* 1993; Martens *et al.* 1996). Work done by Jordaan *et al.* (1997) has indicated the advantage of the degradation gradients over the other methods. Similarly, Van der Westhuizen *et al.* (1999) used the degradation gradient technique in semi-arid sweet grassland of Southern Africa. They reported that the advantage of the technique lies in its simplicity and ease of use. Another advantage is the fact that only the most important indicator and dominant species in the study area are used to determine rangeland condition. Not only the advantages, but they also indicated the limitations. Though the degradation gradient method is seen as objective and scientifically correct, the calculation of the ordination on which this method is based is complicated and only possible with a computer. Furthermore, Hurt & Bosch (1991) pointed out that relatively large sets of data are required to construct the gradients.

In conclusion, in response to the need of developing objective methods of monitoring changes in rangeland condition, many methods have been developed. The general agreement moves towards the more scientific and objective method of assessing change in rangeland condition, i.e., the degradation gradient technique. Although this is true, there are many limitations to use this method in least developed countries like Ethiopia particularly in large-scale rangeland assessment. Some of the limitations are the lack of a large set of data in vegetation, differences in the production systems (nomadic pastoralism vs privately owned commercial farms), the severe degradation of the rangelands, shortage of technical capability both in terms of manpower and advancements in range science. Therefore, the choice of the method to use should depend on the local conditions and it is preferable to use different techniques for different objectives. Moreover, for countries like Ethiopia it is preferable to use the simpler techniques used in developed countries and later develop techniques that best fit local condition.

2.6.2. Woody vegetation importance and their assessment techniques

2.6.2.1. The importance of woody vegetation in the drylands

The crucial role of woody plants as a source of feed for both domestic animals and game, firewood, mulch and soil conservation and as well as vegetation improvement in semi-arid regions has long been recognized (Scholes & Walker 1993; Breman & Kessler 1995; Smit 2002) indicating that they have multiple roles in farming systems. In many cases they provide long-term stability or successful conservation of the production systems especially in an environment of extreme oscillations (Sankary & Ranjhan 1989). Branches from spiny woody species like *Acacia tortilis* and *A. erubescens* are used for the construction of fencing kraals where livestock can be protected from predators (Smit 1999a). With the expansion of the tourism industry the market for wooden carvings from the indigenous tree species also became popular.

Trees play an important role in the diets of browsing ungulates living in arid zones (Walker 1980) and are often browsed or causally lopped and fed (Skerman 1977; Le Houerou 1980). They provided valuable forage to herbivorous animals probably since the time of their domestication (Skerman 1977). Due to the highly irregular nature of rainfall in the drylands and virtual disappearance of nutritious grasses during the dry seasons, trees and shrubs are an essential part of the pastoral environment (Le Houerou 1980).

In Africa, at least 75% of the trees and shrubs serve as browse plants and many of these are leguminous. In northern Africa, browse forms 60-70% of rangeland production and 40% of the total availability of animal's feeds in the region (Nott & Savage 1985, Milton 1988). In India, browse is the principal feed for goats and meets over 60-70% of their forage requirements, of which the leguminous types of browse are especially important. In Mediterranean and arid environments shrubs act as nutritional reserves during the summer drought (Azocar 1987; Azocar *et al.* 1991). In the mid hills of Napal (Thapa *et al.* 1997) more than 75% of the tree fodder that is fed to livestock is used during the dry period. In these areas, browse trees and shrubs often have a higher crude-protein and mineral content and some times higher dry matter digestibility than associated grasses, particularly during the dry season. An important attendant advantage is a lowered cost of feeding due to a reduced dependence on purchased energy and protein supplements. In parts of Africa, animal production is heavily dependent on the availability of browse legumes, while in Australia, interest in fodder trees has focused mainly on native species, particularly the *Acacia* species, but novel browse legumes such as *Leucaena leucocephala* have also been introduced with some success.

Browse legumes are more important than simply being a source of feeds. In many situations, they form complex interactions between plants, animals and crops, the positive aspect of which help to balance a plant-animal ecosystem and from which there is a sustainable source of feeds. The foliages of some are used as vegetables by humans while the roots, bark or stem and leaves of others are used for medicinal purposes (Kaitho 1997). Many pastoral and agropastoral peoples throughout the drylands areas of Africa have traditionally used and managed woody plants to produce fuel wood, fodder, building poles and other products for sale and domestic use. Diress *et al.* (1998) in their study of the influence of land use on woody vegetation in the semi-arid area of Abala district, North Afar identified 43 woody species and indicated their use as fodder for livestock, construction, fuel wood, shade and shelter, human food, fence, medicine, farm implements and household utensils. A non-quantified preliminary study in villages adjacent to the Awash National park of Ethiopia showed a similar pattern of usage (Sharon 2000).

2.6.2.2. Browse production

Compared with the research effort allocated to the study of grasslands in East Africa, the browse component of savanna ecosystems has for long been neglected (Pellow 1983). It is only recently that biomass or productivity measurements have been published and still these are mainly from arid-lands in Kenya (Oba & Post 1999; Rosenschein *et al.* 1999). Recently, Oba & Post (1999) studied the browse production of *Acacia tortilis* under browsed (goat) and unbrowsed conditions. They reported that goat browsing did not result in different tree growth rates between the browsed and unbrowsed treatments. However, browsed trees produced more twigs than unbrowsed trees.

Even in semi-arid savannas, there are limited published results of browse production. Even these are very limited in the number of tree species they have considered for their study. Rutherford (1982) reported some quantative data of aboveground biomass of *Burkea africana- Ochana pulchra* savanna. He estimated the mean aerial biomass to be 16 273 kg ha^{-1}, of which 236 kg ha^{-1} comprised the current season's twigs and 1 100 kg ha^{-1} the leaves. Of the potential browse, only 3.8 % was estimated to be within reach of impala, 5.1% within reach of kudu and 67% within reach of giraffe. Above ground standing crop of *Colophospermum mopane* in the Klaserie private natural reserve, at the peak biomass, has been estimated at 20 840 kg ha^{-1} of wood and 801 kg ha^{-1} of leaves (Scholes 1987). Kelly & Walker (1976) estimated the mean standing crop of *Colophospermum mopane* in Zimbabwe to be 19 940 kg ha^{-1}, of which 1 506 kg ha^{-1}, comprised the current season's shoots. Walker (1980) quoted seasonal production estimates of woody species leaves and twigs, from a *Colophospermum mopane* arid shrub and tree savanna in Zimbabwe that ranged from 594 kg ha^{-1} to 2 121 kg ha^{-1} and demonstrated production varies strongly owing both to inherent site differences (mainly soil depth) and to management. Some other reports of browse production are given in **Table 2.3.**

Dekker & Smit (1996) studied the browse production and leaf phenology of different plant communities in a semi-arid savanna in South Africa. These estimates included the total leaf DM, as well as estimates of the leaf DM at browsing heights of 1.5, 2.0 and 5.0 m. They reported that the total leaf DM in the different plant communities ranged between 1 224 kg ha^{-1} and 2 672 kg ha^{-1}. *Colophospermum mopane* contributed substantially to the total leaf DM in all communities. Their results also indicated variability in the total and season availability of leaves to vary between the different vegetation types and can therefore be considered important factors that influence the distribution of large herbivores.

Foliar phenology is important because of its relation to processes and factors such as tree growth periodicity, flowering and fruiting, plant herbivore interactions and ecosystem properties (Borchert 1980; Reich & Borchert 1982, 1984; Aide 1988; Reich *et al.* 1991, 1992; Wright 1991). In tropical savannas, the temporal patterns in growth and reproduction are linked to the rhythms of the various seasons. Numerous woody species, both dominant and sub-dominant, are deciduous with leaf fall occurring during the dry season. Deciduousness is a feature of trees within savannas across the world, with pronounced seasonal reduction in canopy cover as the dry season progress. There appears to be considerable variation in ecosystem-level patterns of deciduousness in the world's savannas. African savannas are mainly deciduous (Mensat & Cesar 1979; Chidumayo 1990), as are those of India (Shukla & Ramakrishhnan 1982; Yadava 1990). In the Ilanoes of South America, evergreen species predominate (Monasterio & Sarmiento 1976; Sarmiento *et al.* 1985), although forest patches within the Ilanoes are dominated by semi-deciduous or fully deciduous species (Medina 1982) as are the seasonally dry forests of Costa Rica (Borchert 1994).

Table 2.3. Rate of browse production for a variety of savanna woodland types.

Woodland type	**Plant part**	**Production (kg ha^{-1} annum^{-1})**	**Study location**	**Author**	**Remark**
Acacia xanthophloea riverine woodland	New shoots and leaves	5 000	Serengeti National park	Pellow (1983)	Production of browse below 5.75 m only
Acacia ridge-top regeneration thicket	New shoots and leaves	1 750	Serengti National park	Pellow (1983)	Production of browse below 5.75 m only
Colophospermum mopane	Twigs and leaves	1 510	southeast Zimbabwe	Kelly (1973)	Range 590-2120 kg ha^{-1} Annum^{-1}
Dense shrub *Colophospermum mopane* and *Grewia* species	Green leaf	1 490	southwest Zimbabwe	Kennan (1969)	0.2 ha sample area

Rutherford (1979a) stated that it is important to have a clear understanding of what is meant by browse and available browse. He described browse as the sum total of that material on the woody species that is potentially edible to a specific set of animals and that browse is most commonly regarded as the current season's growth of both leaves and twigs. Available browse on the other hand is usually a more restricted quantity than browse and in most studies available browse is simply determined on the basis of maximum height above ground to which a specified animal can utilize browse. The availability of browse below a specified browse height may be reduced by obstruction of browse material towards the centre of the plant by dense branch entanglements (Rutherford 1979b), while leaf senescence of winter deciduous species will lower available browse during certain periods (Styles 1993; Smit 1994).

Possibly more important than the amount of available browse at peak biomass is the continuity of browse availability over the season. A state where leaves are retained on the trees in younger phenological state followed by the early emergence of new season's leaves, is likely to be of greater value to browsers than a state where trees carry no leaves for some time with only dry leaves available on the ground.

Since woody species growth is terminal and greater at the top of the plant (Kozlowwski & Keller 1966), greater productivity occurs in the upper canopy than the lower canopy. Therefore, if the upper canopy is above the browse limit (approximately 1.5 m) of the browsing animal, the plant will grow away from the animal leaving access to only the less productive lower canopy. In order to achieve the highest productivity and keep control on the browse plants therefore, management must aim at maintaining browse at or below the available height.

2.6.2.3. The importance of trees in ecosystem functioning and their role in rangeland condition

There are contradictory views on whether trees at low density improve or degrade the condition of the rangelands. In order to examine the influence of trees at low-density different researchers used many criteria. Among them, the most commonly used are plant species composition, forage yield, soil physical and chemical characteristics and forage quality. In this section, the influences on plant species composition, forage yield, soil physical and chemical characteristics will be reviewed.

Commonly, the influence of trees kept at low densities is studied under light grazing conditions. Therefore, published information on the effects of different grazing gradients for trees kept at low densities is scarce. The only work that can be cited along this line is that of Belsky *et al.* (1993). Belsky *et al.* (1993) studied the effects of widely spaced trees of *Acacia tortilis* and *Adansonia digitata* on their under storey environments in four savannas located along a gradient of increasing livestock utilization (light, medium and heavy). They reported that a unique under storey flora and higher herbaceous yield under tree crowns in the lightly and moderately grazed sites than in the corresponding open grasslands. There was no effect of sub-habitat on the herbaceous layer at the heavily grazed site which was dominated by agricultural weeds whereas, there were differences in the sets of species found under tree crowns and in open grasslands at the lightly and moderately grazed sites.

There is also a lack of consensus in the literature regarding the effects of tree canopies on herbaceous vegetation composition. Studies conducted by Kennard & Walker (1973) in Zimbabwe; Stuart- Hill *et al.* (1987) in South Africa; Belsky *et al.* (1989) in Kenya; Veenendaal *et al.* (1993) in Botswana, Smit & Swart (1994) in South Africa, and Asferachew *et al.* (1998) in Ethiopia revealed a grass species composition turnover from under-storey to open areas. Guevara *et al.* (1992) examined floristic composition and structure of vegetation in three tree species (*Ficus insipida*, *F. colubrinae* and *Nectandra ambigens*) under the canopy, directly under the canopy perimeter and beyond the canopy in the open pasture. In agreement with the above researchers, they reported that mean species richness per quadrat was significantly higher under the canopy than at the canopy perimeter and in the open pasture sites.

Asferachew *et al.* (1998) investigated the influence of the canopy features of three indigenous woodland type species (*Acacia tortilis*, *A. senegal* and *Balanites aegyptica*) under light grazing condition in the Awash National park of Ethiopia. They reported that the highest under-canopy vegetation diversity was recorded for *A. tortilis*, followed by *A. senegal* and *Balanites aegyptica*. In all studies mentioned here, there was no difference among the tree species in terms of their effect on the herbaceous layer composition.

Contrary to the above findings, De Ridder *et al.* (1996) and Moyo & Campbell (1998) reported that there was no effect of canopy on grass species. De Ridder *et al.* (1996) did not find the distinct species suite but did find grass species abundance differences for the under-storey and open area environments based on their dry weight. This finding was further strengthened by Moyo & Campbell (1998) from Zimbabwe. They reported that ordination techniques using grass density and biomass as indices separated quadrats according to soil type but not grass species according to under storey or open areas or according to tree species.

Similar to the herbaceous vegetation composition, published literature presents contradictory results on the effects of tree canopies on the yield of the herbaceous vegetation. Thus, there can be an increase or decrease or no effect of the canopies on herbaceous production. Accordingly, Kennard & Walker (1973); Stuart-Hill *et al.* (1987); Belsky *et al.* (1989); Frost & McDougald (1989) and Smit & Swart (1994) reported higher grass yield in areas directly below tree crowns compared to their corresponding open areas despite the fact that overhead tree crowns intercept and reduce the amount of rain-water and solar radiation reaching the ground and competition for water and nutrients between tree and grass roots in the under- storey areas (Amundson *et al.* 1995).

The increase in the grass yield under tree canopies is attributed to the improvement in soil physical properties such as water infiltration, water holding capacity, aeration, bulk density (Elwell 1986) and exchange capacity of the surface soil due to the improvement in soil nutrient status as a result of high volume of leaf fall under trees (Kennard & Walker 1973; Campbell *et al.* 1994), droppings from birds and mammals (Belsky *et al.* 1989) and the concentration of nutrients from areas beyond the crowns by means of lateral tree roots (Tiedemann & Klemmedson 1973). Other possible reasons include lower under storey solar radiation and soil and plant temperatures (Tiedemann & Klemmedson 1973) resulting in reduced evapotranspiration, which creates mesic under-storey patches which are colonized by palatable perennial grass species that have a higher water use-efficiency (Amundson *et al.* 1995). For example, Belsky *et al.* (1993) reported an increase in the herbaceous vegetation by 95.3% and 64% due to a canopy effect when compared to the open and root zones, respectively.

Contradicting the above results, Grunow (1980); Grossmann *et al.* (1980); Dye & Spear (1982) observed a decrease in herbaceous layer productivity under tree canopies when compared to nearby open grasslands. According to Kay & Leonard (1980); Monk & Gabrielson (1985); Pieper (1990) and Burrows *et al.* (1990) forage production is often reduced by trees that compete with the under storey herbaceous species for water, nutrients and light. In contrast to most published reports, Moyo &

Campbell (1998) reported similarity in grass yield under trees and open areas in both years of their experiment.

Smit (2002) in his extensive review of the importance of ecosystem dynamics in managing the bush encroachment problem in southern Africa indicated that nutrients such as nitrate, phosphorous, a series of anions and cations and various trace elements are essential to the nutrition of plants (Bell 1982) and act as determinants of the composition, structure and productivity of the vegetation. Even though the base richness of the parent material is initially important in determining soil fertility, biological activities are important in the creation and maintenance of localized areas of soil fertility often on base-poor substrates (Scholes 1991). Trees may act as biological agents, creating islands that differ from those in the open. The importance of canopies in soil enrichment is well documented (Bosch & Van Wyk 1970; Kennard & Walker 1973; Tiedemann & Klemmedson 1973; Kellman 1979; Bernhard-Reversat 1982; Belsky *et al.* 1989; Young 1989; Smit 1994; Smit & Swart 1994; Hagos 2001).

Kellman (1979) compared open savannna with canopies under *Brysonima crassifolia* and *Pinus caribaea* in terms of their effect on soil nutrient status. Soils under the canopy of *Brysonima* had a higher calcium (Ca), magnesium (Mg), potassium (K) and base saturation than the soils in the open savanna. There was no difference between the two sub-habitats in terms of sodium (Na), available PO4, organic carbon and moisture content. Studies conducted by Bosch & Van Wyk (1970) found a higher content of nitrogen (N), phosphorous (P), K, Mg and Ca in soil from under *Boscia albitrunca*, *Combretum apiculatum*, *Acacia tortilis* and *A. senegal* in comparison with soils from the open areas. Another study by Bernhard-Reversat (1982) showed that organic carbon and N content of soils of savanna in North Senegal were concentrated in the first few centimetres of soil and increased under tree canopies (*A. senegal* and *B. aegyptica*). A study by Palmer *et al.* (1988) in the Eastern Cape Province indicated that soils of the grasslands were found to be poorer than those of the bush clumps in Ca, Mg, K, and Na. Soils of the grasslands had lower conductivity and pH values than soils of the bush clumps. Bush clump soil contained higher percentages of organic material with a higher moisture, Mg and Ca content.

Belsky *et al.* (1989) reported that mineralizable N and microbial biomass were significantly higher in soil from canopy zone than from the root and grassland zones, whereas organic matter, P, K and Ca (but not Mg) declined in soil from the base of the trees towards the open grasslands. Smit and Swart (1994) investigated the influence of leguminous and non-leguminous woody plants on the herbaceous layer and soil in three sub-habitats (between trees, under leguminous and non-leguminous trees) under varying competition regimes. They reported that the soil both under leguminous and non-leguminous trees was richer in nutrients (% total nitrogen, % organic carbon, electrical resistance, pH (H_2O), Ca, K, Mg) than between tree canopies, whereas there was no significant difference in clay (%), phosphorous and sodium between the two sub-habitats. Moreover, they indicated that soil enrichment differed between tree species that grew in the same environment. Similarly, Asferachew *et al.* (1998) reported that surface soil organic carbon, total nitrogen, available phosphorous, exchangeable potassium and electrical conductivity were higher under tree canopies for all the study trees compared to outside canopy soils.

Moyo *et al.* (1998) examined whether differences in soil nutrient status and microclimate exist between under storey and open areas and whether such differences are affected by soil type and tree species (*Terminalia sericea* and *Acacia karoo*). Their results when pooled across sites revealed a non-significant difference in pH, P_2O_2, Mg, and Ca between open and tree crowns, while soils under crown had a higher K and total N. On the other hand, when the data is examined based on the soil types, there was no difference in pH, P_2O_5, Ca, K and total N in the analysed parameters on sandveld. On red and vertisols, soils under tree crown had a higher K and total N (%), respectively than their corresponding open lands. Very recently, Wezel *et al.* (2000) from Niger reported significantly higher concentrations between 38-51% for carbon, N and P and 22% on ECEC (exchangeable cation exchange capacity) for K in soil under shrubs than nearby open areas. The pH showed only slight, but significant differences.

There is a lack of consensus in published literatures on the influence of trees on pH. While Bosch & Van Wyk (1970); Kennard & Walker (1973); Palmer *et al.* (1988) and Young (1989) reported a higher pH under tree canopies, Belsky *et al.* (1989) and Hagos (2001) recorded a lower pH at the base of *Acacia* trees than further from the trunk. In another study by Falkengren-Grerup (1989) claimed that stem flow appeared to have decreased pH and base saturation in the topsoil of Swedish forests. However, based on the positive association between increases in exchangeable cations and soil pH (higher base saturation) (Barnard & Fölscher 1972; Kennard & Walker 1973; Hatton & Smart 1984), a higher pH under canopies of savanna trees conforms more logically with the higher content of exchangeable cations in this sub-habitat.

2.6.2.4. Bush encroachment

Bush encroachment is the process of open grassland savanna being transformed into thick bushes and shrubs (Barnes 1979; Smit 2002) and is commonly seen as an indicator of rangeland degradation in semi-arid savannas (Skarpe 1991; Perkins & Thomas 1993a,b; Coppock 1994). It is a well-known phenomenon in savanna areas (Archer *et al.* 1988). It involves indigenous woody species occurring in their natural environment and is a widespread phenomenon occurring in many parts of the world, including North America (Hobbs & Mooney 1986; Archer *et al.* 1988; Archer 1989), Australia (Walker & Gillison 1982), South America (Schofield & Bucher 1986), India (Singh & Joshi 1979) and Africa (Van Vegten 1983; Belsky 1990; Perkins & Thomas 1993 a, b; Coppock 1994; O'Connor 1995; Smit 2002).

There is some controversy concerning the driving factor behind the shift in vegetation in grasslands and savannas. However, it is commonly explained in the context of climatic change, fire suppression, the elimination of mega herbivores and overgrazing (Archer 1989; Skarpe 1990a,b, 1991, 1992; Teague & Smit 1992; Scholes & Walker 1993; Smit 1994; Smit & Rethman 1998; O'Connor & Crow 1999; Moleele *et al.* 2002; Smit 2002). For example, in Southern Africa, Ethiopia and Kenya, the shift is associated with anthropogenic activities, especially high cattle densities in communal grazing areas (Coppock 1994; Ringrose *et al.* 1996). However, Abel (1993) challenged this theory of high cattle density. In Ethiopia and Kenya, another factor that has undoubtedly facilitated woody encroachment has been the national policy, which has banned burning of grazing and agricultural lands since the mid-1970s (Coppock 1994).

According to Smit (1994) in a broader sense the increase in the density of woody plants is a natural process in response to certain changes. While the process is natural, the change in secondary determinants, resulting in an accelerated rate of woody plant increase, is not natural. Moreover, the same researcher discussed that tree thickening is primarily a function of two processes, i.e., by the increase in biomass of already established plants (vegetative growth) and by increases in tree density, mainly from newly established seedlings (reproduction). In general, an increase in the woody plant density beyond a critical density limit is normally accompanied by a decrease in herbaceous production and undesirable shifts in composition (Archer 1990) mainly due to severe competition for available soil moisture with a resultant effect of reduction in herbaceous production and grazing capacity (Dye & Spear 1982; Moore 1989; O'Connor 1991; Smit & Rethman 1998b).

Moore *et al.* (1985) reported reduced production of the herbaceous layer with increasing tree abundance in the Kalahari Thornveld and Shrub bushveld of the Molopo area. Treatment with aerial applications of an arborrocide (Tebuthiuron) resulted in increased grass production by between 220 and 740% with a subsequent death of the woody plant. A density of up to 200 tree equivalents (TE) did not show a decrease in grass production, while grass production declined linearly with further increases in tree density. A density of up to 2 000 TE ha^{-1} almost completely suppressed grass production. The range of decrease in grazing capacity (ha^{-1} Large Stock Unit)$^{-1}$ fall between 8.7 ha LSU^{-1} (1 200 kg grass DM ha^{-1}) to 45.8 ha LSU^{-1} (230 kg grass DM ha^{-1}) over the 200 to 2 000 TE ha^{-1} density gradient. A similar report was made by Richter (1991) and Richter *et al.* (2001) from other parts of the

Molopo area of the North Cape in South Africa. Richter *et al.* (2001) indicated that bush encroachment (2 500 tree equivalents ha^{-1}) decreased the potential grazing capacity by as much as 331%, 149%, 58% in the Molopo Thornveld, the mixed Vaalbos Thornveld and the Eastern Grass Bushveld of South Africa, respectively, in comparison to sites with tree densities of less than 400 tree equivalents per ha. On the other hand, Donaldson (1978) obtained small improvement in grazing capacity (9.1 ha AU^{-1} to 7.3 ha AU^{-1}) due to clearing woody plants in mixed savanna dominated by *Combretum apiculatum* and *Acacia tortilis.* The decline in herbaceous biomass due to woody cover is offset somewhat by increased browse production, the magnitude of which depends on species composition and degree of woody cover.

Smit (2002) on his extensive review of the problem indicated that removal of some or all of the woody plants will normally result in an increase of grass production and thus also the grazing capacity. However, the results of woody plant removal may differ between vegetation types, with the outcome determined by both negative and positive responses to tree removal. This is due to the fact that the physical determinants, biological interactions and individual species properties are unique to each spatial and temporal situation. In addition, past management practices have added to the complexity by bringing about different kinds and degrees of modification (Teague & Smit 1992).

In general, Smit (2002) concluded that any bush control programme (chemical, mechanical or biological) should focus on tree thinning rather than clearing of all woody plants. Moreover, in making decisions on the intensity of tree thinning, the sizes of the trees, which should be removed and the species to be thinned, cognisance should thus be taken of the balance between the need to reduce the competitive effect of the trees on the herbaceous layer and the positive influences, which the trees may have. The aridity of the area should also be considered and effective management of bush encroachment should not be considered a once-off event, but rather a long-term programme.

2.6.2.5. Common methods used in the determination of browse production

An area of constant debate in any rangeland management programme is the ability to determine the capability of a given area to sustain browsers (Hughes *et al.* 1987; Melville *et al.* 1999). Estimates of shrub production, however, have been laborious and less reliable than those for herbaceous vegetation for three main reasons. They require manual separation of current growth from past year's growth, difficulty associated with shrub density measurements and the variability of plant form, both inherent and as a result of other influences (Hughes *et al.* 1987). Accordingly, a number of methods have been proposed for the estimation of browse production.

Hughes *et al.* (1987) reviewed some of the techniques used in shrub production and suggested that plots, commonly used in herbaceous production, give variable production results with shrubs and are labour intensive. The weight estimation technique (Pechanec & Pickford 1937), though fast and relatively accurate, required a subjective determination by the person sampling and results in mental fatigue after several hours of use (Cabral & West 1986). Plant density methods may yield differing results (Beasom & Haucke 1975), so methods must be used which are appropriate for the distribution, size and character of the shrubs measured. Researchers have examined various plant measurements to determine their usefulness in estimating production.

The most widely employed method for estimating browse involves the use of standard statistical least square regression analysis, based upon the correlation of some easily measured plant parameter with biomass, determined by destructive harvesting. Rutherford (1979b) demonstrates thirty-five such equations, the simplest of which use regressions based on plant height (Kelly & Walker 1976), stem diameter (Barnes *et al.* 1976; Dayton 1978), a combination of plant height and stem diameter (Rutherford 1979b) and canopy volume (Kelly & Walker 1976). In an effort to improve the technique, Teague *et al.* (1981) introduced a tree equivalent for compensating the difference in tree heights. Accordingly, he defined a tree equivalent as a tree or shrub with 1.5 m height. Smit (1989a) discussed the limitations of TE, as the method does not compensate for structural differences between tree species. Furthermore, TE values increase arithmetically with an increase in tree height, while tree volume increases exponentially.

To estimate the browsing value of the savanna, Teague *et al.* (1981) introduced the use of the browse unit (BU). It represents the total browseable length of palatable trees and shrubs within 1.5 m of the soil surface (the browsing height of goats) and is derived by adding together those portions of all palatable trees and shrubs within the 1.5 m stratum (Tainton 1999). This is an example of quantifying non mass browse data in which browse is not expressed in mass per unit area. Rutherford (1979b) cited several more such techniques as number of twigs per unit ground area (Bookhout 1965; Halls *et al.* 1970; Knierim *et al.* 1971); leaves counted in permanent plots (Crouch 1968); leaf counts per twig (MacOnochie & Lange 1970); elongation of twigs (Halls & Alcaniz 1972) and several others.

Taking into account the ecological implications of trees in savanna areas, Smit (1989a) indicated three important aspects from an agro-ecological point of view: competition with herbaceous vegetation for moisture, food for browsers and creation of sub-habitats suitable for desirable grass species. Accordingly, Smit (1989a) developed three quantative descriptive units, which formed the basis of the Biomass Estimation from Canopy Volume (BECVOL) model (Smit 1989a,b). The three descriptive units are the evapotranspiration tree equivalent (ETTE), browse tree equivalent (BTE) and canopied sub-habitat index (CSI). The BECVOL uses a regression analysis approach using standard statistical least square regression analyses. Various equations relating tree dimensions to leaf mass have been presented, either for complete woody plants (Mason & Hutchings 1967; Barnes *et al.* 1976; Rutherford 1979a) or woody plant proportions (Barnes *et al.* 1976). Smit (1994) indicated the advantage of this technique over the others is the ability to estimate both partial and whole plants. The calculation of the ETTE and BTE is based on the relations between the spatial volume of a tree and its true leaf dry mass and true leaf volume, respectively. The following measurements of trees are used for the calculation of the spatial canopy volume, i.e., tree height (A), height of maximum canopy diameter (B), height of first leaves or potential leaf bearing stems (C), maximum canopy diameter (D) and the base diameter (E) of the foliage at the height of the first leaves (**Figure 2.2**).

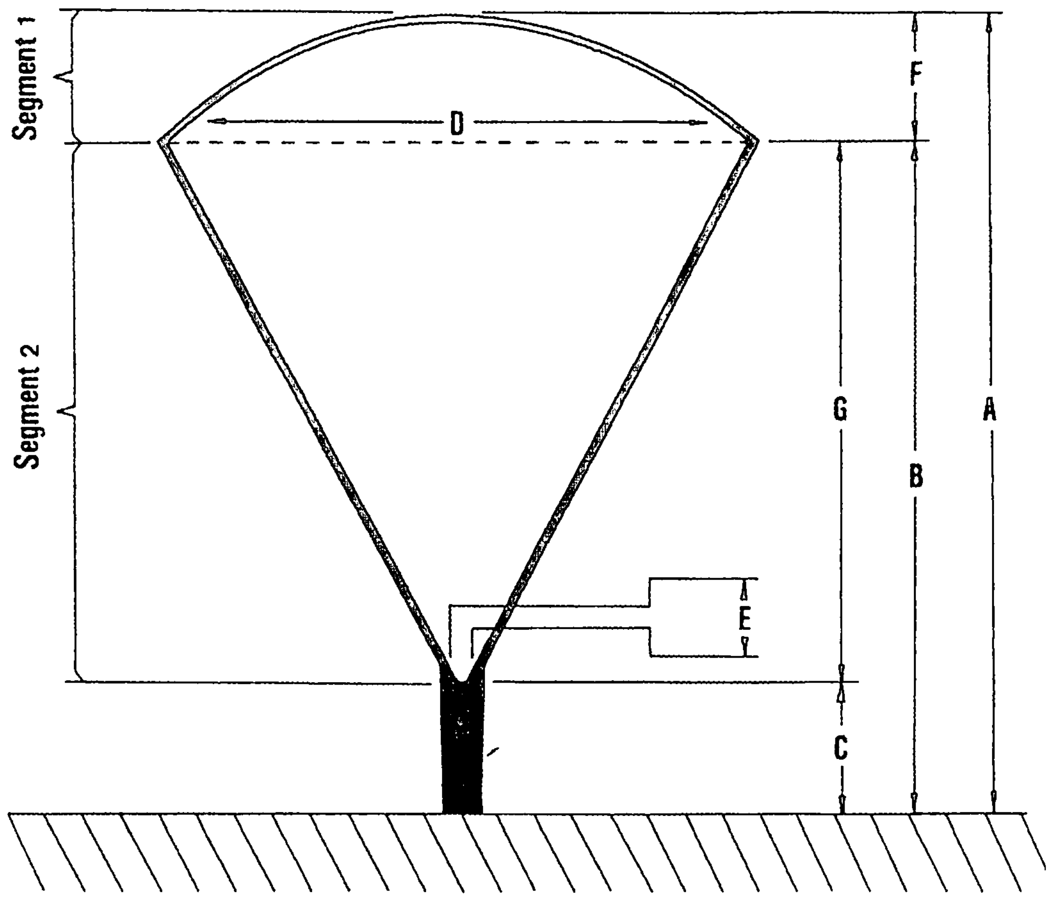


Figure 2.2. Schematic illustration of an ideal tree, its measurements and structure (Smit 1989a).

The modern methods all use the canopy volume of the woody species as the basis for the estimation of available browse. Studies by Orban (1995) gave a clear indication that canopy volume calculations lead to reliable estimates of available dry material. Accordingly, Melville *et al.* (1999) compared the BECVOL with ARBORSTRQU (Arbour structure method) developed by Caldwell (1998), which requires only three measurements for each tree. They found that while the BECVOL method was more comprehensive package than the ARBORSTRQU, the ARBORSTRQU was more users friendly than the BECVOL. Therefore, the choice of which method to use should depend on the person's objective.

2.7. THE CONCEPT OF RANGELAND GRAZING CAPACITY IN PASTORAL PRODUCTION SYSTEM

Grazing capacity is defined as the maximum possible stocking of herbivores that rangeland can support on a sustainable basis (FAO 1988). Its estimation is based commonly on the assumption that livestock require dry matter intake equivalent to 2.5% to 3.0% of their body weight day^{-1}. De Leeuw & Thotill (1990) reviewed two major approaches to determine grazing capacity, i.e., plant or animal oriented. However, both approaches pose problems, which are associated with characteristics of the African environment and the production systems found in the various ecological zones. These problems relate to scale (the area of assessment), species mix, mobility, land tenure and the production goals of the actual producers.

Bartels *et al.* (1993) critically examined the concept of grazing capacity as used in nomadic pastoralism by reviewing different literatures. They indicated that grazing capacity is one of those terms in rangeland management that has the appearance of objectivity but in practice means different things to different people, depending on whether their primary interest is livestock production, wildlife management (Caughley 1976; Macnab 1985; Dhondt 1989) or resource conservation. Even with those involved in livestock production it may mean one thing to a commercial rancher in the developed world and something quite different to a subsistence pastoralist in sub-Saharan Africa. Its use also differs among people depending on their objectives. In addition, inconsistencies are also observed in the methods employed to estimate grazing capacity. Not only this, Scoones (1989a); De Leeuw & Tothill (1990) discussed the difficulty of determining available forage per animal owing to high annual and spatial variability in plant production, seasonal changes in forage quantity and quality, livestock species mix, and the use of supplemental feeds in Sub-Saharan Africa. The use of supplemental feeds indicates that rangelands are not necessarily the limiting resource for livestock production, except perhaps during a severe drought. Breman *et al.* (1983) pointed out that species composition and forage quality (FAO 1988) aspects are often neglected in calculations of carrying capacity; they present an example where these omissions resulted in a gross over estimation. Pratt & Gwynne (1977) and Purnell (1983) stressed the importance of water point distribution in determining grazing capacity in East Africa.

The scale of the grazing capacity assessment has an important bearing on its validity and usefulness. If direct interrelationships between animal output and feed supplies are aimed at, resources within the grazing orbit of the individual producer need to be determined. This is more easily achieved for individual mixed farmers than for nomadic or transhumant pastoralists. For these latter groups, communal use of grazing resources implies that only aggregate values of grazing capacity are meaningful, the size of the area being dependent on the boundaries of common use (De Leeuw & Thotill 1990). Consequently, a calculation of grazing capacity has to include different land units sometimes many kilometres apart (De Leeuw & Thotill 1990).

Application of the grazing capacity concept on North American rangelands assumes that one decision-maker or a cohesive decision-making body has sole control of the grazing resource. In systems where land tenure is communal or open access, numerous households, each making more or less independent management decisions, are using the same grazing resource. Another issue, which brings into question the effectiveness of the grazing capacity concept in pastoral systems, is the investment role of livestock. In Western ranching systems, livestock generally offer a low return on capital (Workman 1986) and any excess capital created through livestock production flows into more lucrative investments. In most of rural Africa, on the other hand, a livestock enterprise can offer the greatest return on investment. For this reason, capital flows into livestock rather than out of it. In the developed world, the concept of grazing capacity has been applied mostly to cattle production enterprises. Even if more than one species of livestock are kept, they are often allocated separate areas of grazing land. In the pastoral production system, multi-species enterprises are the rule. Consequently, several livestock enterprises are combined within the same management unit. As feed preferences between species differ, assessing the fraction of edible feed becomes more complicated.

CHAPTER 3

STUDY AREA

3.1. LOCATION AND AREA COVERAGE

The study districts, Awash-Fantale and Kereyu-Fantale are located in the Southern part of the north-eastern rift valley of Ethiopia, in the middle Awash valley that has taken its name from one of the biggest rivers (Awash) in Ethiopia. The two districts are located adjacent to each other (**Figure 3.1**) and some of the main areas in the text are shown in **Figure 3.2**. Most of the area falls within an altitude of 800 to 1 100 m.a.s.l. However, there are higher peaks such as the Fantale mountain reaching up to 2 007 m.a.s.l. The study districts are found at a distance of 200 to 250 km from the capital city of Ethiopia, Addis Ababa and occur at the border between two Regional National States, i.e., the Afar and the Oromiya Regional National States.

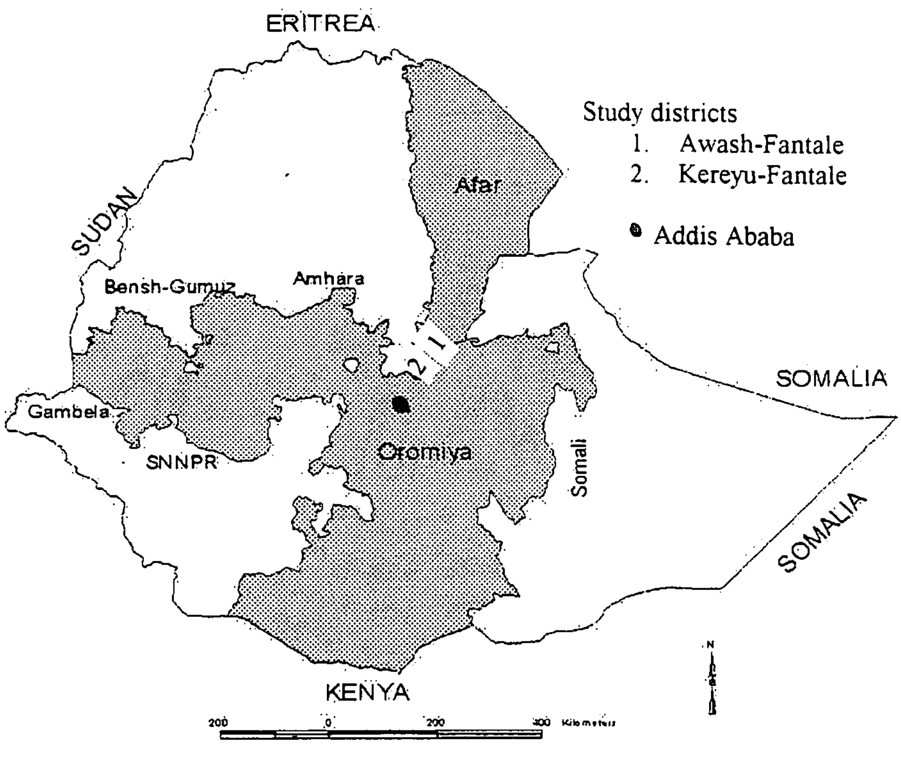
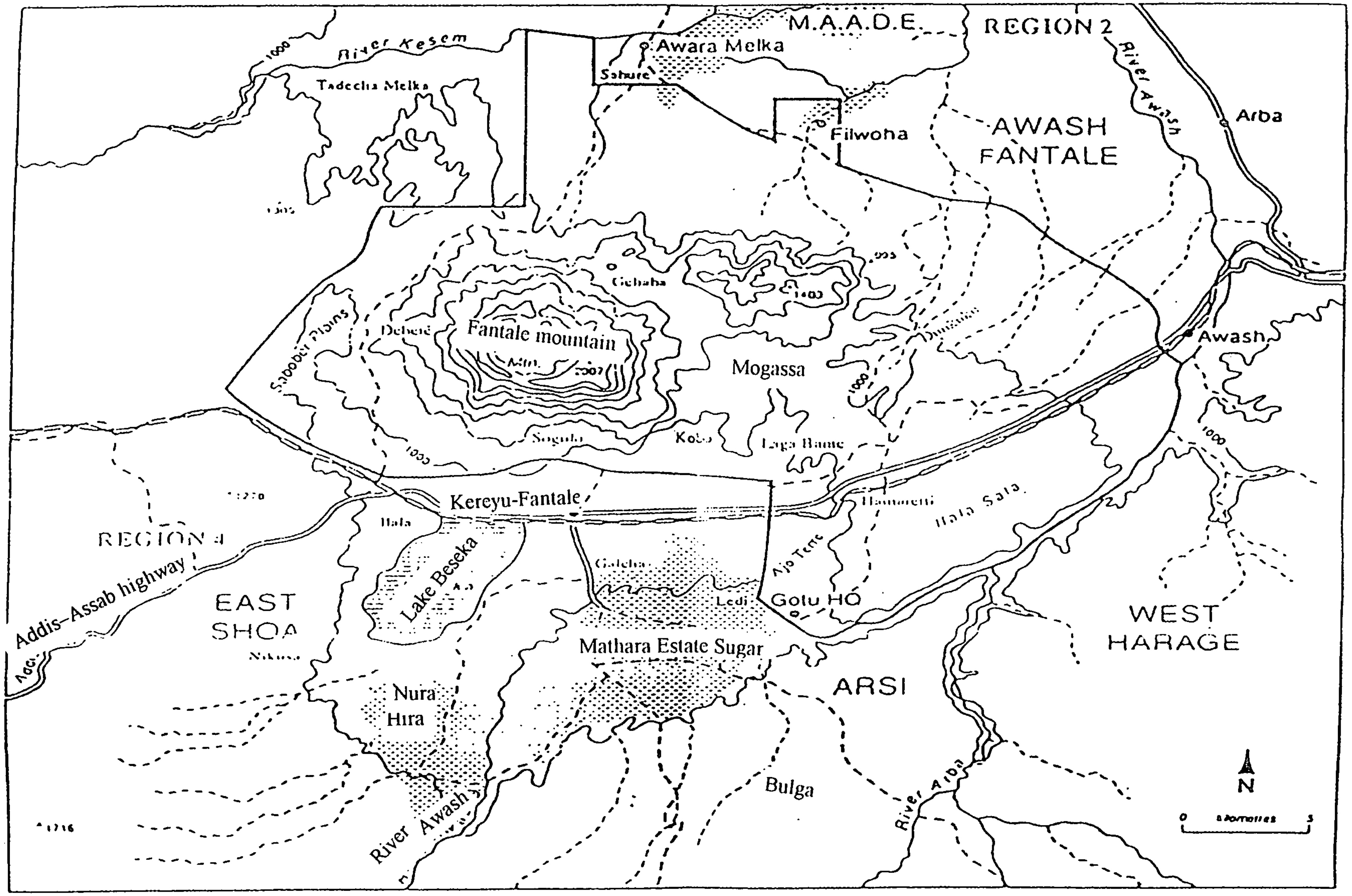


Figure 3.1. Location of the study districts in Ethiopia.



━━━━━ = Awash National Park Boundary

Figure 3.2. Main areas in the study districts.

The area under study is situated along the main transport system in the country, i.e., the highway from Addis Ababa to Assab port and the railway line connecting Ethiopia and Djibouti passes through the study area. Moreover, the area is also crossed by one of the biggest rivers called Awash, which starts from mount Werqa about 150 km west of the capital.

The total land area of Kereyu-Fantale district is 1 169.85 km^2, which is about 8.59 % of the East Shoa zone of Oromiya (CSA 2000), while the area occupied by Awash-Fantale district of Afar is 1 080.0 km^2, which is about 6.43 % of zone III in the Afar Regional National State (Wolde Gebriel 2001). In general the study districts, cover part of the upper and the middle Awash Valley.

3.2. CLIMATE

One of the environmental factors that leads to uncertainty in pastoral and agro-pastoral environment is climatic variability. As a result, it is difficult or impossible to predict the levels of production that the system might produce from one year to the next, or how ecosystems structure may change over time. Therefore, it is essential to look into the nature of the climatic pattern to relate it to its influence on rangeland dynamics.

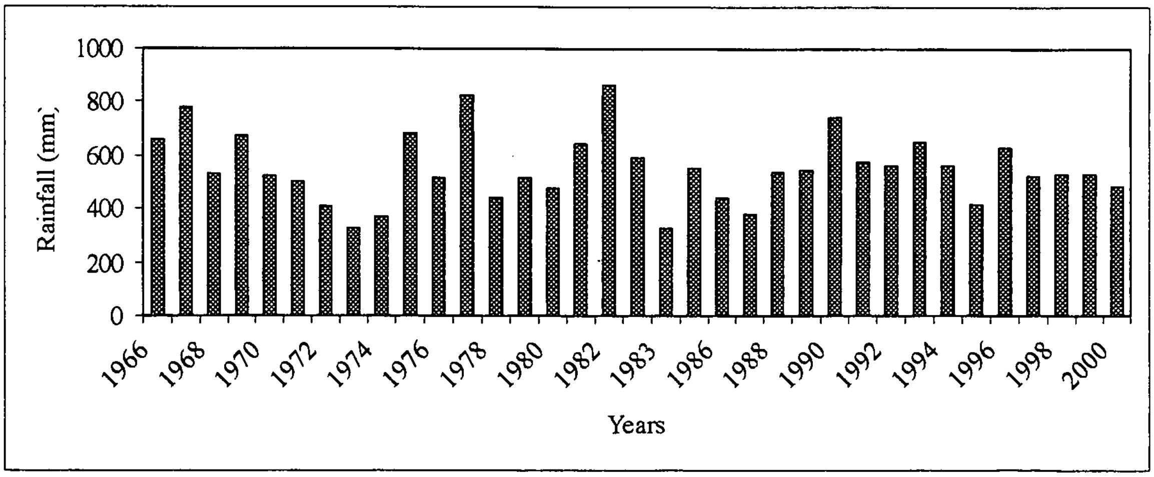


Figure 3.3. Annual rainfall (mm) by year in the study districts (1966-2000).

The study districts fall in a semi-arid zone, a zone that receives an annual rainfall between 400 to 700mm. The summary of the mean monthly meteorological data (rainfall and temperature) and the annual rainfall obtained from Methara sugar factory is presented in **Figures 3.3** and **3.4**, respectively (Mathara Estate Sugar 2001). The nature of rainfall in these areas is weakly bimodal. The main rainy season is from July to September, while there is also a shorter rainy period from February to April. According to the meteorological data obtained from Methara Estate Sugar (1966 to 2001), the annual rainfall ranged from as low as 323 (1984) to as high as 863 (1982) mm, with a mean annual rainfall of 550.9 mm (**Figure 3.3**).

Furthermore, the 35-year record indicates that the rainfall was above the average for 14 years (41.2%), while in the rest of the years it was below the average (58.8%). About 46% (253.3 mm) of the rainfall falls in July and August (main rainy season) (**Figure 3.4**). Very little rainfall is received between November to January (5.27%). Mean monthly rainfall ranges from 5.1 mm in December to 132.2 mm in August. The amount of rainfall received during the short rainy period (Febrruary to April) is about 120.3 mm (21.8%). Moreover, the same data source indicated that the lowest mean minimum temperature was in December (12.9°C), while the highest in June (21.2°C).

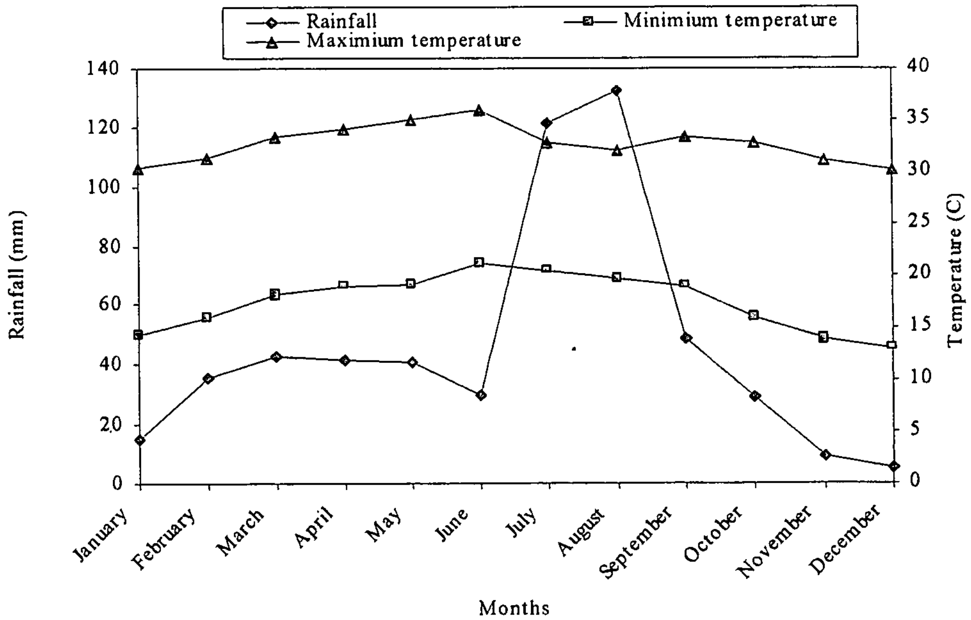
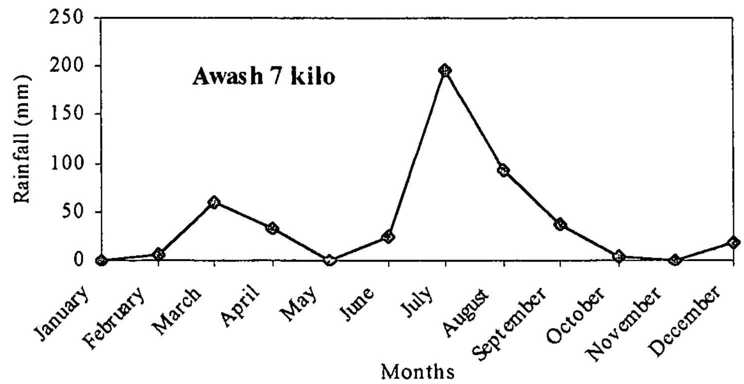


Figure 3.4. Summary of mean monthly rainfall (mm), minimium and maximium temperatures (°C) in the study area.

The mean minimum and maximum temperatures are 17.4°C and 32.7°C, respectively. The lowest mean maximum temperature is 30.1°C (December) and the highest 35.9°C (September). The number of rainy days per month is highest in August (15.3 days) and the mean maximum and minimum relative humidity are 89.6% and 33.4%, respectively. The mean daily pan evaporation varies between 6.3 mm (December) and 7.7 mm (May). Data from two sources, namely Awash 7 kilo and Methara national meteorological stations were taken to look at the nature of the rainfall during the study period (**Figure 3.5**). The mean annual rainfall for Awash 7 kilo was 471 mm, which was 85.7% of the long-term average, whereas, that of the Methara national meteorological station was 421 mm (77% of the long term average).



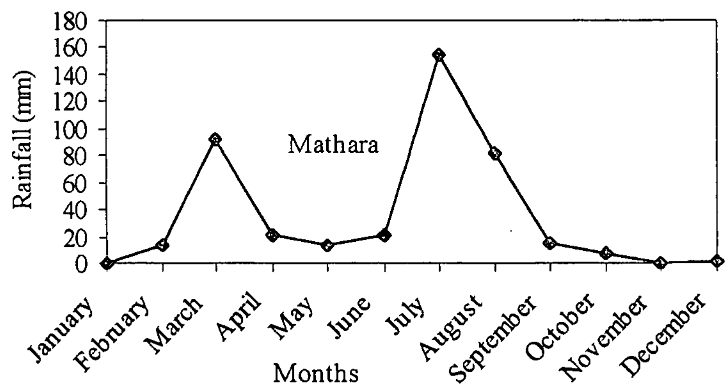


Figure 3.5. Mean monthly rainfall for the year 2001 for Awash 7 kilo and Mathara national meteorological stations.

According to Ayele (1986), both the Afars and the Oromo pastoralists divide the year into 5 major seasons depending on the level of precipitation (**Table 3.1**).

Table 3.1. Classification of seasons according the level of precipitation by the different pastoral groups (Ayele 1986).

Afar naming	Oromo naming	Months	Description
Karima	Genna	July to September	Main rainy season
Hagai	Hageya	May to June	Hot spill period
Dedaa	Furmata	January to February	A period of light showers
Sugum	Abrasa	March to April	Short rainy season
Gilaal	Deda mora	October to December	Cool season

3.3. WATER RESOURCES

The Awash, Bulga Rivers, Lake Beseka and the hot spring at Filwoha dominate water resources in the study areas. The Awash River is very important to the local communities and the country at large. It is the main source of hydroelectric power to the country and is intensively utilized by several large-scale irrigation schemes along the basin (Halcrow 1989; Lane *et al.* 1993).

Another river of importance is the Kesem river on the northern border of the park. Its watershed is limited and large sections of the river regularly dry up during the dry season. Contrary to what one expects, despite the proximity of the Awash and Kesem rivers, the pastoralists have been denied access for long periods because of the establishment of the park and the irrigation schemes (Lane *et al.* 1993). In villages adjacent to Methara sugar plantation the water is considerably polluted and is thought to be the main reason for human diseases in the area (Lane *et al.* 1993; Sharon 2000).

Boreholes and ponds are the other water sources in the study area. Currently, there are many boreholes and ponds established by government and non-government organizations. Temporary water sources like ponds and rock water catchments serve as possible water source in the rainy season and then dry up rapidly in the dry period due to high evaporation rates.

3.4. GEOLOGY AND SOILS

The study area falls in one of the most geologically active regions of the world. It is in the zone of interphase between two tectonic mega structures, the African and the Somalian plates, which are pulling apart and away from the Arabian plate. These activities played a major role in the formation of both the structure and hydrology of the study areas (Schoelder & Jacobs 1993).

The soils of the study area are classified into three types (FAO 1965) according to the parent material from which they are derived. They are the ancient alluvial and colluvials, recent alluvial and volcanic material. In the ancient alluvial and colluvials soils there are histosols and solonchaks. The regosols and andosols, which fall within the volcanic material are derived from basalt gravel of colluvial origin and are the result of the eruptive nature of the parent material. They are found at the base of Fantale mountain and throughout the Mathara area. The recent alluvial soils have developed from recent alluvial deposits and are termed fluvosols. They are found along the banks of the Awash River, which are cultivated as irrigated farms and deposited on recent very slightly, or non-calcareous deposits and saline soils near the hot spring and the Mathara area.

3.5. FAUNA AND PALENTOLOGICAL VALUE

The Awash area is naturally endowed with diverse terrain, which gives opportunity for wildlife viewing, walks and hikes, swimming (hot springs) and museum visits. The East Arican rift valley is best known for the abundance of fossil fauna and flora. Ethiopia is no exception to this since it was here that the oldest hominid remains were discovered (Johannson & White 1979). This site is known as Hadar, located in the Afar triangle just 220 km from the Awash National Park. Here the remains of *Australopithecus afarensis*, more commonly known as "Lucy" and estimated to be 2.9 to 3.3 million years old, were discovered. The same site has yielded several remains of Bovidae as well (Gentry 1981). Closer to Awash National park evidence of hominid remains have also been discovered.

3.6. VEGETATION

Vegetation is one of the rangeland resources that are particularly important for the survival of the different livestock species and wild animals scattered over the rangelands. Both grazers (cattle, sheep and other wild herbivores) and browsers (camel, goat and other wild herbivores) utilize the available rangeland resource through continuous grazing without any form of rangeland improvement. Both herbaceous and woody vegetation contribute to the forage required by the different browsers and grazers. There is variability in the density and species composition of both herbaceous and woody vegetation in the grazing land owing to the difference in biotic and abiotic factors of which human induced change being the most prominent. The grass cover of the area consists predominately of *Chrysopogon plumulosus*, while different *Acacia* and *Grewia* species dominate the woody vegetation. Studies related to the nature of the vegetation in the area, are done primarily in relation to the development activities of the different plantations and the Awash National park. Accordingly, the vegetation type within or immediately surrounding the Awash National Park has been classified by different authors FAO (1965); Robertson (1970); Hillman (1993); Schloeder & Jacobs (1993). Vegetation types are generally classified as grassland, shrubland/ bushland and riverine vegetation.

3.6.1. Grassland

The grassland areas are mainly found in Ilala Sala (found in the interior of the park), Sabober, Arole, scattered grasslands at the base of Mount Fantale. The dominant grass species is *Chrysopogon plumulosus*, while other grass species like *Hypharrenia* *hirta*, *Cymbopogon commutatus*, *C. excavatus*, *Aristida adscensionsis*, *Heteropogon contortus*, *Ischaemmum afrum*, *Lintonia nutans*, *Bothriochloa radicans* and *Themeda triandra* are also found.

3.6.2. Shrub/bushland

These are predominately found on shallower alluvial and colluvial soils. The predominant shrub/bush species are *Acacia mellifera*, *A. senegal*, *A. nubica*, *Dichrostachys cinerea* and *Grewia* species.

3.6.3. Riverine vegetation

The riverine vegetation is dominated by *A. nilotica*, *A. seyal*, *A. tortilis* and *A. mellifera* along the Awash River.

3.7. PASTORAL GROUPS AND HUMAN POPULATION

This study addressed three pastoral groups; namely, the Afars, Kereyu and the Ittu. The latter two fall within the same ethnic group and live in the same district.

3.7.1. The Afar

The Afars are one of the largest pastoral groups in Ethiopia inhabiting the vast rangelands of northeastern Ethiopia, most of the middle and almost the entire lower Awash valley. They occupy the northern part of the Rift valley, which runs through the eastern horn of Africa to form a geographical entity that is accurately known as the "Afar triangle".

Today, they have lost access to much of their land due to irrigation (Helem 1993; Waktola & Micheal 1999). They are politically dispersed in Ethiopia, Eriteria and the Republic of Djibouti. Afar is the name the people speak of themselves rather than "Dankil" or "Adal" by which their traditional adversaries know them (Harbeson

1978). Over the last 50 years, the Afar clans have moved in a generally westerly direction as the military strength of the Issa has increased in the east. The Argoba tribe prevented movement further west. To the south, there has been a period of fighting between the Afar and the Kereyu and Ittu, Argoba on the western border, with territorial boundaries shifting back and forth (Tibabu 1997). Currently however, the relationship between the Afars and the Argoba is peaceful. In the district considered for this study, the Afars are sub-divided into two tribes, the Debene and the Waima. The Debene are the larger and more widely dispersed tribe and they are said to have been in the area for at least 200 years (Schloeder & Jacobs 1993). They are mainly found around Filwoha hot spring, Sabure, Boliyata and Kebena villages. The Waimas have moved to the area from the east some 30-50 years ago when the Issa took over their territory. The drought in 1970's and 1980's also contributed to their expansion. This put the land of Debene under pressure, which has already been shrinking due to the expansion of state farms and conservation areas. Conflicts between the two clans forced the majority of Waima to move eastwards to the Awash town areas (Tibabu 1997). However, currently their relationship is peaceful and they share grazing lands. The Afars are generally Muslims.

3.7.2. The Kereyu

The Kereyu and Ittu pastoralists belong to the same ethnic group and they speak the same language. The Kereyu people are believed to have their origin in southern Ethiopia with the Borana people (Wilding 1985). They are thought to have arrived in the area around 200 years ago establishing themselves around Fantale mountain, lake Beseka, Sabober plains and Metahara. The dominant inhabitants and the users of the resources in Kereyu-Fantale district until early 1950 were the Kereyu pastoralists. In the early 1950's, the Ittu from western Hararghe came around Fantale and north of the Awash river because of the competition within their tribe as well as with the Issa's. This, together with, the establishment of National park, state farmers and the increase in the size of lake Beseka has substantially decreased their traditional grazing land.

There are two sub-tribes within the Kereyu people namely, Baso and Dulcha. The Baso are mainly found along the Awash river, close to the large scale irrigated farms around Methara town. The Dulcha are settled far out in the rangelands. Basos are mostly Muslims, while Dulachas are mostly Wakefata (Mudris 1998). Traditional rule of the social system known as the "Gada" system regulate cultural events and economic and social decisions. The Gada system is an institution that represents an extreme development of a type of social structure known as age set. The basis of the social organization is a kinship system and the organization is referred to as lineage. The social relations are based on genealogical reckoning and tracing ancestors through the father's line of descent (Asmarom 1973).

3.7.3. The Ittu

The Ittu were pushed out of their traditional area by the expansion of the Issa tribe in the early 1950`s (Schloeder & Jacobs 1993). The number of immigrants has increased and now the number of Ittu is thought to exceed that of the Kereyu (Futterknecht 1995). During the establishment of the Awash national park, some Ittu were resettled south of the Awash river. However, several fled back to the Fantale area having lost a considerable amount of livestock during attack by the Issa tribe. Immigration into the area steadily increased during Mengistu's policy of free and equal access for all and continuing expansionist policies of the Issa and Howiya Somalia clans. The Ittu have placed considerable pressure on the Kereyu pastoralists and the Awash National park. Ittu are found living with Kereyu and sometimes on their own. The majority of the Ittu are Muslims.

3.7.4. Human population

The human population of Kereyu-Fantale district is estimated to be 74 932, which is about 3 % of the human population in the East Shoa zone of Oromiya. The density per square km is 64.1. Compared with the density in East Shoa zone of Oromiya, it is the lowest but it is high when compared with other districts in the rangelands. The Awash-Fantale district has a human population of 21 442 which is about 12.42% in zone 3 of the Afar Regional National State (CSA 2000).

3.8. RELATIONSHIPS AMONG THE TRIBES AND OCCUPATION

The relationship between the Oromo groups (Ittu and Kereyu) is smooth and they live in a harmony. Owing to the pressure in the shortage of land, occasionally there is disagreement on the use of land. The Ittu are generally involved in crop production, while the Kereyus exercise both systems (crop production and pastoralism). The Oromo groups (Kereyu and Ittu) are also involved in charcoal and firewood making as well as off-farm employement (Mudris 1998). The relation between the Oromos and the Afars is based on hostility. There is no trust between them. The intensity of the conflict is high when the dry season gets severe. It is at this time that both move to the border to utilize the available land. Because of the fear among them the grazing lands bordering the two districts have excellent cover and species composition, which will be treated in depth in the rangeland evaluation chapter. The Afars also exercise off-farm employment, charcoal and firewood making and some cropping activities.

3.9. TERMINOLOGY

The terminology used in this thesis is in accordance with Trollope *et al.* (1990), unless referenced or described.

ANIMAL UNIT (AU): An animal with a mass of 450 kg and which gains 0.5 kg day^{-1} on forage with a digestible energy percentage of 55%.

AVAILABLE BROWSE: The browse material determined on the basis of maximum height above the ground to which a specific animal can utilize it (Smit 1996).

BIOMASS: Total amount of living plant material present above and below ground in a particular area at any given time – kg ha^{-1}.

BROWSE: The sum of the total material of woody species that is potentially edible to a specific set of animals, and browse is commonly regarded as the current season growth of both leaves and twigs (Rutherford 1979a).

BROWSE UNIT (BU): Metabolic equivalent of a kudu (100% browser) with a mean body mass of 140 kg (Dekker 1997).

BUSH ENCROACHMENT: The phenomenon of increasing tree and shrub density in savanna (Smit *et al.* 1996).

CANOPY: Cover of leaves and branches formed by the tops or crowns of plants.

CARRYING CAPACITY: Potential of an area to support livestock through grazing and/or browsing and/or fodder production over an extended number of years without deterioration to the overall ecosystem (ha^{-1} AU).

DECIDUOUS: The seasonal senescens and shedding of leaves (Smit 1999a).

DEHISCENT: The splitting open of ripe pods to release the seed (Smit 1999a).

GRAZER UNIT (GZ): A metabolic equivalent of a blue wildebeest (100% grazer), with a mean body mass of 180 kg (Dekker 1997).

GRAZING/BROWSING CAPACITY: Productivity of the grazable/browseable portion of a homogeneous unit of vegetation expressed as the area of land required to maintain a single animal unit over an extended number of years without deterioration to vegetation or soil- ha^{-1} AU or AU ha^{-1}.

PHENOLOGY: Study of time of appearance of characteristics periodic events in the life cycles of organisms in nature and how these events are influenced by environmental factors.

QUADRAT: A small clearly demarcated plot or sample area of a known size on which ecological observations and measurements are made.

SHRUB: A perennial woody plant with two or more stems arising from or near ground level (Smit 1999a).

TRANSECT: An imaginary or real line along which measurements or surveys of ecological observations are made (Vorster 2000).

A TROPICAL LIVESTOCK UNIT: is the equivalent of one bovine animal of 250 kg live weight (ILCA 1990).

CHAPTER 4

PASTORALISTS PERCEPTIONS OF RANGELAND RESOURCE UTILIZATION AS RELATED TO LIVESTOCK PRODUCTION

4.1. INTRODUCTION

Research studies about indigenous rangeland management around the world show that indigenous people consider resource preservation in their management strategies (Fortman 1989; Bayer & Grell 1994, 1995). The indigenous pastoral management system is the basis of the nomads' way of life (Wang & Zheng 1998). However, as seen in Ethiopia and in many nomadic pastoral areas, rangeland-based life styles and industries are in difficulty and the rangeland environment is under threat because of extreme climatic fluctuations, animal diseases, over estimation of the grazing capacity, land-use changes and the demand from an increasingly important cash-based economy (Roderick *et al.* 1998; Scholes 1991; Beruk & Tafesse 2000). In this segment of Ethiopia, rangeland has further decreased due to volcanic activity (**Figure 4.1**). Owing to the wide fluctuations in climatic conditions, overgrazing and other interacting influences, the household's use of rangeland resources can vary between years and seasons within a year. A study of the existing rangeland resource base, their utilization and possible constraints as related to livestock production is an important first step as this will pave the way for any type of rangeland intervention to be undertaken in the study area. Therefore, the objectives of the study were to assess the perceptions of the pastoralists about the existing rangeland resource base, utilization, constraints and possible solutions. It was also intended to compare the two pastoral groups in terms of their perceptions about rangeland resources and related affairs. Finally the perceptions of the pastoralists about the rangelands were compared to the findings of the scientific way of rangeland evaluation.

Figure 4.1. Loss of rangeland due to volcanic eruption in Kereyu-Fantale district and the plants grown on the erupted volcanic soil are not grazed by animals.

4.1. PROCEDURE

4.2.1. Survey design

Secondary information relevant to the study was collected from previous studies, organizations and other sources. Both informal and formal surveys were carried out. The informal survey was aimed to confirm or complement the information obtained from secondary data sources and to get insights from producers and community members who are directly or indirectly involved in the system. This was undertaken through interviewing individuals, groups, key informants and personal observations. The information gathered through the above processes was summarized and used as a basis to design structured questionnaire to quantify the most important parts of the study and hence to have an overall understanding about the rangeland resource base of the pastoralists taking households as a unit of analysis. A structured questionnaire was prepared to elicit information on rangeland resources, perceptions of vegetation composition, water resources, feed resources, migration, rangeland condition, livestock population and production constraints. The questionnaire was used to gather both quantitative and qualitative information at each of the sampled households. In the questionnaire prepared, there were single and multiple response questions. Single response questions are those questions where the sampled household has a single reply and multiple response questions are questions where the individual household can give more than one answer to a given question. In case of the latter, the percentage of responses (respondents) will be greater than 100%. Examples of multiple response questions are marked in **Appendix 4.1**. To administer the interview, enumerators were recruited and training was given in collaboration with the relevant near by organizations. Before conducting the actual survey, the structured questionnaire was pre-tested by interviewing some households from both pastoral groups. Thereafter, the necessary adjustments and corrections were made on the prepared questionnaire. The actual data was collected by both the student (20% of the households from both pastoral groups) and the trained enumerators under the close supervision of the student. In the Kereyu-Fantale district (Oromo pastoral group), there are 20 Kebeles (lowest administrative units) of which two are in the town. Of the rest, nine were selected randomly after stratifying them into different production systems. From the identified villages, 90 households were chosen randomly and interviewed independently.

In the Awash-Fantale district (Afar pastoral group), there are six Kebeles of which, four were selected randomly for the study. Accordingly, 55 households from the identified Kebeles were selected randomly and interviewed independently.

4.2. 2. Data Analysis

The data collected was summarised in SPSS (Statistical Package for the Social Sciences) and analysed using the same programme (SPSS 1996). Descriptive statistics such as means, percentages, range and standard deviations were calculated to present the results.

4.3. RESULTS

4.3.1. Demographics of the pastoralists surveyed and main source of income

The study households had an average total family size of 6.74, with those in Awash-Fantale district being about 24.6% larger than those in Kereyu-Fantale district (**Table 4.1**). The respondents in both districts had a similar average age (40.00 ± 11.2 years), which varied between 22-75 years. All the respondents were males and the majority (72.6%) were married to a single wife, while the remaining to two (25.3%) and three (2.1%) wives. The households belong to an Afar and Oromo ethnic groups, of which the Afars were of the Debene and Waima tribes. The Oromos were of the Ittu, Kereyu-Dulcha and Kereyu-Baso tribes. Of the respondents, 3.3% were from the Somale ethnic group. The majority (79.3%) of the respondents did not have any kind of education (**Table 4.1**).

The main source of income in both pastoral groups was from the sale of animals (**Figure 4.2**). The interesting difference between the two pastoral groups lies in the contribution of the sale of milk and milk by- products to their source of income. To the Afars, the sale of milk and milk by- product is the second most importance source of income, while to Oromos it stands last.

Table 4.1. Profile of respondents by family size (mean ± SD), ethnic group, tribe and educational background (Respondents: Oromo = 90 and Afar = 55).

Category	Kereyu-Fantale (Oromo)	Awash-Fantale (Afar)
Family size (number)		
Male	3.26 ± 1.8	3.87 ± 1.8
Female	2.92 ± 1.9	3.96 ± 1.8
Total	6.17 ± 3.1	7.69 ± 2.8
Ethnic group (%)		
Afar		100.0
Oromo	96.7	
Somale	3.3	
Tribe of the household (%)		
Ittu	47.8	
Kereyu (Dulcha)	28.9	
Kereyu (Baso)	20.0	
Debene (Afar)		83.0
Waima (Afar)		17.0
Somalia	3.3	
Educational background (%)		
Formal	9.9	5.6
Read and write	11.0	14.8
None	79.1	79.6

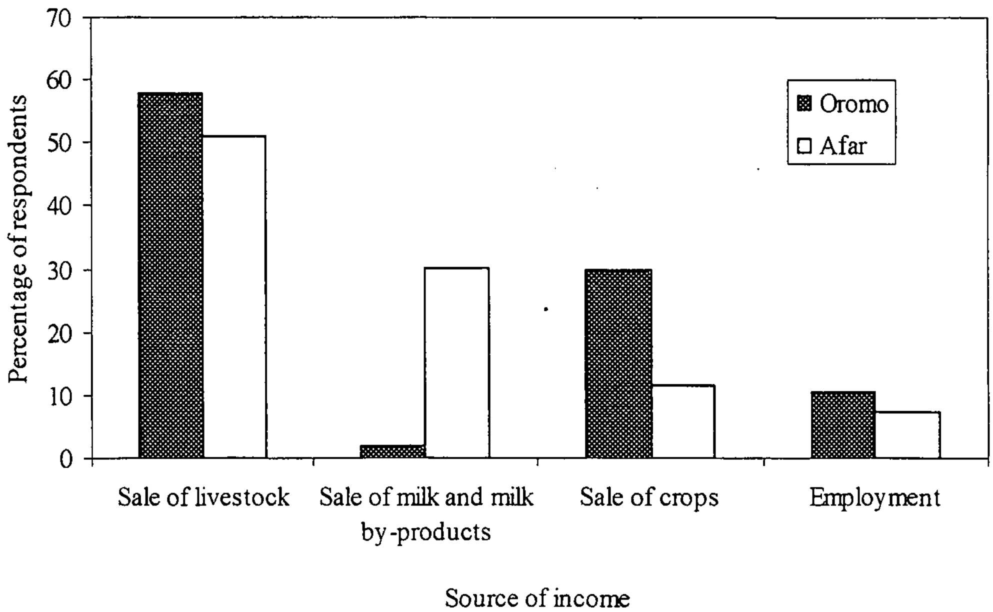


Figure 4.2. The main sources of income in the study districts (Respondents: Oromo= 89 and Afar = 53).

4.3.2. Livestock ownership in the study districts

With few exceptions, livestock in the traditional pastoral and agropastoral societies are owned by individuals (Perrier 1995) and in nearly all traditional pastoral and agro-pastoral systems livestock are herded. Accordingly, the mean number of livestock owned by an Oromo household was lower than that of an Afar household (**Table 4.2**). For all animal species, females dominate the population. The majority of the respondents in Kereyu-Fantale (92.9%) and Awash-Fantale (88.4%) do keep a mixture of livestock species.

Table 4.2. Mean number of livestock species owned per household in the study districts (Respondents: Oromo = 90; Afar = 55).

Animal category	Kereyu-Fantale (Oromo)	Awash-Fantale (Afar)
Cattle		
Cows	4 ± 3.0	10 ± 6.9
Heifers	2 ± 1.6	4 ± 3.4
Calves	2 ± 1.7	4 ± 3.6
Bulls and oxen	2 ± 1.7	2 ± 1.3
Camels		
Male	1 ± 0.7	3 ± 2.3
Female	4 ± 3.6	12 ± 7.2
Sheep		
Male	2 ± 1.4	2 ± 1.3
Female	6 ± 4.8	10 ± 5.4
Goat		
Male	2 ± 1.6	5 ± 3.5
Female	9 ± 7.0	21 ±11

4.3.3. Pastoralists perceptions to rangeland resources and utilization

4.3.3.1. Rangeland plants

4.3.3.1.1. Poisonous plants

The importance of poisonous plants to the livestock industry of Africa cannot be over-estimated because about 600 indigenous poisonous plants are known to occur in Southern Africa alone. In Africa, where livestock is traditionally kept under extensive conditions on rangeland that is frequently denuded by droughts, overstocking and uncontrolled fires force the animals to eat poisonous plants, which they would normally avoid (Naude *et al.* 1996). Accordingly, in the study districts, 90% of the Oromo respondents and 98% of the Afar respondents replied that, they knew poisonous plants affecting their livestock production, indicating their accumulated wealth of plant knowledge over generations. The results indicated that both herbaceous and woody plants were identified as poisonous to animals (**Tables 4.3** and **4.4**). The ranking order of these poisonous plants, based upon their importance as poisonous plants to livestock by the Oromo pastoralists was *Cryptostegia grandiflora* (Haqonqol), *Tribulis terrestris* (Kumeto) and *Capparis fascicularis* (Harangama) in decreasing order. Interestingly, the grass species *Cynodon* (Aredo) was also identified as a poisonous plant. The Afar pastoralists ranked the poisonous plants *C. grandiflora*, *Erythrina abyssinica* (Dunbeya), *Flueggea virosa* (Raberba) and *Tephrosia subtriflora* (Aro) in decreasing order (**Figure 4.3.**).

In the district occupied by the Afars, the poisonous plants are abundant in marshy, swampy areas and along the riverbanks, while the difference between the two pastoral groups in the ranking order was mainly related to the availability of a specific plant in a particular area.

Table 4.3. Percentage of respondents indicating common plants as poisonous in the study districts (Respondents: Oromo = 82 and Afar = 54).

Botanical name	Local names		Percentage of respondents	
	Awash-Fantale (Afar)	**Kereyu-Fantale (Oromo)**	**Awash-Fantale (Afar)**	**Kereyu-Fantale (Oromo)**
Cryptostegia grandiflora	Halimero	Haqonqol	83.3	76.8
Cynodon dactylon and Cynodon plectostachys		Aredo	-	43.9
Tribulis terrestris		Kumeto	-	74.4
Capparis fascicularis		Harangama	-	61.0
Erythrina abyssinica	Denubeya		51.9	
Flueggea virosa	Rebreba		24.1	
Tephrosia subtriflora	Aro		13.0	

Table 4.4. Poisonous plants affecting the different livestock species as ranked by the two pastoral groups in Kereyu-Fantale and Awash-Fantale districts (1 = animal species highly affected by the specific poisonous plant; 4 = animal species least affected by the specific poisonous plant; Respondents: Oromo = 82 and Afar = 54).

Type of poisonous plant	Region and livestock species				Region and livestock species				
	Kereyu-Fantale (Oromo)				**Awash-Fantale (Afar)**				
	Cattle	**Sheep**	**Goat**	**Camel**	**Cattle**	**Sheep**	**Goat**	**Camel**	**Season of incidence**
Cryptostegia grandiflora	3	4	2	1	3	4	2	1	Mainly dry season
Cynodon dactylon and Cynodon plectostachys	1	2	2						Wet season
Tribulis Terrestris	2	1	3	4					Wet season
Erythrina abyssinica	4	3	2	1	4	3	2	1	Mainly dry season
Flueggea virosa					4	3	2	1	Mainly dry season
Tephrosia subtriflora	–				2	1	1	3	Mainly dry season
Capparis fascicularis	3	4	2	1					Mainly dry season

Figure 4.3. Example of *Cryptostegia grandiflora* as a poisonous plant.

According the pastoralists, the different plant species act as poisons to the different livestock species at different growth stages and different plant parts also act as poisons to the animals. For example, *Cynodon* species cause poisoning and can kill cattle and sheep when they are grazed at the early stage of growth. Unfortunately, the pastoralists were unable to give a clear reason as to why this poisoning happens at the early stage. *Tribulis terrestris* and *T. subtriflora* are leguminous plants that cause bloating and kill animals particularly when eaten at the early flowering stage. *Cryptostegia grandiflora* is the most important climbing type of poisonous plant, which kills animals when the leaves are eaten and this plant upon consumption, based upon the information obtained from the pastoralists, will distend the animal with a large production of saliva. The seeds of *Erythrina abyssinica,* upon consumption cause continuous diarrhoea and paralysis leading to the gradual death of the animal.

According to the information obtained from the pastoralists, *Flueggea virosa* is a woody plant that has an effect only on camels in such a way that it paralyses the camel progressing to a gradual death of the animal. However, the Afar pastoralists, in periods of critical feed shortage, will chop the leaves with the branches and give it to cattle, sheep and goats. *Capparis fascicularis* will kill camels and goats, initially by paralysing the animal and eventually causing the death of the animal. The animals consume the poisonous plants accidentally when grazing in the field and the incidence of an animal being poisoned is more common on the side of the Afars than the Oromos.

Poisoning from the woody plants mainly occur during the dry season, while that from herbaceous plants during the wet season. Both pastoral groups have developed traditional methods of treating animals poisoned with different plants (**Table 4.5**). Wide ranges of local practices are applied ranging from the provision of water and milk, to the preparation of soup. They prepare soup from goat's meat indicating their clear commitment to the welfare of their animals. They are very caring to their animals and at times, they even carry the calves of the camels to take them for treatment (**Figure 4.4**).

With regard to the abundance of poisonous plants, in comparison to the past, 31.0% of the Oromos replied that there is an increase, while 21.1% reported a decrease, 39.4% said that it is the same as before and 8.5% replied that they do not know. On the other hand, 81.6% of the Afars replied that there is an increase in the abundance of poisonous plants, 14.3% indicated that it is the same as before and the remaining argued that they do not know. Many of the Afar pastoralists could not explain the reason why poisonous plants have increased, but suggest that the repeated diversions in the direction of the Bulga river can be one possibility, which brings different plants from the highlands.

Table 4.5. Percentage of respondents practising different traditional methods of treating animals poisoned with different poisonous plants (Respondents: Oromo = 82 and Afar = 54).

Treatment	***Cryptostegia grandiflora***		***Cynodon dactylon and Cynodon plectostachys***		***Tribulis terrestris***		***Capparis Fascicularis***		***Erythrina abyssinica***	
	Oromo	**Afar**	**Oromo**	**Afar**	**Oromo**	**Afar**	**Oromo**	**Afar**	**Oromo**	**Afar**
Provision of local beer (Tella)	24.4		4.0		4.9		30.3			
Provision of local liquor (Areke)	19.5		16.0				18.2			
Provision of milk	75.6	35.7	56.0		31.7		69.7		29.0	37.5
Provision of butter	4.9	32.1	16.0		17.1		6.1		19.4	18.8
Provision of lemon		14.3								
Provision of tobacco		3.6								
Washing the body of the animals		3.6								
Provision of kerosene	7.3		12.0		31.7		3.0			
Provision of pepper	2.4	3.6	20.0		39.0		3.0			
Provision of water	26.8	21.4	32.0		14.6		30.3			43.8
Provision of goat meat soup	17.1	35.7			7.3		27.3			
No control method	7.3	3.6	12.0		14.6		3.0			18.8

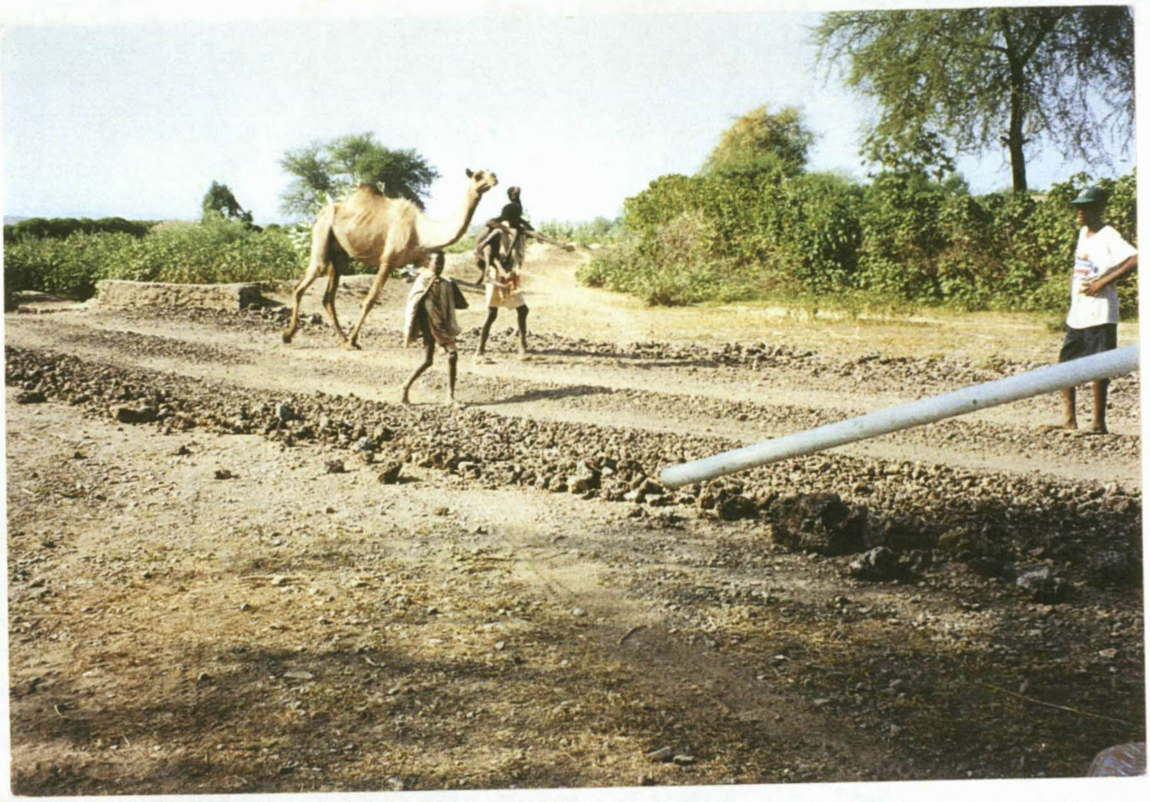


Figure 4.4. An Afar carrying his young camel on his back for treatment at a clinic.

4.3. 3.1.2. Grasses

Grasses can mean different things to different people, depending on the objective or attitude towards the plant. Nevertheless, to the pastoralists, different grass species are the source of feed to their livestock, in addition to their usage for other purposes. In the study districts, both pastoral group use grasses of different species for livestock feeding and house roofing, although the type of grass species used for different activities differ. In the case of the Oromos, 97% and 3% of the respondents use *Cymbopogon commutatus* (Senblete) and *Chrysopogon plumulosus* (Daremo) for house roofing respectively, while *Cenchrus ciliaris* is also used for house roofing where there are no other alternatives. On the other hand, 38.1%, 23.0%, 10.6% and 28.3 % of the Afar respondents use *C. commutatus* (Isisu), *C. excavatus* (melefe), *Enteropgon* species (Koref) and *Sporobolus ioclados* (Hamilto), respectively for house roofing. Although both pastoral groups use *Cymbopogon* species for house roofing, the difference between the two pastoral groups in the usage of other grass species for house roofing, particularly with reference to the Afars, lies on the abundance of the specific grass species within their vicinity.

Seventy six percent of the Oromos and 77% of the Afar do not harvest grasses, but 24 % of the Oromos and 23 % of the Afars do harvest grasses from the rangelands, while in both pastoral groups, harvesting of grasses is undertaken by women and transported using donkeys or on the back of the women.

The two pastoral groups differed in terms of the main reason for not harvesting grasses from the rangelands. The Oromos attributed it mainly to the type of ownership of the land, the Afars on the other hand, ascribed it mainly to the lack of experience (**Figure 4.5**). In the communal system, land is owned communally, where decisions regarding usage of the rangeland resources are made collectively. Thus, the grasses are considered as a common property. A small proportion of the households indicated that because of the high number of livestock there is no enough grass to be harvested.

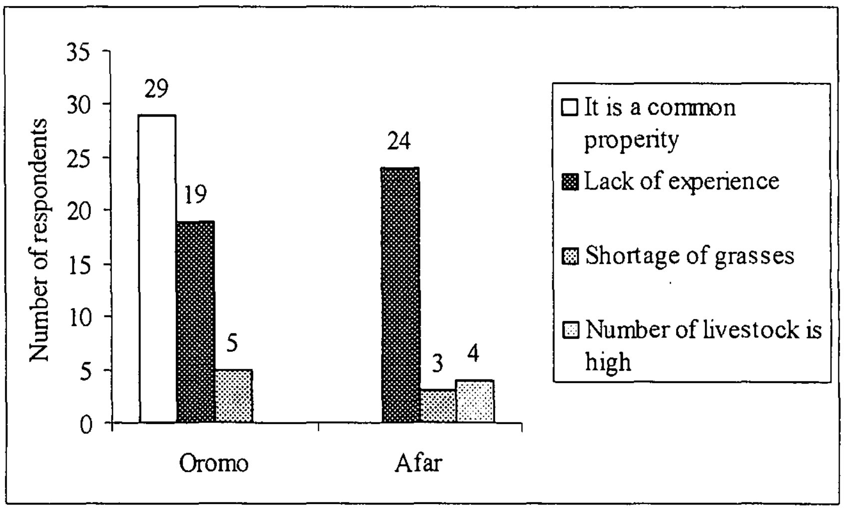


Figure 4.5. Number of respondents giving various reasons for not harvesting grasses from the rangelands (Respondents: Oromo= 53 and Afar = 31).

All pastoralists indicated that compared to the past, there is a decrease in the abundance of grasses and legumes. The main reasons given by the respondents for the decrease in the abundance of grasses and legumes were a decline in the amount of rainfall and drought, population pressure, increase in livestock numbers, expansion of farming, pests, pressure from weeds, bush encroachment and change in the channel (direction) of the Bulga river in the case of the Afar.

4.3.3.1.3. Woody plants

Woody plants play a central role in the farming systems of the study districts, where both pastoral groups use woody plants for a wide range of uses, the primary being as a source of livestock feed (**Table 4.6**). Eighty six percent of the Oromo respondents and 94.4% of the Afar pastoralists use browse as a source of feed for their livestock. The importance of woody plants is not only limited to the ones listed in **Table 4.6**, but their usage extends as a source of medicine and cosmetics. For example, Oromo women use the bark of *Grewia tenax* to soften their hair by soaking the bark in water overnight. The water will have thick oily characteristics. They will roll their hair either with hand or using sticks by pouring the liquid material. Through their traditional practices, the pastoralists have developed good skills in the usage of woody plants as a source of medicine to treat different kinds of diseases. Some of the woody plants used as a source of medication are: the fruit of *Balanites aegyptica* and the roots of *Euphorbia* species for treating wounds, the fruit of *Acacia nilotica* for treating wounds during circumcision of boys, the leaves of *Cadaba rotundfolia* for the treatment of influenza and the branches of *Salvadora persica* for teeth brushing and the bud or the tip of the leaves used for treating influenza. The list of usage presented here is not considered comphrensive for the fact that only some individuals or families within the community know the knowledge of woody plants as a source of medicine for both humans and animals.

Traditionally the Afars do not cut big trees, as a part of their indigenous knowledge of natural resource management. If there is a need to do so, the community members will be informed about the issue and then trees will be cut thereafter. This good traditional practice is, however, diminishing, either because of poor control in natural resource conservation, clearing of land for agricultural activities and charcoal making.

Table 4.6. The uses of woody plants in the study districts as ranked by the pastoralists (1= highest use and 6= least use; Respondents: Oromo = 89 and Afar = 51).

Tree uses	Kereyu-Fantale (Oromo)	Awash-Fantale (Afar)
House construction	3	3
Firewood/charcoal	4	4
Browsing	1	1
Fencing	2	2
Wild fruits	5	5
Shade	6	6
Implement preparation	6	6

4.3.3.1.4. Bush encroachment

Bush encroachment is commonly considered a major limiting factor to livestock production and natural resource conservation because it alters habitat structure and decreases herbaceous production (O`Connor & Crow 1999). This phenomenon is in fact common in semi-arid savannas and grasslands of the world (Blackburn & Tueller 1970; Barnes 1979; Bucher 1987; Harrington *et al.* 1984; Archer 1989; Matheson & Ringrose 1994). Accordingly, the majority (78.7%) of the Oromo respondents and 100% of the Afar pastoralists replied that compared to the past, their grazing land are more covered with bush and shrubs, which was responsible for a decline in rangeland condition. In Kereyu-Fantale, there are two scenarios taking place. Firstly, big trees like *A. tortilis* are being cleared for firewood, charcoal making and expansion of agricultural lands and secondly, shrubs and bushes are increasing in many grazing lands that did not have any kind of woody plants before. Both pastoral groups ranked a decrease in grass production as the first problem associated with bush encroachment followed by difficulty in herding.

The pastoralists did not only mention the problems they faced with bush encroachment, but equally indicated the benefits of an increase in bushes and shrubs.

However, the response from many of the Afar pastoralists (75%) was on the negative side, i.e., they do not appreciate the benefit obtained from the bushes and shrubs, while the reply from the side of the Oromo pastoralists was 50:50. The benefits derived from those who appreciated the benefical side of an increase in bushes were: feed for livestock, fencing, house construction, firewood, erosion control and shade. Both pastoral groups indicated that overgrazing and drought are the main causes of bush encroachment (**Table 4.7**).

Table 4.7. Reasons for the increase of bushes and shrubs ranked as percentage of the respondents (1= highest reason; 6= lowest reason; the number in parenthesis indicate % respondents; Respondents: Oromo = 80 and Afar = 49).

Reasons	**Kereyu-Fantale (Oromo)**	**Awash-Fantale (Afar)**
Overgrazing	1 (62.9)	2 (57.1)
Uncontrolled livestock and wildlife movement	3 (52.9)	3 (55.1)
Banning of burning	5 (11.5)	5 (22.4)
Drought	2 (54.3)	1 (65.3)
I do not know	4 (24.3)	4 (24.5)

It was argued by the elders that thirty years ago no two trees stood together. They further elaborated on the reasons for such an increase of woody plants. According to them, livestock graze everywhere, where forage is available and animals may act as a dispersal mechanism. Birds were also indicated as possible agents for carrying seeds from place to place. The other possible explanation given by the elders, specific to the Afars was transportation of seeds by Floodwater. Big rivers like Awash, Bulga and others transport different kinds of plant materials during the rainy season. These seeds will easily germinate and grow quickly along the rivers and from there animals carry the seeds upon ingestion and deposit it in their dung on grazing sites. The other possible mechanism indicated by the pastoralists was that, when there is feed shortage or drought in the adjacent districts, herders bring all their stocks into the grazing lands occupied by the Afar and the Oromo pastoralists and as a result seeds from different places might be transported this way.

Both pastoral groups indicated that *Acacia nubica, A. senegal* and *A. mellifera* are the main encroaching woody plants in the area. Furthermore, other non-woody plants were also indicated to increase such as *Tribulis terrestris*, *Parthenium hysterophorus* and *Datura* species. So far, there are no measures taken by the pastoralists to control bush encroachment, except discussing the problem among themselves.

4.3.3.1.5. Rangeland

Ten to 20 years' back, forty-nine households from the Oromo respondents and 46 from the Afar pastoralists used the rangelands mainly for grazing (**Figure 4.6**). The traditional pastoral herd management system was sustainable and well suited to the region's natural resource base. Livestock converted rangeland forage into milk, meat and blood, thereby providing a source of human subsistence. However, with regards to changes in land use all respondents in both pastoral groups replied that there was an increase in the size of cropland with a subsequent decrease in the grazing land. Pastoralists were of the opinion that a shortage of rainfall (drought) associated with an increase in human and livestock population, were some of the reasons for the decrease in the size of grazing land and an increase in the size of the cropland. In addition, all respondents in the Awash-Fantale district, considered bush encroachment and the repeated change in the direction of Bulga river to have an immense contribution in decreasing the size of the grassland area. None of the Afar and only 12% of the households in Kereyu- Fantale district had private grazing land (0.64 ha on average), and they ascribed this to the shortage of land and to the traditional communal type of ownership where land is collectively owned.

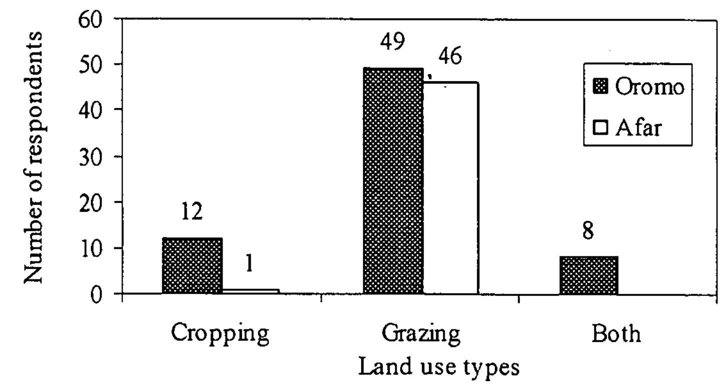


Figure 4.6. Purpose of using rangeland by the different pastoral groups in the last 10-20 years (Respondents; Oromo = 69; Afar = 47).

With regard to the type of land ownership almost all the Afar (47 respondents of the total 55) and 62 respondents of the total 90 Oromo respondents, wanted in the future to continue with the communal type of ownership (**Figure 4.7**). The rationale behind this choice was reasonably clear: different resources pose different problems and possibilities of exploitation, accordingly the possibility of increasing the size of the land to be grazed by the animals of an individual household and the decrease in land size if owned individually, were the main reasons wanting to continue with the communal type of ownership (**Table 4.8**).

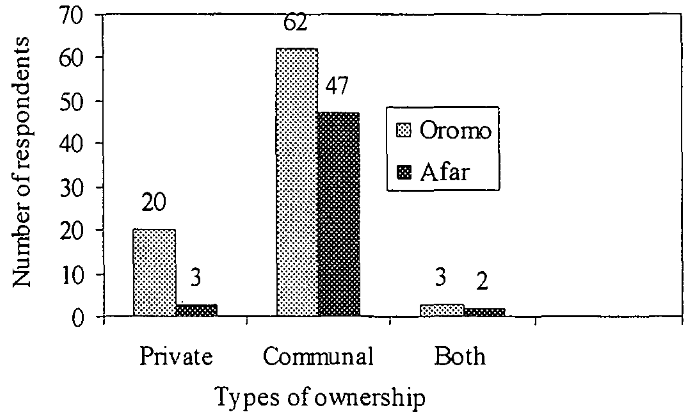


Figure 4.7. Type of ownership preferred by the pastoralists for managing their rangelands in the future.

Table 4.8. Percentage of respondents by type of reasons for the choice of communal type of ownership in the grazing lands (Respondents: Oromo = 62 and Afar= 47)

Reasons offered	**Kereyu-Fantale (Oromo)**	**Awash-Fantale (Afar)**
The size of land will decline if privately owned	53.7	-
Not possible to use migration	5.6	-
Possible to graze as desired	37.0	52.7
Strengthens relations among people	3.7	18.4
For good protection of animals		10.5
Tradition		18.4

The future use of the land, the livelihood and lifestyle of the family depends partly on the type of ownership of the land. To this effect, the Oromo pastoralists, preferring individual type of ownership, attached two reasons for their choice. On the one hand it was intended to block the usage of the rangeland by immigrants, as this was one of the major problems in the study area. It was also meant to block free access to land for members of the community. This dilemma in the type of land ownership led the Oromo pastoralists to undertake repeated discussions amongst themselves ending with no clear direction. Sustainable grazing management or land resource use is a key issue of concern in most arid and semi-arid regions of the world.

The sustainability of arid and semi-arid rangelands requires constant adaptation to change, not only utilising the opportunities, but also using resources at a sustainable rate so that they remain available year after year. Pastoralists, in the study district used to follow their practical knowledge of the landscapes and resource assessments to determine grazing at landscape level. However, many complexities are involved in assessing the sustainable use of rangeland in the study districts, particularly with reference to the Oromo groups. Subsequently, sub-division of the grazing land into different units for efficient utilisation of the rangeland and which also allow for recovery thereafter did not exist in the study districts. The main reasons attributed were the shortage of land for proper allocation, tradition, the lack of common agreement, lack of knowledge, increased livestock number and the expansion of crop farming.

The Afars traditionally subdivide their grazing land into what is locally known as "Alta" and "Kalo". Alta is a mountainous, rocky area with a high potential for livestock production and is mainly used in the wet season, whereas Kalo areas are swampy, marshy and usually located along riverbanks and mainly used in the dry season. However, this traditional practise of rangeland management is diminishing, as one of the elders indicated that his brother has stayed continuously at Alta for 10 years. In addition, in the past, when grass was abundant, both pastoral groups used to rest and burn their grazing land as measures of rangeland improvement. However, due to the shortage of land and the lack of appropriate technology in rangeland improvement practices, there is currently no rangeland improvement practice applied.

4.3.3.1.6. Perceptions towards rangeland condition

Since vegetation is the foundation for rangeland use, developing rangeland management strategies and plans requires information about the vegetation ecology and an understanding of the rangeland ecosystem processes. One possible way of studying the condition of the rangelands is through interviewing the pastoralists who are knowledgeable of their rangeland ecosystem. This in turn can be integrated with the scientific way of rangeland evaluation for a better understanding of the rangeland ecosystem and development of possible intervention mechanisms. Accordingly, 99% of the Oromo pastoralists and 73% of the Afars indicated that the condition of their rangeland, based on their own subjective judgement, is poor. Twenty six percent of the Afars and 1% of the Oromo pastoralists rated the grazing land as moderate in condition. Many interacting reasons, with profound implications for the future of the rangelands and pastoral production systems, were given for this poor state of the rangelands. The most important is overgrazing followed by drought (**Table 4.9**). According to the Oromo pastoralists the other major problems were increase in human population and immigrants coming from other districts creating pressure on the rangelands. The Afars further identified bush encroachment and the repeated change in the direction (channel) of the Bulga river as their major problems (**Table 4.9**).

Periodic assessment of the condition of the rangelands is part of the traditional natural resource management practices on which the welfare of their animals is based. This assessment, which is mainly based on the availability of grass, water, suitability to the different livestock species and security to the herders, can be unconditional or be carried out on an individual or group basis. In general, greetings in these pastoral groups mean holding discussions about water, rainfall, rangeland

Table 4.9. Reasons contributing to the poor rangeland condition, as ranked by the pastoralists (1= Most important reason; 11= Least important reason; Respondents: Oromo= 87 and Afar= 51).

Constraints contributing to poor Rangeland condition	**Kereyu- Fantale (Oromo)**	**Awash –Fantale (Afar)**
Drought (Shortage of rainfall)	2	2
Increase in human population decreasing the amount of grazing land	3	7
Overgrazing	1	1
Immigration	4	-
Bush encroachment	7	3
Little support from the government in rangeland management	6	7
Lack of knowledge	5	5
Poor soil status	8	8
Expansion of crop cultivation	9	-
Poisonous plants	10	6
Expansion of towns	11	9
Repeated change in the direction of the Bulga river		4

condition and welfare of their animals. Given the above problems related to the rangelands the study also assessed the pastoralist's perceptions of the possible ways on how to improve the condition of the rangelands. To this effect, 46% of the Afar respondents did not suggest any solution (**Table 4.10**), while the rest of the respondents suggested a wide range of solutions such as the adoption of new agricultural technologies, stopping migration, resting of the grazing land, stock reduction, sharing of the grazing lands and others.

It was also an objective of this study to identify the major grazing areas for rangeland assessment. Accordingly, the results of the household survey indicated that the most frequently grazed lands by the animals of the Oromo pastoralists were those near the villages, Fantale, Harole, Bulga riverside, Haroresa, Kara, Jirmee and Fati and Ladi. In the case of the Afars grazing lands near the villages, Fantale, Bulga riverside, near the hot spring, Samayu meda and Degage are the most important grazing areas.

Table 4.10. Pastoralists suggestions on how to improve the rangelands as percentage of the respondents (Respondents: Oromo= 70 and Afar= 43).

Suggested solution	Kereyu- Fantale (Oromo)	Awash-Fantale (Afar)
I do not know		45.5
Adoption of agricultural technologies	1.7	12.4
Stop migration	13.6	
Availability of alternative feed resources	5.10	12.1
Resting of the grazing lands	13.6	15.2
Reduce number of livestock	6.8	9.1
Requires setting rules on the use of the rangelands	11.9	
Share of the grazing land	20.3	
Rotational grazing (Dry and wet season)	27.1	3.0
Use of irrigation	1.70	6.1
Stopping deforestation		3.0

4.3.3.2. Water resources

Tracking water of consumable quality for livestock is one of the major occupations for pastoralists and one of the key determinants of pastoral movement and migration. Accordingly, water in the study area is available from 6 possible sources, which include boreholes, wells, rivers, rock water catchments, irrigation canals and ponds. The perceptions and realities of water availability and quality (rated subjectively) were quantified in the study districts. The results showed that the majority (85.2%) of the sampled households in Afar replied that there was no problem related to the quantity of water, while 65.4% indicated that the water was not clean. On the other hand, for the Oromos, both quantity (65%) and quality (62.5%) of water is a major problem.

The influence of water shortages both in terms of quality and quantity on the pastoralists, particularly on the side of the Oromos has been significant in these marginal environments. The distribution and type of water facilities can influence the frequency with which animals are watered. In general, the further a producer lived from the water source, the more likely he will be forced to practise alternative day watering of his animals, which is quite common within the Oromo pastoral groups. Accordingly, nearly 50% of the Oromo households water cattle, sheep and goats in the dry season every other day and nearly all of them travel between 13-18 hours a day to the watering place in a round trip. This can have a substantial demand on the labour required to water the animals with loss of energy both to the herder as well as the animals.

The critical months of water shortage as reported by both pastoral groups was from November to June. In both pastoral groups, the alternative water sources when there is critical shortage are buying water from the pumps (6.6-13.3% of the respondents) and to move to distant water sources (86.7-93.4% of the respondents). The most important sources of water for animals in Awash-Fantale (Afar) in the dry season were rivers and hot springs, while in Kereyu-Fantale (Oromo) they were boreholes, different rivers and irrigation canals. In Kereyu-Fantale, during the wet season, the main sources of water were ponds, surface water and irrigation canals, while in Awash-Fantale it comprised of ponds and rivers (**Figure 4.8**). In Kereyu-Fantale, the distant water sources include lake Beseka and different river sources, while in Awash-Fantale it consists mainly of rivers. All of the Oromo respondents and 71% of the Afar pastoralists replied that the sources of water for humans and animals are the same (**Figure 4.9**). The water collected on the surface is only available when there is rain and it is also dirty (**Figure 4.10**), while the water from the irrigation canals (**Figure 4.11**) carry wastes from the factories or farms, which held a health hazard for humans and animals alike.

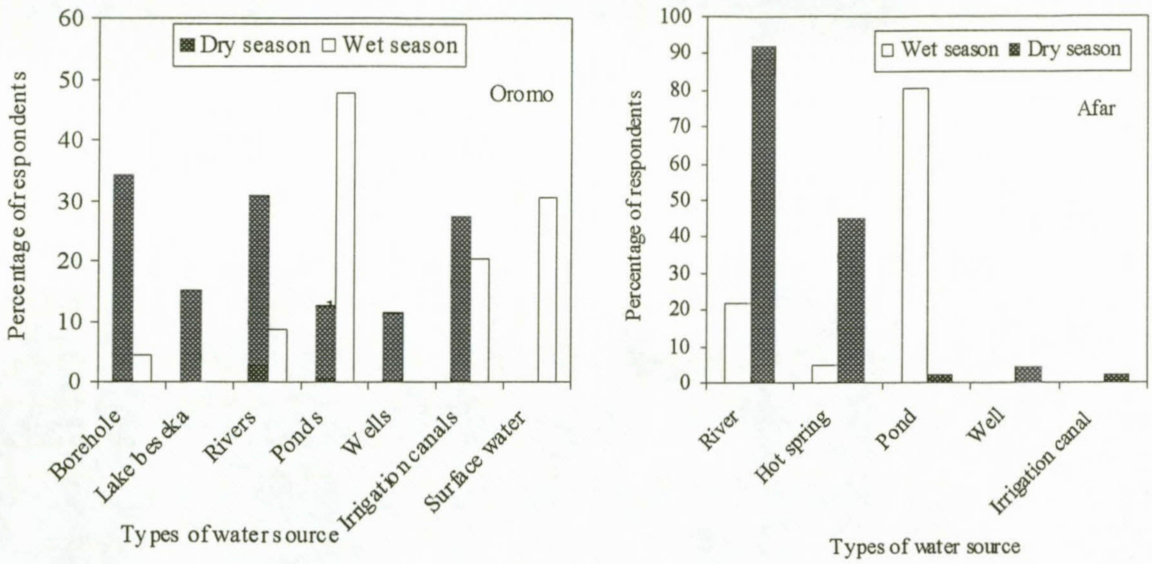


Figure 4.8. Percentage of Afar and Oromo respondents utilising different water sources by season (Respondents Oromo= 88 and Afar= 49).

Figure 4.9. Livestock and people utilising the same sources of water at a borehole (Oromo).

Figure 4.10. An Oromo woman fetching water from the surface of a shallow pond.

Figure 4.11. Calves watered from an irrigation canal (Afar).

According to the opinion of the Oromo pastoralists, the main problem regarding water resources is the inequity in their distribution. Due to such an inadequate distribution of water sites at times both humans and livestock have suffered greatly and some livestock even died. In some grazing lands there is abundant grazable forage material but there is a shortage of water, while the opposite is also true. In the case of the Afars there is also an imbalance in the distribution of watering points. In both districts there are unutilised grazing lands in the dry season due to water shortages and the pastoralists make use of such grazing lands by grazing the animals for two days and watering them on the third day. Alternatively they use the grazing land only during the wet season. Therefore, proper distribution of watering sites and forage quantity is of paramount importance for the proper utilization of the rangeland resources. Both pastoral groups appreciate the efforts that were undertaken by both government and non-government organizations in improving the water supply. However, further efforts must be made to improve the quantity and quality (to the Oromos) and the quality of water to the Afars.

4.3. 3.2. Natural minerals

The information obtained from the group discussions with the respective elders and the response of the sampled households indicated that there are 3 types of natural minerals, which are utilised by animals. The Oromo groups locally call them as Haya, Bole and Bojjii. The Afar generally know them as Haya and classify them as black, red and white based on the colour of the soil from which the minerals are derived.

Haya

Haya is a kind of soil mineral in dry, wet or dust form (powdered and as a wet muddy lump). It is obtained from the ground by digging the soil on the areas where this mineral is found. It has a grey or cement colour with a very fine-textured materials. This mineral is suitable for all kinds of animals and it tastes salty or like sour sugar.

Bole

Bole is a kind of soil mineral, which has a different texture from that of Haya. It consists of a mixture of large gravel like materials. Bole is found scattered in spots among other soils. Animals get the mineral by going to the spot and licking the spot where the mineral is found. It is more salty than Haya and licked more by cattle and goats than by sheep and camels.

Bojjii

Bojjii is a mineral salt having a dull whitish colour and is found as very fine salt grains. It is mainly available near the banks of salty water and is baked on the ground after the salty water has evaporated. According to the respondents and the elders it has the highest salt concentration. It is well taken by cattle, while it is harmful for sheep and goats. Sheep and goats take this mineral indirectly i.e., by eating the salt tolerant grasses. Camels also consume this mineral in the diluted form, which is locally known as Hora (**Figure 4.12**).

Figure 4.12. Saline water under preparation for camels (Oromo).

The respondent households and the elders indicated that if their animals do not get the above-mentioned minerals in time their productive and reproductive performance will be affected (decrease in milk production, do not increase in weight, will have poor physical condition and they will be weak). Without these minerals, the animals will be more susceptible to different kinds of diseases.

In both pastoral groups, Haya is the most frequently used natural mineral. Almost all the respondent households indicated that the minerals are offered or consumed by the animals mainly during the wet season and the main reasons for such usage were the abundance of water and grasses during the wet season. These salty natural minerals induce thirst in the animals and only during the wet season have the animals enough water to drink after consuming the mineral source. During the dry season the animals will obtain the elements from plant sources. With regard to the availability to animals, 39.2% of the Oromo respondents indicated that the animals will lick these mineral resources directly in the grazing fields, while 58.1% of the households transport the mineral soil to home and feed them and 2.7% use both methods. Similarly, 85.7% of the Afars practise feeding the animals directly in the field, while 14.70% feed their animals by bringing the mineral soil to their home.

4.3.4. Feed resources

The feed resources that are available in Kereyu-Fantale district are natural pasture, woody plants, crop residues (residues of maize stover, teff straw, remaining of tomato production), weeds and sugarcane tops. In some villages, they also harvest grasses from the different plantations. The grazing lands are grazed continuously throughout the year. Crop residues are fed mainly from October to January, while sugar cane tops are fed during the dry season from November to June. Despite the production of large amounts of sugar cane by-products in the vicinity, only 26.7% of the Oromo respondents use sugarcane by-products (sugar cane tops) as a feed resource. The molasses produced is mainly exported and the remainder is used by enterprises or organizations outside of the study districts. The lack of transport, financial shortage, accessibility and the lack of knowledge are the major problems in not using sugar cane by-products by the pastoralists for livestock feed. Migration in response to feed shortages is common throughout the year, but mainly from November to June. The feed resources that are available in Awash-Fantale are natural pasture and browse. The use of crop residue is limited to villages that have started cropping very recently, like Sabure and Bolyita. Migration in response to feed shortage is similar to that of the Oromo pastoralists.

All the sampled households in both pastoral groups reported that there is a critical feed shortage during the dry season (November to June). The first measure taken by both pastoral groups to solve feed shortage is migration. Both pastoral groups rarely sell animals as the first measure to solve feed shortages (**Figure 4.13**). Buying feed for coping feed shortage is also practised by those households close to the towns but not by the pastoralists far out in the rangelands.

Fifty eight percent of the Oromos and 28 % of the Afar provide supplements to their animals during the dry season: There is some variation between the two pastoral groups as to which feed they supplement their animals (**Table 4.11**). This was due to the variation in the availability of a specific feed in a given area. The Oromo respondents involved in crop production make use of crop residues as a supplement to their animals.

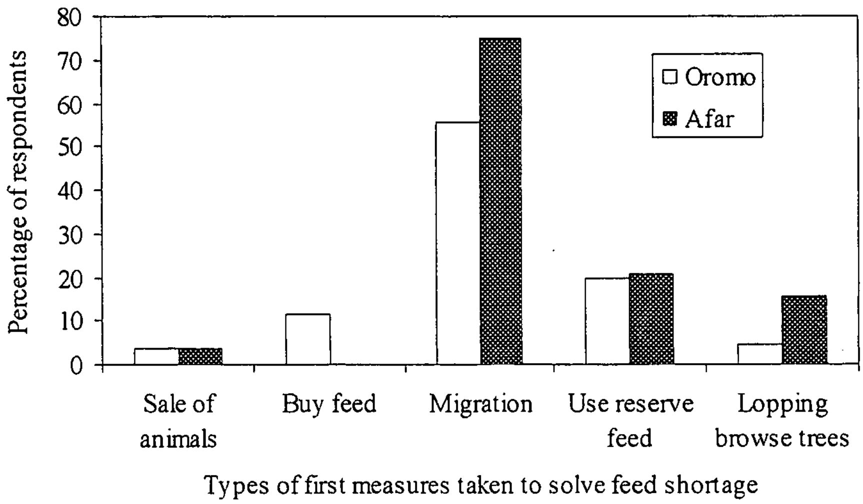


Figure 4.13. First measures taken by the different pastoral groups (percentage of respondents) to solve feed shortages; Respondents: Oromo= 86 and Afar=52).

Table 4.11. Type of supplement offered during the dry season by the different pastoral groups (1= Most used; 5= Least used; Respondents: Oromo= 52 and Afar= 15).

Types of supplement	Kereyu-Fantale (Oromo)	Awash-Fantale (Afar)
Sugarcane by-products	3	
Crop residues	1	
Browse	2	2
Grasses	4	1
Wheat milling by-products	5	

The main animal categories given the supplements are calves, small ruminants, milking cows and oxen. The main reasons of offering the supplements according to their purpose they are given is milk production, to alleviate weakness in calves, for ploughing oxen and to strengthen sick animals.

In response to a question asked whether they conserve feed for the dry season or not, the households in both pastoral groups had a 50:50% reply. In the case of the Afars, they conserve standing hay and browse, while the Oromo groups conserve mainly crop residues and browse (**Table 4.12**). The difference between the two pastoral groups lies in the type of production system in which they are. In general, the Afars are more pastoral than the Oromos.

Table 4.12. Type of feed conserved during the dry season in the study districts ranked as percentage of the respondents (1= the highest; 4= Lowest; Respondents: Oromo= 47 and Afars= 28).

Type of feed conserved	Kereyu-Fantale (Oromo)	Awash-Fantale (Afar)
Standing hay		1
Crop residues	1	
Browse	2	2
Cut hay	3	
Sugar cane residues	4	

Both pastoral groups replied that there are browse species that provide year round browsing. Some of these are *Balanites aegyptica*, *Ziziphus mauritania*, *Acacia tortilis*, *A. nilotica*, *Grewia bicolor*, *Salvadora persica* and *Capparis fascicularis*. Some of them are found along river or in marshy and swampy areas. On the other hand, some browsed species are deciduous (**Figures 4.14** and **4.15**).

4.3.5. Migration

Migration (mobility) is an inherent strategy of the pastoralists to optimise production of a heterogeneous landscape under a precarious climate.The fact that grazing resources are found in different places at different times affects the herder's strategy. For example, pastoralists tend to prioritize mobility (whether in the form of nomadism or seasonal transhumance) and an opportunistic approach to resource management (Hussein *et al* 1999; Ndikumana *et al.* 2001). These strategies ensured the persistency of pastoralism over centuries, leading to perceptions of its benign nature as practiced in semi-arid environments (Dyson-Hudson 1980). Accordingly, 75% of the Oromo pastoralists and 98.1% of the Afar respondents, move their

Figure 4.14. Condition of the browse during the dry season with only *Grewia* species retaining some yellowing, senescing leaves.

Figure 4.15. Condition of the browse in the dry season with only *Cadaba rotundfolia* retaining leaves.

livestock from place to place in search of feed and water. Three main factors determine the route of migration namely, distance to grazing, availability of feed for livestock and the security of the route. In both pastoral groups, the duration of stay of camels and the other livestock species (cattle, sheep and goats) in migration differs. The camels migrate year round, while the mean duration of stay in migration for cattle, sheep and goats was about 4 months.

It was important to identify the most frequent places of migration for rangeland evaluation and for the study of the implication of this migration on the rangeland ecology. The Oromo pastoralists indicated the most frequent places of migration in the study districts were Bulga riverside, Harole, Kara, Haleme, Fantale, Churcher, Gababa and Aleka. In the case of the Afars, Samayu, Madala, Fantale, Bulga river side, near the hot spring (top of bud) were some of the most important places of migration. The Afars also move their animals outside of the study district (mainly in the neighbouring Afar districts). In the case of the camels, 90% of the Oromo pastoralists move their animals to other districts inhabited by other Oromo tribes by travelling up to 250 km away from their residence. Both pastoral groups indicated that compared to the past, the intensity of migration has increased because of the shortage of rainfall and drought, which resulted in a decrease in the amount of forage produced for the animals.

This migration, which is indicated by Toupet (1975) as highly adaptive and based on a profound symbiosis between herders and environmental conditions of risk and uncertainty, was not carried out without the pastoralists facing many problems. The major problems faced by the pastoralists, as ranked by them in a decreasing order were: (1) feed and water shortage, (2) death of animals, (3) increase in the incidence of diseases and (4) problems from wild animals. The elders also discussed other problems during group discussions. At times the temporary houses at the migratory places will be destroyed by wind. In another circumstance, stubborn camels on which they transport their goods will leave away the women transporting the materials. Furthermore, the elders and the community members discussed difficulties in handling babies, management of lambing, kidding or calving and thirst and hunger of the herders during migration. This information mainly obtained from the group discussion coincided with the perception of the individual household response. Accordingly, 90% of the Oromos and about 60% of the Afar pastoralists replied that migration is a bad practice (**Figure 4.16**). A small proportion of the Afar pastoralists indicated its importance as a measure to decrease cattle diseases. Many diseases affecting all classes of livestock species arise during migration (**Table 4.13**), whose importance varies from one class of livestock to another.

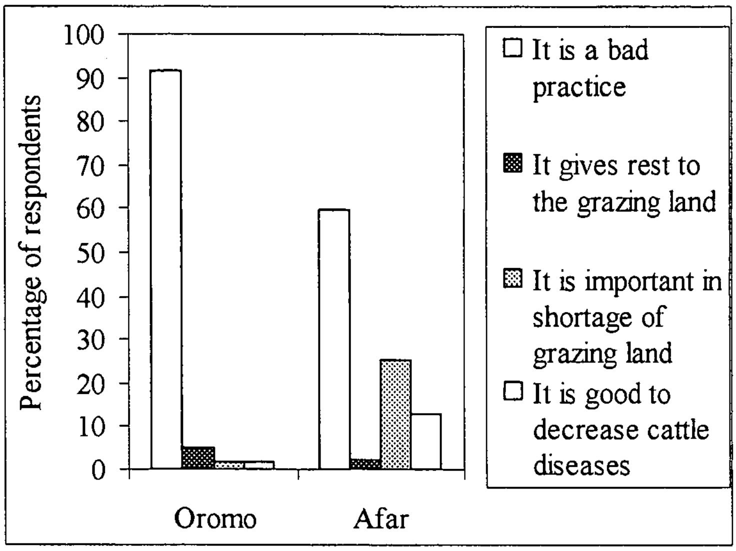


Figure 4.16. Perceptions of Oromo and Afar pastoralists towards migration (Respondents: Oromo= 85 and Afar= 47).

Table 4.13. Common diseases observed during migration by livestock species (Percentage of the respondents; Respondents: Oromo= 75 and Afar= 42).

Type of diseases	Kereyu-Fantale (Oromo)				Awash-Fantale (Afar)			
	Cattle	**Sheep**	**Goat**	**Camel**	**Cattle**	**Sheep**	**Goat**	**Camel**
Rinder pest	44.1	68.0		43.3	2.2			
Contagious Bovine (capparine) Pleuro Pneumonia	50.0		62.1		53.3	35.7	56.1	39.3
Pastrolisis	2.9		6.8	6.7	51.1	57.1	46.3	75.0
Anthrax	35.3				42.2	21.4	12.2	
Black leg	38.2				4.4		4.9	
Actino-bacillius					4.4			
Foot and mouth	23.5				4.4		4.9	
Deep wounds on foot pad	1.5	2.3		23.3	2.6			
Bloat		20.0	4.4	3.3	1.3			3.6
Liverfluke		13.6	24.1	6.7	4.4	2.4		
Diarrhoea		11.4	10.3					3.6
Coenuruses (Plant poisoning)		15.9	31.0	6.7				
Bottle jaw oedema		2.3	3.4					
Cough			6.9	10.0	2.2		2.4	
Skin disease			3.4					
Forest fly						7.1		

4.3.6. Rangeland use conflict

The word conflict has been used to describe a wide range of interactions between herders and farmers over natural resources, interactions that are qualitatively different from each other and clearly of different degrees of severity. Thus, the umbrella term conflict has been used to cover tension between resource users, straightforward arguments between individuals, disputes between individuals or groups, or with the state, legal proceedings between resource users, political action to evict certain resource users, theft, raiding of livestock, beatings, killing of humans or livestock, and large-scale violence between groups involving multiple killings (Hussein *et al.* 1999). The usage of this term under the context of this study was to explore land use conflict in the study districts, which reflects ongoing competition over access to scarce land resource between different pastoral groups. Conflict has been conspicuous for over 30 years and is intensifying. To this effect, information referring to conflicts on rangeland resources in this part of the country is quite sensitive. Nevertheless, 42% and 46.3% of the Oromo and Afar pastoralists, respectively reported that there is a conflict in resource use among the pastoralists and the main conflict is between the Afar and Oromo pastoralists. There was a variation in opinion to a question asked if the intensity of the conflict over rangeland resource use increased over the last 3-4 years (**Figure 4.17**). Many of the pastoralists in both districts replied that the intensity has increased in the last 3-4 years. The main reason for the increase of conflict by both pastoral groups was livestock feed shortage (86.7-90.5% of the respondents in both pastoral groups), where the intensity of the conflict increase in the dry season when feed shortage is critical. The other reason given by both pastoral groups was a lack of clear boundary demarcation between the two neighbouring pastoral districts. Some households, on the other hand, reported that there was a decrease in the intensity of the conflict over the last 3-4 years and have attributed this to a change in attitude of pastoralists due to education, agreement among the pastoralists and protection by the government.

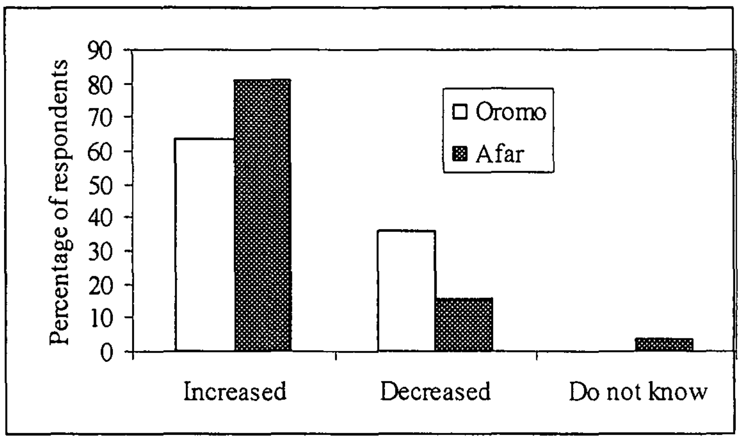


Figure 4.17. Pastoralist's perceptions to the intensity of conflict in the last 3-4 years (Respondents: Oromo= 85 and Afar=51).

4.3.7. Resource utilisation from conservation area

Both pastoral groups are directly or indirectly dependent on the Awash national park of Ethiopia for their livestock feeding. Particularly in the dry season when there is critical feed shortage women usually harvest grass from the park (**Figure 4.18**) or herders will graze their animals in the park. Twenty percent of the Oromos and 56.6% of the Afars replied that their stock graze in the park during the dry season. This response however, seems low from what is actually happening in the study districts. Similarly, 73.3% of the Oromos and 94.2% of the Afars replied that the game and their livestock use the same source of water.

Figure 4.18. Grass harvested from Awash National Park by an Oromo woman and transported with a donkey.

4.4. DISCUSSION

4.4.1. Demography of the pastoralists surveyed

The average family size in the study districts was 6.74 and this was comparable with the results of Tibabu (1997) and Mudris (1998). The result also indicated that the level of education of the respondent households was low in both pastoral groups. This has many implications. In one way, it shows that the status of education in the study districts must be improved. The low level of education can also be a hindrance for the transfer of technology.

Both pastoral groups in the study districts depend primarily on the sale of livestock as a source of income and this is in agreement with a report of Perrier (1995). The second source of income for the Afars was the sale of milk and milk by-products, while for the Oromos it was the sale of crops. This is a very interesting difference because these two pastoralist groups are living in neighbouring district where one would expect a similar pattern. This reflects in part the difference in the type of production system they are following. The Afar pastoralists in general are more involved in pastoralism than the Oromo respondents. This difference might also be associated with the culture of the two pastoral groups.

4.4.2 Livestock ownership

The results of the study indicated that females dominate the livestock population for all species. This is in agreement with the reports of others (Coppock 1994; Tibabu 1997; Mudis 1998; Roderick *et al.* 1999; Ndikumana *et al.* 2001) who indicated that a female dominated herd structure was used to offset long calving intervals and thus stabilise milk production. Perrier (1995) argued that western ranchers focus strongly on the production of livestock for terminal products, especially meat. Most traditional pastoral and agropastoral groups, on the other hand, place at least as strong emphasis on harvesting a continuous flow of non-terminal products, such as milk, fibre, manure, traction and transport. The traditional goal of almost all communal land livestock owners is an unlimited increase in the number of animals owned. Numbers and not productivity have been the major objective (Bembridge & Tapson 1993). Many pastoral and agropastoral households keep more than one species of livestock, which is also practiced by the pastoralists in the study districts. Herd diversity appears to be a strategy that is particularly useful in arid areas, where advantage can be taken of the various adaptations of the different livestock species. Studies have shown that mixed stocking with two or more species of different feeding habits make more effective use of vegetation and are often more profitable. Moreover, different livestock species are valued for different reasons (Behnke *et al.* 1993; Scoones 1995b).

The mean number of sheep and goats owned per household was lower than that mentioned in previous reports (Tibabu 1997). Although previous data indicating ownership per household in the case of Afars was not segregated into sheep and goats, it was reported that the mean ownership of sheep and goats per household to be 47. The result of this study indicated the mean number owned per household for sheep and goats in Awash-Fantale district to be 38. This decline in the number of small ruminant mainly comes from sheep and this could possibly be associated with disease problems, which was supported by the elders in the study districts. Disease as a major constraint to small ruminant production over the years has been noted by Coppock (1994) in the Borana rangeland of Ethiopia and by Wilson (1988) in Africa.

4.4.3. Poisonous plants

Plant poisoning is a problem that can have an economic impact on the livestock owner when animals succumb and reports of animals being poisoned by a variety of plants is documented in different countries (Garland 2000). Devastating outbreaks of poisoning have been reported under conditions of droughts, overstocking and uncontrolled fires in Africa. For example, during 1926 and 1927 about 600 sheep died of plant-induced photosensitivity in the Northern Cape Province and during 1929 and 1930 over one million were killed by *Geigeria* species in Griqualand west (Naude *et al.* 1996).

It was indicated by the pastoralists that both woody and other herbaceous plants at certain times cause poisoning to livestock. Although resource and time did not permit chemical analysis on the poisonous properities of the mentioned plants, the incidence of being poisoned by these plants is indicated in the literature (Irvine 1961; Verdcourt *et al.* 1965; Drummond & Moll 1977) from Kenya, Uganda and Southern Africa. Verdcourt *et al.* (1965) for example, indicated that 0.05% of a quaternary ammonium compound was found in *Capparis fascicularis*. The genus *Tephrosia*, containspoison (Verdcourt *et al.* 1965) a very few plants whose foliage appears to be somewhat toxic, e.g., *Tephrosia taub* is poisonous to rabbits. According to an old record of a German officer in Tanganyika, *T. radicans*, causes diarrhea in cattle, though it is a good cover and liked by cattle. The principle toxin is tephrosin, which also has insecticidal properties. *Cryptostegia grandiflora* is also reported to be poisonous to livestock in Mexico and Australia where it was introduced (Irvine 1961) and according to Irvine (1961), *Erythrina abyssinica* was found to contain traces of alkaloids (0.05- 0.10%). *Erythrina abyssinica* contains a curare- like poison, which if injected into the blood stream produces anaesthesia, paralysis and even death due to respiratory failure (Drummond & Moll 1977).

In East Africa, no species of grass is considered poisonous. However, several have been known to develop toxic properties under certain conditions. Species of the grasses *Aristida, Cymbopogon, Themeda triandra, Cynodon dactylon* and *Cynodon plectostachyus* have all shown to be capable of building up quantities of hydrocyanic acid in their tissues. This abnormal production of hydrocyanic acid is brought about under the influence of drought, frost, trampling, mowing or wilting by the action of enzymes on the *cyanophoretic glycosides* normally present in the plants (Verdcourt *et al.* 1965).

The season in which poisonous plants of woody origin affect animals was indicated to be mainly during the dry season, while that of the other plants during the wet season. The reason for this is related to the abundance of these plants in marshy, swampy areas and along the river. During the dry season, animals graze in these mentioned areas and get these plants accidentally when they are grazing on other plants. This is particularly true in the case of the Afars. For the other plants, the wet season is related to their abundance in that specific season. The incidence of poisonous plants is more common on the side of the Afars than on the side of the Oromos. This suggests that their distribution, ways of dissemination, economic effects and the effectiveness of the traditional control methods be studied in more detail.

In general, plant poisoning will continue to be a problem and there are numerous reports to this effect in the veterinary literature (Garland 2000). It is not uncommon to find poisonous plants growing on sown and natural pastures and public lands (James *et al.* 1992).

4.4.4. Uses of plants and Bush encroachment

The results of the study indicated that both pastoral groups use rangeland plants such as grasses and woody plants for different purposes. The uses of woody plants by the pastoralists for different purposes have been described by many authors (Skerman 1977; Le Houerou 1980; Walker 1980; Woodward & Reed 1989; Scholes & Walker 1993; Breman & Kessler 1995; Diress *et al.* 1998; Sharon 2000; Smit 2002). The primary use of woody plants in the study district was as a source of feed for livestock, which is in agreement with the report of Diress *et al.* (1998) who reported that in the northern tip of Afar the pastoralists primarily use woody plants for livestock feeding. Both pastoral groups have an excellent knowledge of native vegetation, a common fact among the rural people in Africa that has spurred interest in ethno botany (Morgan 1981; Stiles & Kassam 1984; Marx & Wiegand 1987; Mathias-Mundy & McCorkle 1989). Accordingly, plants used as traditional medicines for people or animals may have a role to play in developing more sustainable health practices in situations where imported drugs are expensive or unavailable (Tafesse 1990). Further research is required to investigate the usage of different woody plants species. Forage value of plants should not be the sole criteria for management objectives and the community should be taught to conserve woody plants that are disappearing.

Increase in bushes and shrubs in the grazing lands was one of the problems indicated by the pastoralists, which is in agreement with the general problem of the rangelands in Ethiopia (Coppock 1994; Alemayehu 1998; Beruk & Tafesse 2000; EARO 2001) and other semi-arid savannas and grasslands of the world (Buffington & Herbel 1965; Blackburn & Tueller 1970; Barnes 1979; Bucher 1987; Harrington *et al.* 1984; Archer 1989; Matheson & Ringrose 1994). The causes of bush encroachment are not absolutely clear to both the pastoralists and the rangeland ecologists. However, varied and complex reasons are associated with bush encroachment. In light of the existing knowledge and the debate about the possible causes and mechanisms of bush encroachment, the possible reasons indicated by the pastoralists fall within the scientific context. The decrease in grass production due to increase in the density of woody plants is well known (Abel 1997; Smit 2002). Smit (2002), based on his extensive review of the bush encroachment problem in Southern Africa indicated that both natural process and secondary determinants could result in increases in the density of woody plants. The details of the bush encroachment problems will be discussed in Chapter 5.

4.4.5. Rangeland and perceptions towards rangeland condition

The fact that the communal type of ownership within the grazing lands is preferred by almost all the Afars and many of the Oromos confirms the fact that, in a pastoral production system, in contrast to the individually owned livestock, land resource is frequently owned and managed by groups (Perrier 1995). Pierrier (1995) explained that the socio-economic conditions of the pastoral system tends to favour individual ownership of valuable productive resources that can be controlled, such as livestock, and communal ownership of less valuable and difficult to control resources such as rangelands. The difference between the Afars and the Oromos with regard to choice of land ownership is an indication of the situations in which the two pastoral groups live and the type of production system in which they are operating. The Afars in general are more pastoral than the Oromos. Tsui *et al.* (1991) argued that with population increase and the expansion of the agricultural frontier, land use and tenurial arrangements will change more towards privatized rangeland areas.

The numerous problems faced by the pastoralists in the study districts with regard to rangeland resource, be it from problems imposed externally such as the allocation of rangeland to non-pastoral use, immigration or internally (e.g., population growth) is a common characteristics among nomadic pastoralists living in a semi-arid area (Unruh 1990; Thurow & West 1996). The external forces, particularly the allocation of land to non-pastoral use have displaced and up setted the ecological viability of their economies in Ethiopia (Desta 1993; Ali 1993; Tibabu 1997; Mudris, 1998; EARO 2001) and elsewhere (e.g., Harbenson 1990; Unruh 1990; Behnke 1994). Behnke *et al* (1993); Kipuri (1995); Scoones (1995b); Mokwunye (1996) and David *et al.* (2000) argued that pastoral people are suffering considerable erosion of their lifestyles in many arid parts of Africa through both external and internal problems.

If one traces back the root cause of land allenitation, it can be attributed to the attitude towards the pastoralists and their mode of production. International development agencies and African governments have devoted considerable effort to the suppression of the pastoral techniques of land and livestock management on the presumption that pastoralism was inherently irrational, ignorant, unproductive and ecologically destructive (Hardin 1968; Picardi & Siefert 1976; Livingstone 1977; Sandford 1983). However, recent studies by anthropologists, ecologists and economists indicated that the indigenous systems of pasture protection and sustainable mode of exploitation were compatible (Homewoods & Rodgers 1989; Galaty & Johnson 1990; Fratkin 1997). In contrast to the previous generations of researchers, these people have stressed the immense body of indigenous knowledge of the environmental processes (Unruh 1995; Sillitoe 1998). This study supports the latter assumption as was evident from people's response to issue of their grazing lands and their excellent knowledge of plants. Most of the problems the pastoralists face in the study area were created externally without leaving alternatives to the pastoralists such as land allenitation. In general, the pastoralists living in the study area are dealing with grazing systems, which are characterised by complexity, high variability and uncertainty. Feasible management options in these unstable environments are not simply attenuated or less precise versions of management in more temperate settings. Furthermore, this system as it stands now cannot be moved sustainably and alternatives like modernizing livestock production and improving social welfare needs attention.

Previous studies (Tibabu 1997; Mudris 1998; Sharon 2000) and different overviews (Desta 1993; Ali 1993; EARO 2001) have indicated that the study area is a resource use conflict area. Land is occupied by different development enterprises, conservation areas, crop producers and the pastoralists. Furthermore, land is required for the expansion of farming by people living in the town and by workers in the different plantations. Just considering the Oromo group alone, because of the difference in the type of production systems they are following (crop production and pastoralism), rangeland can mean one thing to those involved in crop production and mean another thing to those who are exclusively deriving their livelihood from livestock production. Therefore, the coming conflict in land should not be expected from the different pastoral groups alone, but also from pastoralists of the same ethnic group and this was quite evident when collecting data in the field. Numerous studies have confirmed that with the increase in human and livestock population and accompanied by the repeated drought, more pressure will be exerted on the land (Baxter 1994; Ward *et al.* 1998; Freudenberger & Wood 2000). To this effect, many places in the study districts have already reached a threshold point (Schloeder & Jacobs 1993), where the rangelands cannot be upgraded without assistance. Although it is quite unjustified to put all the blame on the animals, research done elsewhere have indicated that overgrazing can lead to a decline in the quality and productivity of the rangelands (Lazenby & Swain 1969; Coupland 1979; Cossins & Upton 1985; O`Connor 1985).

Hussein *et al.* (1999) indicated that an important characteristic of the semi-arid regions, which affects the livelihood strategies of both herders and farmers, is a short rainy season (3-4 months), whether this is mono-modal (west Africa) and bimodal (East Africa), and the unreliability of rainfall (inter-annual fluctuations, fluctuations in seasonal and spatial distribution). In addition, they have suffered recurrent, prolonged and extensive droughts during which the rains sometimes have failed completely. Drought was one of the problems indicated by the community as a factor increasing more pressure on the land. Since drought is a gradual phenomenon, it is difficult to clearly demarcate the beginning and end of drought. Wilhite & Glantz (1985) defines drought as (a) meteorologically (b) agriculturally (c) hydrologically and (d) socio-economically.

In meteorological terms, Pratt *et al.* (1997) suggest that drought can occur when rainfall is below half the long-term average or when rainfall in two successive years falls 75 % below average. According to Coppock (1994) drought is defined as "when two or more consecutive dry years occur in which the length of the growing period (LGP) is less than 75% of the mean, i.e., a drought is driven by several consecutive rainy seasons in which deficient rainfall has a detrimental effect on the production system.

The Society of Range Management (1974) defines drought as the prolonged dry weather where the precipitation is less than three-quarters of the average rainfall. The major criticism forwarded in using meteorological criteria in defining drought rests on the limitations of so called normal precipitation of an area. Drought with respect to agriculture is the stress that causes plants to wilt or die and it lowers production. This is not only a function of the amount and distribution of rainfall, but also a function of other determinants such as temperature, soil characteristics and management of the land. Vegetation cover and vigour in a given area can provide a valuable indicator of meteorological drought. Degraded areas are very much prone to physiological stress and drought is likely to recur. This explains in part why pastoralists living in poor condition or degraded areas are affected by recurrent droughts. The people with degraded rangelands are creating their own droughts and increase the intensity or frequency of it (Snyman 1998).

Hydrological drought is largely concerned with underground and irrigation water supply. Snyman (1999a) indicated that catastrophic droughts caused by a succession of low rainfall years are common on the African content and at these times forage resources dwindle to very low levels. Examination of the rainfall data in the study area, even in the last five years, indicated that the rainfall was below average by about 4-23%. The details of the problem of drought are discussed in Chapter 5.

In conclusion, the future of the rangeland in this study area is dependent in careful planning of land, considering the different components of the ecosystem in such a way that one is complementary to the other.

4.4.6. Natural minerals

Optimum livestock performance is possible only if the forage contains the necessary mineral elements. Essential mineral required for normal functioning and productivity such as Sodium (Na), Phosphorous (P) and Copper (Cu) are often insufficient amounts in natural forage (Kabaija & Little 1987). According to Oba (1998), in the lowlands, a primary constituent of improved range management technique is mineral supplements and the pastoralists practice is quite related to the improvement of the productive and reproductive performance of their animals. Furthermore, Simonsen & Mitiku (1998) in their study at the northern tip of Afar indicated usage of minerals for livestock but from a different source (from hot springs). This study was conducted at the southern tip of Afar, a region with 29 districts and the studies generally indicate that pastoralists have developed traditional methods of combating mineral deficiency, though they cannot put it in a scientific way. Mohammed *et al.* (1989) studied soil minerals by collecting soil samples from the Rift valley of Ethiopia, which encompasses the study districts as well. Their results showed that these mineral soils are rich in sodium (Na) but generally poor in other elements. The red soil has relatively better amount of phosphorous (P), which improves the P level in the other mineral soils when mixed with them.

4.4.7. Water resources

The result of this study showed that both quantity and quality of water was a major problem to the Oromo groups, while the Afars express more on the quality problem. Within the arid rangelands, water is clearly the decisive resource affecting productivity (Snyman 1989,1998; Solomon *et al.* 1991; Falkenmark & Suprapto 1992; Falkenmark & Rockström 1993; Smith 1992). Steen (1994) argued that water shortage is so great that it strongly restricts the potential for producing plant and animal biomass even with the best-known techniques. The competition for water will also increase as the human population continues to grow and countries become increasingly industrialised. In the arid and semi-arid areas, surface water is scarce and most of these water sources are recharged by rainfall. Other water sources are dependent on underground reservoirs whose supply are unknown and are often affected by insufficient recharge. Water sources, therefore, reflect the climate and thus the number and proximity of the water sources will change with climate. Quality of water is also affected by climatic factors. Problems related to water, particularly to the Oromo groups, is a reflection of denial of access to water sources for long periods due to the establishment of the irrigation scheme and the national park (Lane *et al.* 1993; Sharon 2000). Therefore, improving the supply of water both in quantity and quality should deserve due attention to improve the welfare of the pastoralists.

4.4.8. Feed resources

In extensive rangeland systems, livestock production is highly dependent on the availability of natural grazing, the quantity and quality of which are primarily determined by the amount and distribution of rainfall, given the temperature regime, soil type and topography of a particular rangeland site. In East Africa, rainfall fluctuates widely from year to year (Solomon *et al.* 1991). Accordingly, livestock in the rangeland areas, experience large seasonal fluctuations in feed availability and quality, which is a normal phenomenon in the arid and semi-arid areas (Snyman 1998). In the study area, there is no available data on livestock weight variations amongst the traditionally managed stock. However, from the general situation in Ethiopia and the pastoralist's perceptions in the area, there is a loss in live-weight and a decrease in milk production throughout the dry season and during the drought. The stress on cattle due to shortage and low quality of forage results in low productivity characterized by low calving rates (50-70%), high death rates for calves before weaning (25-35%), a slow rate to mature size, and a low commercial off take (Sullivan & Farris 1976). The critical shortage of feed reported in this study is in agreement with the situation prevailing across the rangelands in Ethiopia (Coppock 1994; Alemayehu 1998; Mudris 1998; Oba 1998; Beruk & Tafess 2000; EARO 2001) and the shortage in the study districts is mainly a reflection of keeping large stock numbers in a relatively small area. Furthermore, in a tropical environment, availability and quality of forage remain high for a short period of time because of the rapid rate of senescence and decay.

The Afars had limited choices of feed resources in comparison to the Oromo pastoralists. Scoones (1995b) argued that mixed farming systems usually increase the diversity of feed available to animals compared with access to rangeland resources alone. Pastoralists in this segment of the country follow different mechanisms to cope with feed shortage like migration, lopping browse trees, buying feed, using reserve feed and the last was the sale of animals, which are the general practices in these pastoral systems (Solomon *et al.* 1991; Smith 1992; Behnke *et al.* 1993; Coppock 1994; Scoones 1995b). The reason why the sale of animals in response to feed shortage was the last option can be explained by the fact that the marginal nature of the pastoral environments has imposed certain constraints to livestock production. Hogg (1997) and UNDP (1997) argued that livestock are bred for their resilienceto drought and disease rather than productivity. Livestock are both the backbone of their economies and a cultural value in their own right.

In the study area, there are a large amount of by-products produced from the sugar factory. However, the result in the study indicated that only 27% of the respondents use the by-products from the factory for livestock feeding. These are people close to the factory and those involved in crop production and partly employed in the factory. Pastoralists far out in the rangelands and which do not have alternatives (like the use of crop residues) do not have access to this by-product. In this part of the country, the rangeland is degrading rapidly. Therefore, it is essential to facilitate the use of this by-product for those pastoralists without any alternative by organizing the people in the form of cooperatives.

4.4.9. Migration

Scoones (1994) & Swallow (1994) argued that flexible movement over rangelands means that a great variety of grass and tree associations can be exploited, making good use of the varied phenology, production dynamics and forage quality of the different sources. Migration in response to resource availability by different pastoral groups is well documented in Ethiopia (Coppock 1994; Tibabu 1997; Alemayehu 1998; Mudris 1998; Oba 1998; Sharon 2000) and elsewhere in the Africa (Smith 1992; Behnke *et al.* 1993; Scoones 1995a).

The central focuses of the issue of migration in this study rely on three major points, namely, (1) what does this migration mean to range ecology? (2) expansion of bush encroachment and (3) disease incidences and the perception of the pastoralists about migration. This migration in smaller areas creates pressure on the rangeland resources leading to high grazing intensity. High grazing pressure, in turn, reduces the growth rate and reproductive potential of individual plants and in doing so influences the competitive relationships among the different species. Overgrazing of grasses is identified as the main cause of increased woody plant density in the eastern areas of Botswana (Van Vegten 1983). Furthermore, when animals move from place to place in search of feed and water, they can serve as agents in the dispersal of seeds of different species increasing the chance of bush encroachment.

Diseases could also be transmitted from place to place and from domestic to wild animals and visa versa where the significance of this problem is discussed by Grootenhuis (1995), considering the wildlife of Kenya. Macpherson (1995) also discussed the importance of transhumance on the epidemiology of animal diseases, which include the relative importance of factors like risk of coming into contact with geographically limited or seasonally abundant pathogens and also the opportunity for the interaction of domestic and wild animals. Solutions to address this situation remain unclear but unless they are investigated the importance of many parasitic infections go unrecognised (De Beer *et al.* 1991). The perception of the pastoralists indicating that migration is a bad practice opens more room for looking at ways and means of modernizing their life style and the production system they are following.

4.4.10. Rangeland resource use conflict

In semi-arid Africa, a number of analysts see tensions, competition and violent conflict over natural resources as omnipresent in these regions (e.g., Mathieu 1995a, 1995b). Accordingly, the result of this study is in agreement with the report of others in Ethiopia (Tibabu 1997; Alemayehu 1998; Coppock 1994; Mudris 1998; Oba 1998; Sharon 2000; Beruk and Tafesse 2001) and in other pastoral areas in Africa (Smith 1992; Behnke *et al.* 1993; Scoones 1995b). Hussein *et al.* (1999) argued that increasing conflict is mainly due to two factors: (1) changing patterns of resource use and increasing competition for resources and (2) the break down of traditional mechanisms governing resource management and conflict resolution. Conflicts could arise from many problems; however, in the study area the main reason was feed shortage. Therefore a break-through in solving the nutritional constraints of livestock in the study area can solve a major portion of the problem in the study area.

Pastoralists perceptions of the intensity of the conflict varied, but many indicated that the intensity has increased. In light of the growing pressure on rangeland resources in arid rangelands, compounded by population growth and settlement by immigrants (Hussein *et al.* 1999; World Bank 2001) it is likely that the intensity of conflict will increase unless proper interventions are made.

4.4.11. Resource utilisation in conservation area

Like the situation that exists in Eastern and Southern Africa (e.g., Lane & Swift 1989; Coe & Goudie 1990; Schulz & Skonhoft 1996; Bourn & Blench 1999), the pastoralists living in the study districts compete with wildlife for livestock feeding. The result of the study indicated that the pastoralists either harvest material or graze their animals in conservation areas particularly during the dry season. In light of the existing situation in the study area, where efforts to improve the nutritional constraints of livestock is not quite visible, the dependency of the pastoralists on the conservation area for livestock production will increase, which will gradually lead ecological deterioration of the rangelands. Ultimately, the rangeland resource base will reach to a point where it cannot support the different components of the ecosystem. Therefore, mechanisms to utilise all possible alternative feed resources must be planned, if the further degradation of the rangeland ecology is to be prevented.

4.5. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and possible recommendations are made from this study:

- These two pastoral groups live in neighbouring districts. Nevertheless, one of the interesting differences between them lies on their source of income. While the Afars second source of income was the sale of milk and milk by-products, the Oromos usually do not sell these products.
- The problem of poisonous plants and bush encroachment is more prevalent on the side of the Afars than that of the Oromos whereas, water is one of the major problems to the Oromo respondents.
- Livestock feed shortage is the major constraint in the study area. This problem will continue to be the major cause of conflict between the different pastoral groups unless proper interventions like the use of the by-products from the sugar plantation and increasing the productivity of the rangelands are made.
- Despite the difference in ethnicity, it is essential that the management of the two districts work close together as they share common problems.
- The development of incentives like giving prices for those actively involved in natural resource conservation and other mechanisms (involving the elders and village leaders) to encourage the community to get involved in conservation activities should be considered.
- Equipping the agricultural offices with trained personnel in rangeland and wildlife sciences needs due consideration. None of the agricultural offices have even one person trained in rangeland management.
- With the current approach of the communal grazing systems, sustainable utilization of the rangeland ecosystem is not possible. Therefore, alternatives must be planned like better education and employment opportunity.
- The findings in this study clearly justify the need of a more in depth study on the rangeland ecosystem, which is presented in the next chapters.

CHAPTER 5

RANGELAND EVALUATION IN KEREYU-FANTALE AND AWASH-FANTALE DISTRICTS

5.1. INTRODUCTION

Poor nutrition caused by inadequate amounts and low quality of feed is one of the major causes of low livestock productivity in tropical areas (Kaitho 1997). Convectional feeds such as grains and oilseed cakes are not produced in sufficient amounts to meet the requirements of man and livestock in the tropical areas. In these areas, native or natural pastures make up the bulk of the feed. In contrast to the highlands, in which exotic forages are more easily established (Jahnke 1982), sustainable forage interventions in the rangelands depend to a greater degree on improved use of promising indigenous plants (Coppock & Reed 1992). Forage plants usually consumed by domestic animals and game consist mainly of grasses and woody plants. Therefore, assessment of the condition of the vegetation utilised by grazing and browsing herbivores is fundamental for the sustainable utilisation of the grazing ecosystem.

Trollope *et al.* (1990a) defined rangeland condition as the state of health of the rangeland in terms of its ecological status, resistance to soil erosion and potential for producing forage for sustained optimum livestock production. Furthermore, rangeland condition is a function of all plant forms (trees, grasses and shrubs) that occur in it (Danckwerts 1982; Friedel 1987). Rangeland condition cannot, therefore, be simply indexed according to its usefulness for a single priority land use. As with grassland, the composition and structure of each of the other components vary, which adds an extra and complicating dimension to rangeland assessment. In addition, the rangeland is frequently used by pastoralists who own different animal types (browsers and grazers). Assessment techniques need to consider the different vegetation components for the proper utilization of the available rangeland resources. Since animal production is directly related to rangeland condition, rangeland degradation will result in a lower income (Danckwerts & Tainton 1996).

A large number of shrub and tree species have been documented as useful livestock fodders. These plants form an important component of the diet, especially for a variety of the herbivores and also have been used traditionally as a source of fodder for domestic livestock in Asia, Africa, and the Pacific (Skerman 1977; NAS 1979; Le Houerou 1980; Smit 2002). Owing to the importance of both components (grasses and woody vegetations) as a source of feed, it was deemed necessary to assess both components by using different techniques for each of them. The accuracy of determining rangeland condition and trend will depend on the assessor's ability to measure changes as well as the correct interpretation thereof (Van der Westhuizen *et al.* 1999). Adequate knowledge of the particular veld type, as well as of determinants such as soil type, topography and climate are therefore essential. In addition to the assessment of the woody vegetation in terms of density by species, a preliminary investigation was also undertaken on browse (leaf) production using the techniques developed by Smit (1989a, b, 1994, 1996).

Until recent times, research on rangeland dynamics has historically focused on the effects of various management practices on forage production and animal response, little attention given to the impact of grazing on the nutrient dynamics of the soil. Therefore, the objectives of this study were to determine the condition of the rangelands by using herbaceous and woody measures and some soil parameters. In the end, the intention was to come up with possible recommendations to minimize the further degradation of the rangeland ecosystem.

5.2. PROCEDURES

5.2.1. Site selection

In the identification of major rangelands commonly grazed by the animals of pastoralists for the assessment, initially important documents and maps pertinent to the study area regarding vegetation were reviewed and examined. This was followed by a discussion with the respective agricultural development officers and the elders of the two pastoral groups about the nature and location of the major rangelands that are commonly grazed by the animals of the pastoralists. A repeated reconnaissance survey was made with respective elders and experts from the agricultural development offices throughout the study districts to observe the nature and condition of the rangelands. The final decision was also supported by results from **Chapter 4**. Therefore, in the selection of rangelands sites for the study, the importance of each of the major rangelands as perceived by the pastoralists and the respective agricultural development officers was taken as a major criteria and their representation of the major rangelands areas in the study districts proper was also considered. However, one rangeland area in Awash-fantale district was included in the rangelands sites identified for the study, because of the pastoralists fear of the expansion of *Prosopis juliflora* to their rangelands from the neighbouring districts. Accordingly, 10 rangelands sites from Kereyu-Fantale and 11 rangelands sites from Awash- Fantale were identified for the assessment (**Table 5.1**).

5.2.2. Field layout

Two different field layouts were used for the study. In rangelands sites without woody vegetation, three sampling sites (the minimum number of replicates) were identified through repeated ground surveys after thoroughly observing the nature of the vegetation and slope. Adequate care was also taken in such a way that each identified sampling site be representative of the rangeland site from which the sampling site was identified. For rangeland sites where both components (grass and woody layer) contribute as a source of livestock feed, a sampling block of land, 3 km x 1 km (300 ha), representative of the vegetation under consideration, was demarcated. In all of the rangeland sites, a 25-50 m strip of land was left aside in order to avoid edge effects. The demarcated area was further sub-divided into three equal plots for the purpose of stratification (1 km x 1 km). In each of the sub-divided plots, a belt transect of 50 x 4 m was laid out randomly. The total number of belt transects per rangeland site was, therefore, three. At each of the belt transects, the four corners of the plot were marked using wooden pegs and this was undertaken before the beginning of the rainy season. The above lay out was done for both of the study districts.

In three rangeland sites that were either close to a river or lake, sampling was undertaken not closer than 400-600 m from the river or lake, depending on the situation.

5.2.3. Data collection

From the rangeland sites of the two study districts, grass species composition, basal cover, estimated soil erosion and natural pasture yield data were collected for the herbaceous layer, while woody species composition, density, browse production and phenological data were collected for the woody layer. Soil samples were also taken to undertake physical and chemical analyses for some parameters. The techniques and/or methods followed in collecting the different parameters are given below.

5.2.3.1. Floristic composition of the herbaceous layer

The species composition of the herbaceous layer was determined, based on the frequency of occurrence, using a wheel point apparatus (Tidmarsh & Havenga 1955) where the nearest plants were recorded. For the rangeland sites without the woody vegetation, at each of the sample site, two plots of 100 x 15 m were marked in such a way that they give a total of 1 000 point observations per site. In rangeland sites with woody vegetation, 300 point observations were recorded at each of the belt transect and the readings were undertaken at 3 m interval by revolving the wheel point. Although, the use of the wheel point method in rangeland condition assessment has not been practiced in Ethiopia, studies conducted by Hardy & Walker (1991) using the Richards function (Richards 1959), have shown that a sample size of 300 point observations are adequate for detailed scientific studies.

Table 5.1. Rangeland sites identified for the study in Awash-Fantale and Kereyu-Fantale districts.

Awash-Fantale	**Altitude (m.a.s.l)**	**Vegetation components Studied**	**Kereyu-Fantale**	**Altitude (m.a.s.l)**	**Vegetation component studied**
Lahali	932	Herbaceous and woody layers	Aleka	1050	Herbaceous layer
Degage	1028	Herbaceous and woody layers	Harole1	1036	Herbaceous and woody layers
Madala	909	Herbaceous layer	Harole	993	Herbaceous layer
Madala1	909	Herbaceous and woody layers	Chopi	1137	Herbaceous and woody layers
Top of bud	811	Herbaceous layer	Mogassa	1046	Herbaceous and woody layers
Samayu	999	Herbaceous and woody layers	Kara	1384	Herbaceous and woody layers
Top of bud1	809	Herbaceous and woody layer	Kolbayu	1063	Herbaceous and woody layers
Bulga riverside (BRS)[1]	778	Herbaceous and woody layers	Tulu Dimitu	1474	Herbaceous and woody layers
Dellakara	868	Herbaceous and woody layers	Fantale[1] Near to the Cretor	1654	Herbaceous and woody layers
Awash-Dulcha junction	811	Woody layer	Beseka	990	Herbaceous layer
Asobabad	865	Herbaceous layer			

[1]The marked rangeland sites fell on either side of the two pastoral groups.

At each point observation, the nearest herbaceous plant, within a radius of 300 mm was recorded by species for grasses which included both annuals and perennials. Non-grass herbaceous species were combined as forbs. If no herbaceous species of the given criteria occurred within the given radius of the point, it was recorded as "bare ground". Bare ground was treated as if it was a plant species and gave an indication of plant density (Mentis 1984), which is also an important additional parameter for recording real changes in rangeland condition (Danckwerts & Teague 1989).

Identification of the species was undertaken at two levels. Plants that can be identified easily in the field were identified using field guides (Irvine 1961; Verdcourt *et al.* 1965; CADU 1974; Ibrahim & Kabuye 1987; Reinhard & Admasu 1994; Van Oudtshoom 1999) and experienced field technicians' knowledge from Adami Tulu research center was also used. For those plant species not identified in the field, a herbarium sample of each species was pressed, labelled and sent to the National Herbarium of Addis Ababa University for identification. The vegetation survey was undertaken from 15 August 2001 to 15 September 2001, at the time when most plants were in their flowering stage.

The identified grass species were classified into three groups based upon desirability. The desirability ratings were based on their long-term reaction to grazing (ecological groups) and palatability. The ecological status (decreaser and increaser species) as defined by Foran *et al.* (1978) was also taken into consideration. Accordingly, they were divided into highly desirable, desirable and less desirable species. Highly desirable grass species include species that are decreasers and perennials with a high palatability based upon the pastoralists perceptions, while the desirable grass species are those that increase in abundance with moderate over-utilisation (Increaser IIa), perennials and which were average or high in terms of their palatability. The less desirable species include those species of grasses that increase in abundance with severe or extremely severe over utilisation (Increaser IIb and IIc). This group includes both perennial and annual species that were less palatable as perceived by the pastoralists. The classification of the grass species into decreaser, IIa, IIb and IIc followed the method described by Vorster (1982) with some modification to suit the local conditions. However, Increaser I species were not considered in the study, the reason was indicated by Tainton (1981), in the more arid region, the Increaser I group is not represented since climatic limitations, notably rainfall, prevent succession from proceeding beyond a certain stage.

5.2.3.2. Basal cover

The same apparatus (wheel point) used in determining species composition was used for basal cover assessment and was determined from the proportion of strikes as described by Tidmarsh & Havenga (1955) and Foran *et al.* (1978).

5.2.3.3. Grass dry matter yield

The standing crop of the natural pasture was used to estimate the available yield as a measure of annual productivity. At each of the sample sites, the herbaceous vegetation (grasses & forbs) was harvested at stubble height when the herbaceous plants were at 50% flowering stage. This was done by clipping the vegetation in 5 randomly placed quadrates (1 x 1m each) per identified sampling site. Separation was made between grasses and forbs, but the scale of the sampling, did not permit separation into the different grass species. At the end of the fieldwork, the samples were oven-dried at 105 °C for 24 hours and weighed.

5.2.3.4. Soil erosion

At each of the sampling site, the status of the soil surface was assessed visually at every fifth point of the wheel point during the vegetation survey. The assessment of soil erosion was based on the amount of pedestals (higher parts of soils, which can be held together by plant roots, with eroded soil around the tuft) and in severe cases, the presence of pavements (terraces of flat soil, normally without basal cover, with a line of tufts between pavements according to the method described by Baars *et al.* (1997). The values given were 5,4,3,2,1 and 0 for no soil movement, slight sand mulch, slope-sided pedestals, steep-sided pedestals, pavements and gullies, respectively.
Of the rangeland sites identified in Awash-Fantale district, in one of them, it was not possible to study the herbaceous layer, because it was difficult to cross the Bulga river during the time when plants could be identified. As a result, no survey in the herbaceous layer was undertaken.

5.2.3.5. Woody vegetation sampling

All rooted live woody plants in each of 50 x 4 m (200 m^2) belt transects, regardless of being single-stemmed or multi-stemmed, were counted and used for an estimate of woody vegetation density per hectare. Furthermore, the spatial canopy of all rooted live woody plants encountered in the belt transects, were measured at peak biomass. The measurement consisted of the following: (i) maximum height, (ii) height where the maximum canopy diameter occurs, (iii) height of first leaves or potential leaf-bearing stems, (iv) maximum canopy diameter, and (v) base diameter of the foliage at the height of the first leaves. The spatial canopy volume of each woody plant was calculated using the BECVOL model (Smit, 1989a,b, 1996).

In order to measure the heights and diameters of the woody vegetation, two calibrated aluminium poles of 2 and 4 m were used. Dimensions of those woody plants too tall to measure with the poles were taken using a dimension meter (Smit 1989 c). Furthermore, each woody plant was allocated a leaf carriage score, in order to determine leaf phenology : where, 0= no leaves, 1= 1-10% of full leaf carriage, 2= 11-40 % of the leaf carriage, 3= 41-70% of the full leaf carriage, 4 = 71-100% of full leaf carriage (Smit 1994; Smit 2001). The leaf phenological scoring was undertaken for two consecutive months during the wet seasons (third and fourth week in August and September, 2001) and for two consecutive months during the dry season (third and fourth week in December 2001 and January 2002). For the purpose of leaf phenological observations during the dry season, 12 representative plants per species, were randomly selected in each plot but, in the case of less abundant species, the available individuals were selected. The selection procedure for the woody vegetation was based on a proportional sampling of all representative sizes of the woody vegetation in each plot.

5.2.3.6. Soil sampling and chemical analysis

Ten soil samples were taken randomly in each of the sample sites to a depth of 150 mm with an auger. Each set of 10 samples was bulked to account for short-range spatial variability, thoroughly mixed and one sub sample taken, labelled and kept in a plastic bag for analysis. The analyses included pH (H_2O), electrical conductivity (EC), percent total nitrogen (N), percent organic carbon (OC), texture, available phosphorous (P) and available potassium (K). Initially the soil samples were air-dried then sieved to pass a 2 mm sieve. The pH of the soil was determined in a 1:2.5 ratio of the respective suspensions (Thun *et al.* 1955), while electrical conductivity was determined in a 1:2.5 soil water suspension (Chopra & Kanwar 1976). Percent OC was determined according to the Walkley & Black method (1934), total N using the Kjeldahl procedure (Jackson 1958) and available P using the method of Bray & Kurtz (1945). The different particle sizes were determined using the Bouyoucous hydrometer method (Day 1965) and available K determined using the Morghan extracting solution.

Of the rangeland sites, identified for the study in Awash-Fantale, soil samples were not taken in two of them. In one case the soil was too rocky and in the other, there was a logistical problem in obtaining the sample.

5.2.4. Data analysis

5.2.4.1. Grass species composition and other related parameters

The frequency of occurrence of each species, including that of the bare ground, was expressed as a percentage of the total number of points, while the proportion of the different grass species according to their desirability (highly desirable, desirable and less desirable) and life form (annual and perennial) was also calculated using percentages. In the ordination of the different grass species, a detrended correspondence analysis (DCA) in the DECORANA package (Hill 1979), was used, unfortunately failed to reveal a meaningful community gradient in both districts (**Appendix 5.1 and 5.2**). Basal cover was calculated from the proportions of strikes as described by Foran *et al.* (1978) and Mentis (1981). For data on grass DM yield, estimated soil erosion values and soil parameters, mean and standard deviations were calculated for each of the studied rangeland sites.

Estimation of the grazing capacity was made from the yield of the grass layer, using the formula proposed by Moore *et al.* (1985) and again described by Moore & Odendaal (1987) and Moore (1989) as follows:

$$Y = d \div \frac{[DM \times f]}{r}$$

Where, y = grazing capacity (ha AU^{-1})
d = number of days in a year (365)
DM = total grass DM yield (kg ha^{-1})
f = utilization factor
r = daily grass DM required per LSU (2.2% of body mass = 10 kg day^{-1})

The grazing capacity was calculated using both hectare per Large Stock Unit (ha LSU^{-1}) and hectare per Tropical Livestock Unit (ha TLU^{-1}). In the calculation of grazing capacity based upon TLU, the assumption taken was that, an animal will consume 2.5 % of its body weight (Boudet and Riviere 1968; Minson & McDonald 1987), thus each TLU will consume 6.25 kg of forage dry matter daily. In both LSU and TLU, the utilization factor used is 0.35. Theoretically, the utilization factor expressed as a decimal value represents that part of the available material that can be consumed. Actual consumption is limited by grazing preferences of the animals and losses due to trampling and environmental factors. The percentage of available dry matter that the animals will actually consume is determined by factors like, palatability of the plant material and the species of the animal (bulk feeder or concentrate feeder). However, even when the animals will be able to consume a high percentage of the available dry matter, their intake should be limited to pre-determined level to avoid overgrazing. The utilization factor may thus vary from 0.2 (20%) to 0.5 (50%) with an average of 0.35 (35%) that is commonly used (Smit 2002).

The condition of each of the rangeland sites, based upon species composition, was calculated by multiplying the percentage frequency of each of the species with the value attributed to each species based upon desirability and this was summed for each rangeland and expressed as a percentage. The experience and knowledge that was developed in South Africa particularly Vorster (1982), Tainton (1999) and Van

Oudtshoorn (1999) were used with some modifications to suit local conditions. Grass species of highly desirable, desirable and less desirable qualities were multiplied with a value of 10, 7 and 4, respectively, while bare ground and forbs were allocated a value of 1 as they were undesirable. The maximum score is 1000, i.e., 100% highly desirable species and the minimum is 100, i.e., 100% undesirable species.

5.2.4.2. Woody layer

Leaf dry mass and leaf volume estimates were calculated using a modified version of the quantative description technique of Smit (1989a) and Smit (1989b) as described by Smit 1994. This technique provides estimates of the leaf dry mass and the leaf volume at peak biomass, based on the relationship between the tree's spatial canopy volume and its leaf dry mass and leaf volume. This technique was compiled into the BECVOL-model (Biomass Estimates from Canopy Volume) (Smit 1994). It incorporates regression equations, developed from harvested trees, which relate spatial volume (independent variable) to leaf volume (dependent variable): in $y = -3.880 + 0.708x$, $r=0.941$, $p<0.001$, and leaf volume (dependent variable): In $y = -2.933 + 0.697x$, $r = 0.948$, $p<0.001$. Spatial tree canopy volume (x) was transformed to its normal logarithmic value, while y represents the estimated leaf dry mass (g) and leaf volume (cm^3) respectively. The number of ETTE ha^{-1} was subsequently calculated from the leaf volume estimates (1 ETTE = mean leaf volume of a single-stemmed tree with a height of 1.5 m = 500 cm^3 leaf volume (Smit 1989a). The BECVOL-model, in addition to the regression equation for specific tree, incorporates a number of "general" regression equations (e.g., for microphyllous and broad-leaved tree species), which (Smit 1989a, b) facilitated the calculations for those species that did not exist on the list of the harvested tree species. In addition to the total leaf DM ha^{-1}, stratified estimates of the leaf DM ha^{-1} below 1.5 m, 2.0 m and 5.0 m respectively, were also calculated, with the BECVOL- model (Smit 1994). The height of 1.5 m represents the mean browsing height of goats (Aucamp 1976) and impala (*Aepyceros melampus*) (Dayton 1978), while 2.0 m and 5.0 m represents the mean browsing height of kudu (*Tragelaphus stepsiceros*) (Wentzel 1990) and giraffe

(*Giraffa camelopardalis*) (Skinner & Smithers 1990), respectively. These browsing heights are mean heights and not maximum browsing heights, which were only used to draw comparisons. It is known that large individuals are able to reach higher than those mean heights, e.g., 2.5 m and 5.5 m for kudu and giraffe, respectively (Dayton 1978), while breaking off branches may enable some browsers to utilize browse at higher strata (Styles 1993).

Estimates of the browsing capacity for the most important woody plants based on leaf DM were made from the leaf DM estimate, using the formula proposed by Smit (1999b).

$$Y = \frac{DM^{(1.5)} \times p \times f}{r}$$

Where, y	=	browsing capacity (ha BU^{-1})
$DM^{(1.5)}$	=	total leaf DM yield ha^{-1} up to a height of 1.5 m
p	=	phenology (0= no leaves, 1.0 = peak biomass)
r	=	daily browse DM required per BU (3.5 kg day^{-1})
BU	=	Browser unit defined as the metabolic equivalent of an average kudu with a mass of 140 kg (Dekker 1997)
f	=	utilisation factor

From the stratified BECVOL estimates of leaf dry mass below 1.5 m and leaf dry mass greater than 1.5 m up to a height of 5 m, the approximate browsing capacity was calculated for the year. The available dry mass of the two strata was calculated by multiplying the total dry mass with a utilization factor and phenology of the different woody plant species in different months. The leaf phenology for December and January (critical dry months) and August and September (wet months) was obtained by collecting data in the field, while for the rest of the months it was estimated based upon the long term experience of the pastoralists. The rainfall pattern of the study area was also taken into account. The leaf phenology and palatability for each of the specific rangeland sites were obtained by taking the average of the species in the respective rangelands. The allocated leaf phenological values ranged from 0.2 (lowest leaf yield) to 1 (maximum leaf yield).

5.2.4.3. Statistical analysis

In order to establish relationships among the variables studied (Grass yield, basal cover, bare ground, estimated soil erosion values, ETTE ha^{-1}, soil parameters and altitude), particularly with reference to their relation with the grass yield, a correlation matrix was undertaken using SAS (Statistical Analysis System) (1987). Based on the results obtained in the correlation matrix and taking into account the normal restrictions with regard to the inclusion of correlated variables in multiple regression functions, a series of stepwise multiple regression analyses were conducted with grass DM yield as the dependent variable and the other measured environmental variables as independent variables using SAS (1987).

5.3. RESULTS

5.3.1. Awash-Fantale district (Afar)

5.3.1.1. Herbaceous layer

5.3.1.1.1. Grass species composition

A total of 32 grass species were identified in the study district, with *Chrysopogon plumulosus, Dactyloctenium aegypticum, Tetrapogon cenchriformis, Sporobolus natalensis, Cymbopogon commutatus, Paspalm dilatatum, Sporobolus spicatus and Sporobolus ioclados*, being the most abundant species (**Table 5.2**). Based upon their life form, 71.9% were perennials and the remaining (28.1%) annuals, whereas, based upon desirability, 18.8%, 28.1% and 53.1% comprised highly desirable, desirable and less desirable grass species, respectively. Of the 10 rangeland sites studied in Awash-Fantale district, in 5 of them *C. plumulosus* was the dominant grass species ranging in abundance from 3.7% to 86.3%. At the Lahlai site, the most dominant grass was *T. cenchriformis* (44.8%), while Madala 1 was dominated by *D. aegypticum* (30.0%). The two dominant grass species at Asobabad were *S. spicatus* (41.8%) and *S. ioclados* (29.1%), while *S. natalensis* (13.4%) and *D. aegypticum* (12.0%) were abundant at Samayu, and 36.0% of the grass layer along the Bulga riverside was dominated by *P. dilatatum* (**Figure 5.1**). The non-grasses, combined as forbs, comprised 10.5%, despite the variation in the abundance of forbs across the rangeland sites, which varied between 0.6% (Top of bud) and 32.2% (Samayu).

5.3.1.1.2. Bare ground

The percent bare ground (mean ±SD), over the rangeland sites within the Awash-Fantale district, varied from 1.8 to 10.8 with a mean of 5.5, which was highest at Asobabad and lowest at Top of bud (**Table 5.3**).

5.3.1.1.3. Basal cover

The percent basal cover (mean ± SD) for the rangeland sites was highest at Top of bud (4.8 ±0.4), and lowest at Samayu (2.4 ±0.6), while the overall mean basal cover across the rangeland sites studied was 3.4%. Of the studied rangeland sites, 30% had a basal cover less than 3%, whereas, 50% of them had a cover value of less than four percent. Only 20% of the studied rangelands had a cover value greater than 4%, which in general implied that most of the rangelands have a very low basal cover (**Table 5.3**).

5.3.1.1.4. Grass dry matter yield

The dry matter yield of the grass layer (mean ± SD) was lowest at Samayu (256.6 kg ha^{-1}) and highest at Degage (857.0 kg ha^{-1}) with a mean yield of 437.1 kg ha^{-1}

Table 5.2. Desirability, life form, and frequency (%) of the different grass species in Awash-Fantale district.

Species	Desirability	Life form	Frequency (%)
Chrysopogon plumulosus	Highly desirable	Perennial	29.73
Dactyloctenium aegypticum	Less desirable	Annual	8.05
Tetrapogon cenchriformis	Highly desirable	Perennial	6.90
Sporobolus natalensis	Less desirable	Perennial	5.85
Cymbopogon commutatus	Desirable	Perennial	4.59
Paspalum dilatatum	Less desirable	Perennial	4.47
Sorobolus spicatus	Less desirable	Perennial	4.17
Sorobolus spicatus	Less desirable	Perennial	4.17
Sorobolus ioclados	Desirable	Perennial	2.92
Paspalum glumaceum	Desirable	Perennial	2.59
Setaria verticellata	Less desirable	Annual	2.18
Coelachyrum poiflorum	Less desirable	Annual	1.73
Cynodon dactylon	Less desirable	Perennial	1.45
Tragus berteronianus	Less desirable	Annual	1.37
Eragrostis cilianensis	Less desirable	Annual	1.36
Pennisetum stramineum	Desirable	Perennial	1.32
Cymbopogon excavatus	Highly desirable	Perennial	1.30
Cenchrus ciliaris	Highly desirable	Perennial	0.90
Cenchrus setigerus	Highly desirable	Perennial	0.86
Heteropgon contortus	Desirable	Perennial	0.70
Panicum coloratum	Highly desirable	Perennial	0.52
Urochloa panicoides	Less desirable	Annual	0.29
Lintonia nutans	Desirable	Perennial	0.25
Chloris roxburghiana	Desirable	Perennial	0.20
Hyparrhenia hirta	Desirable	Perennial	0.11
Aristida adscensionis	Less desirable	Annual	0.06
Aristida adoensis	Less desiable	Perennial	0.05
Sporobolus festivus	Less desirable	Perennial	0.02
Digitaria ternata	Less desirable	Annual	0.02
Eragrostis racemosa	Desirable	Perennial	0.01
Chloris pycnothrix	Less desirable	Perennial	0.01
Sorghum purpureosericeum	Less desrable	Annual	0.01
Enneapogon schimperanus	Less desirable	Perennial	0.01

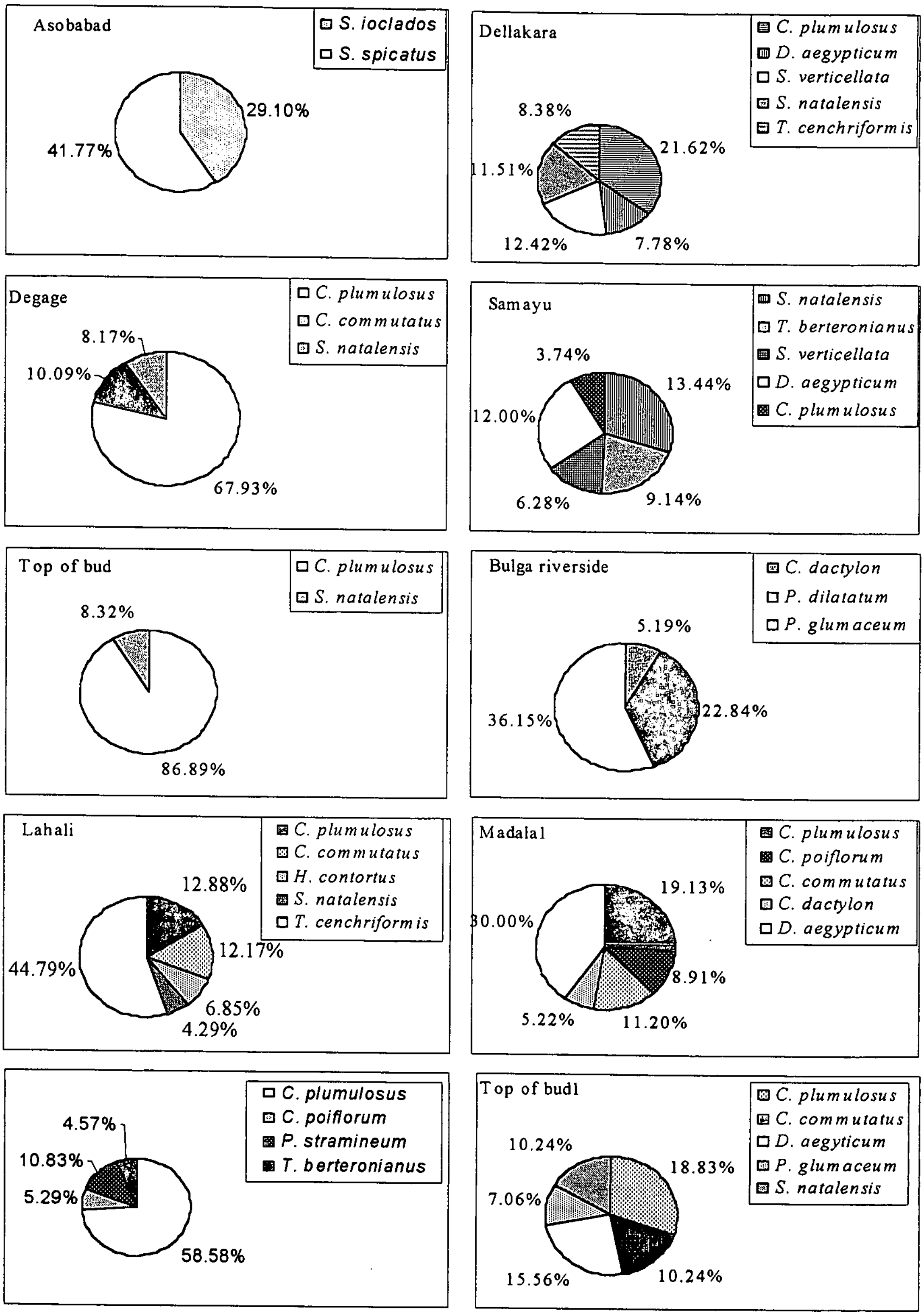


Figure 5.1. The most dominant grass species in each of the rangeland sites in Awash-Fantale district.

Table 5.3. Mean and standard deviation of bare ground (%), basal cover (%), grass yield (kg ha^{-1}), estimated soil erosion values and grazing capacity (ha LSU^{-1} and ha TLU^{-1}) for the rangeland sites studied in Awash-Fantale district (N= 10; HL = Herbaceous layer and WL = Woody layer).

Parameter	**Rangeland**									
Rangeland sites	**Lahali**	**Dega-ge**	**Bulga River**	**Madala-1**	**Top of bud1**	**Della-Kara**	**Sama -yu**	**Top of bud**	**Madala**	**Asob-Abad**
Vegatation layer studied	**HL & WL**	**HL & WL**	**HL & WL**	**HL & WL**	**HL & WL**	**HL**	**HL & WL**	**HL**	**HL**	
Bare ground (%)	4.3± 1.44	3.4 ± 0.63	8.1 ± 1.6	2.9± 0.9	4.6± 2.2	4.1± 0.5	10.2± 4.4	1.8± 1.1	5.0± 0.5	10.8± 3.1
Basal cover (%)	2.9± 1.2	4.6 ± 2.0	2.3 ± 0.8	3.9± 0.6	3.4± 0.3	3.3± 0.8	2.4± 0.6	4.8± 0.4	3.7± 0.7	3.0± 0.0
Grass DM yield (Kg ha^{-1})	360.2± 20.2	857 ±44.6	292.8 ± 35.8	328.8± 96.9	325.0± 90.3	359.8± 43.2	256.6± 69.5	558.8± 90.9	488.1±1 41.8	543.8± 45.8
Estimated soil erosion	Rocky	3.00± 1	4 ± 0.0	3.00± 0.6	3± 0.0	4± 0.0	4± 0.6	3± 0.6	3± 0.6	2± 0.6
Grazing capacity (ha/ LSU^{-1})	25.3± 1.4	10.7± 0.6	31.2 ± 4.1	27.5± 9.6	28.1± 8.6	25.4± 3.0	35.6± 10.7	16.3± 2.8	18.7± 6.3	16.8± 1.4
Grazing capacity (ha TLU^{-1})	15.8± 0.9	6.7 ± 0.4	19.5 ± 2.6	17.4± 6.0	17.6± 5.4	15.9± 1.9	22.2± 6.4	10.2± 1.7	11.7± 3.9	10.5± 0.9

for the studied rangeland sites. The lowest and the highest grass DM yields were obtained in rangeland sites with a woody layer (**Table 5.3**). Unfortunately, the grass DM yield was not studied on a seasonal basis.

5.3.1.1.5. Estimated soil erosion

The estimated soil erosion values, across the rangeland sites, varied between 2 and 4 (**Table 5.3**), while 11.1%, 55.6% and 33.3% of the studied rangeland sites had a value of 2, 3 and 4, respectively. This indicates that the condition of the soil surface varied between steep sided pedestals to slight sand mulch, which clearly shows the loss of soil from the surface.

5.3.1.1.6. Grazing capacity

The grazing capacity varied from 10.7 to 35.6 (ha LSU^{-1}) with a mean value of 23.6 (ha LSU^{-1}), whereas, when the grazing capacity expressed in ha TLU^{-1}, the values varied between 6.6 and 22.2 with an overall mean value of 14.7 (**Table 5.3**). The grazing capacity was the lowest at Samayu, where the yield of the grasses (256.6 kg/ha) and the basal cover (2.4) of the site was the lowest. On the other hand, the grazing capacity of Degage was better than other sites, where the yield of the grass was higher than the others.

5.3.1.1.7. Rangeland condition

The condition of the rangeland sites, based on desirability (grass species composition, forbs and bare ground) was highest at top of bud (90.52%), and the lowest at Samayu (30.52%) (**Figure 5.2**), while the mean across the rangeland sites was 62.79%.

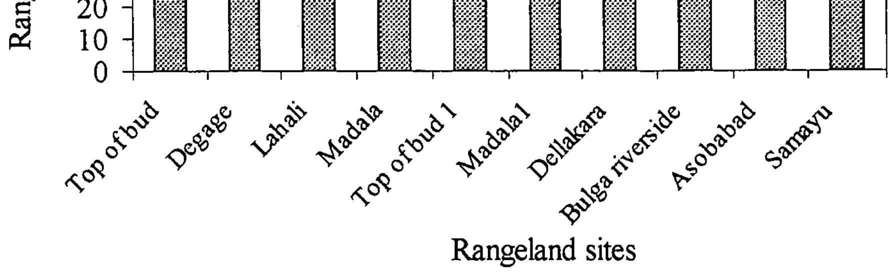


Figure 5.2. Rangeland condition of the rangeland sites in the Awash-Fantale district based upon desirability of species.

5.3.1.2. Woody vegetation

5.3.1.2.1. Woody vegetation composition, density, ETTE and palatability of woody plants

In the rangelands studied, 25 woody species were recorded in the transects (**Figure 5.3**). There were also other woody species that were not recorded within the transects, such as *Dobera glabra*, which will increase the number of woody species in the area. Based upon abundance (%), the dominant woody plants in the rangeland sites studied were species of Acacia (*A. senegal and A. nubica*), species of *Acalypha (A. fruticosa* and *A. indica*) and species of *solanum* (*S. marginatum* and *S. incanum*) and *Vernonia cinerascens* (**Figure 5.3**). The *Acacia* species (*A. senegal, A. robusta, A. mellifera, A. nubica, A. tortilis, A. nilotica* and *A. seyal*) generally comprised 43% of the total woody vegetation density, which implies that the area is dominated by Acacia species. Of the species of *Acacia*, *A. tortilis* (0.31%) and *A. nilotica* (0.57%) were the least abundant (**Figure 5.3**).

When the woody vegetation data is expressed in terms of ETTE (%) three woody species were dominant, namely, *A. senegal, A. nubica* and *P. juliflora* (**Figure 5.4**), which were followed by *A. nilotica*, *C. rotundfolia*, *Acalypha* species and *A. mellifera*.

The woody vegetation density was highest at Top of bud (3 733 plants ha^{-1}) and lowest in rangeland dominated by *P. juliflora* (467 plants ha^{-1}). However, when the woody vegetation density data was expressed in terms of ETTE ha^{-1}, the values were higher in rangeland sites dominated by *P. juliflora* (10 722 ETTE ha^{-1}) than at top of the bud (10 130 ETTE ha^{-1}). Of the 8 rangeland sites, in three of them, the highest ETTE ha^{-1} value was contributed by *A. senegal* (Dellakara= 4 633; Lahlai= 3 617 and Top of bud1= 7 999 ETTE ha^{-1}), while two rangeland sites were dominated by *A. nubica* (Madala1= 6 602; Samayu= 6 984 ETTE ha^{-1}). In the remaining three-rangeland sites, *A. robusta* (1 658 ETTE ha^{-1}), *A. nilotica* (4 296 ETTE ha^{-1}) and *P. juliflora* (10 722 ETTE ha^{-1}) contributed the highest ETTE values ha^{-1}. This result indicated that description of woody vegetation in terms of density alone might not be a good indicator of the competitive behaviour of woody plants on the herbaceous layer. Therefore, from the viewpoint of competitive behaviour, it is better to express the values in ETTE ha^{-1} rather than density. The general conclusion is that the area is bush encroached particularly with *A. senegal, A. nubica* and *P. juliflora*.

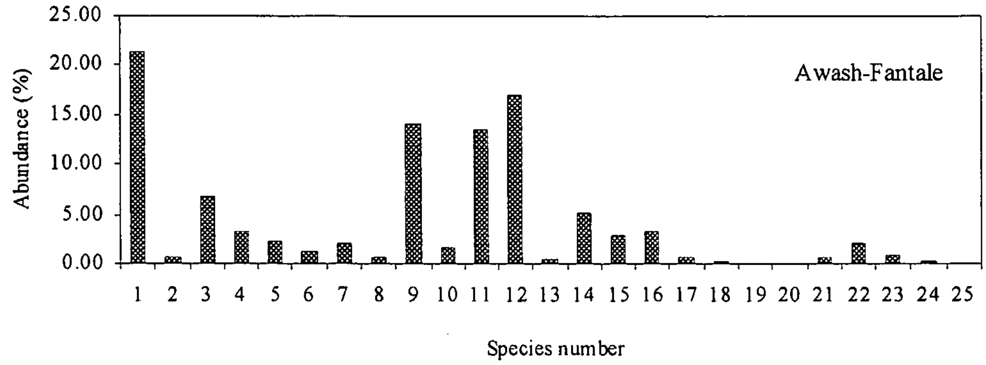


Figure 5.3. Abundance (%) of woody vegetation in Awash-Fantale district (based upon woody plants ha^{-1}). Key to the species: 1 = *Acacia senegal*; 2= *Grewia bicolor*; 3 = *Vernonia cinerascens*; 4= *Grewia tenax*; 5= *Acacia robusta*; 6= *Grewia villosa*; 7= *Balanites aegyptica*; 8= *Rytigynia neglecta*; 9= *Acacia fruticosa & Acacia indica*; 10= *Acacia mellifera*; 11= *Solanum marginatum & Solanum incanum*;12= *Acacia nubica*; 13= *Acacia tortilis*; 14= *Cordia sinensis*; 15= *Withania somnifera*; 16= *Cadaba rotundfolia*; 17= *Salvadora persica*; 18= *Causerina equisetifolia*; 19= *Capparis fascicularis*; 20 = *Ficus gnaphalocarpa*; 21= *Acacia nilotica*; 22= *Prosopis julifloria*; 23= *Cryptostegia grandiflora*; 24= *Erythrina abyssinica*; 25= *Acacia seyal*.

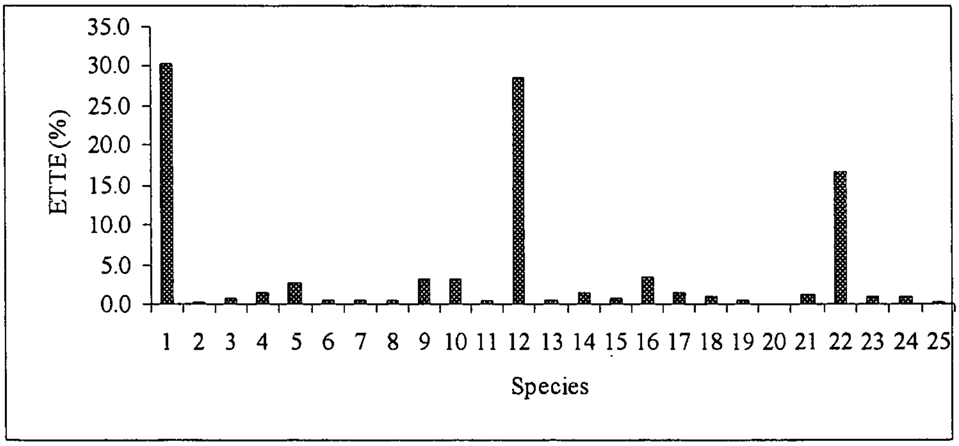


Figure 5.4. Species composition of woody vegetation based on ETTE (%) in Awash-Fantale district. Key to the species: 1 = *A. senegal*; 2= *G. bicolor*; 3 = V. *cinerascens*; 4= *G. tenax*; 5= *A. robusta*; 6= *G. villosa*; 7= *B. aegyptica*; 8= *R. neglecta*; 9= *A. fruticosa & A. indica*; 10= *A. mellifera*; 11= *S. marginatum & S. incanum*;12= *A. nubica*; 13= *A. tortilis*; 14= *C. sinensis*; 15= *W. somnifera*; 16= *C. rotundfolia*; 17= *S. persica*; 18= *C. equisetfolia*; 19= *C. facscicularis*; 20 = *F. gnaphalocarpa*; 21= *A. nilotica*; 22= *P. juliflora*; 23= *C. grandiflora* ; 24= *E. abyssinica*; 25= *A. seyal*.

The pastoralists classified each of the woody species on the basis of palatability, i.e., highly palatable, intermediate and unpalatable. Accordingly, 51.9%, 14.8% and 33.3% were highly palatable, intermediate and unpalatable, respectively (**Table 5.4**).

Table 5.4. Palatability of woody plants as rated by the pastoralists in Awash-Fantale district.

Highly palatable	**Intermediate**	**Unpalatable**
Acacia senegal	*Grewia bicolor*	*Solanum incanum*
Vernonia cinerascens	*Acacia robusta*	*Withania somnifera*
Grewia tenax	*Acacia nubica*	*Acalypha indica*
Ficus gnaphalocarpa	*Cadaba rotundfolia*	*Erythrina abyssinica*
Acacia mellifera		*Casuarina equisetfolia*
Acacia tortilis		*Cryptostegia grandiflora*
Grewia villosa		*Acalypha fruticosa*
Cordia sinensis		*Solanum marginatum*
Balanites aegyptica		*Prosopis juliflora*
Rytigynia neglecta		
Salvadora persica		
Acacia nilotica		
Capparis fascicularis		
Acacia seyal		

5.3.1.2.2. Browse production

The leaf DM for the rangeland sites and for each individual woody plant that contributed more than 1% to the total leaf DM are presented in **Figures 5.5** and **5.6**. In addition, the results of the phenological observations for these species, where 1 means the highest leaf DM and 0.2 the lowest leaf DM for each of the species in the respective rangeland site for the month of August and September (wet months) and December and January (dry months) are presented below.

Lahlai

The total leaf DM for the Lahlai site was 1 056 kg ha^{-1} (**Figure. 5.5**), dominated by *A. senegal* (842 kg ha^{-1}, **Figure 5.6**) and four additional species of woody plants contributed more than 1% to the total leaf DM, whereas the total leaf DM below 1.5 m and greater than 1.5 – 5.0 m was 340 kg ha^{-1} and 716 kg ha^{-1}, respectively. The leaf phenology for the 5 species during August and September was 1.0 meaning that the trees were full of leaves, while, *A. senegal*, *G. villosa*, *R. neglecta* had a value of 0.4 (low leaf abundance) during December and January. *Balanites aegyptica* and *G. tenax* had a value of 0.6 and 0.2 (least in December and January), respectively.

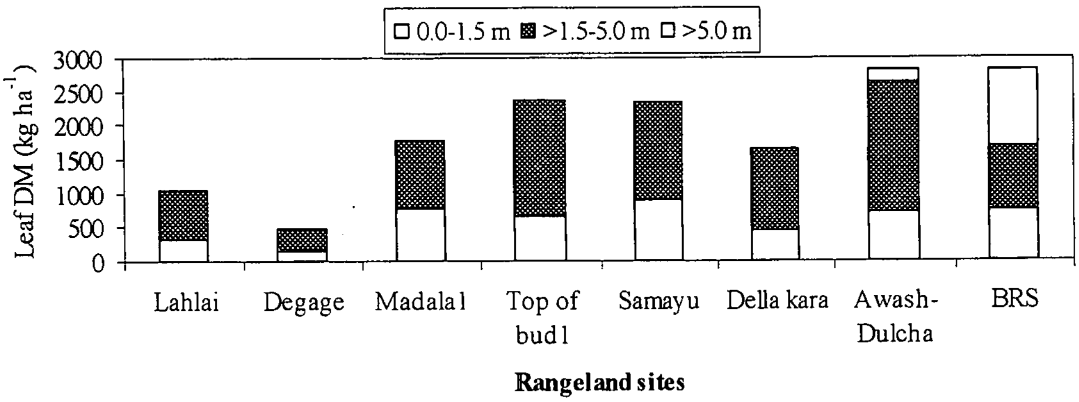


Figure 5.5. Browse production stratified into height strata across the rangland sites in Awash-Fantale district.

Degage

Degage had the lowest total leaf DM (489 kg ha^{-1}) with a leaf DM below 1.5 m and greater than 1.5 up to 5 m Of 155 kg ha^{-1} and 334 kg ha^{-1}, respectively (**Figure 5.5**.). On a leaf DM basis, *A. robusta* contributed the most (387 kg ha^{-1}, **Figure 5.6**) and four other individual woody plants contributed more than 1% to the total leaf DM. The phenology of the leaves for *G. bicolor*, *G. tenax* and *A. robusta* was 1 in August and September, while it was 0.6 in December and January. *Acacia senegal* had a leaf phenological value of 1 during the wet months and 0.4 in the dry months whereas, *V. cinerascens* had a phenological value of 1.0 (wet months) and 0.2 in December and January.

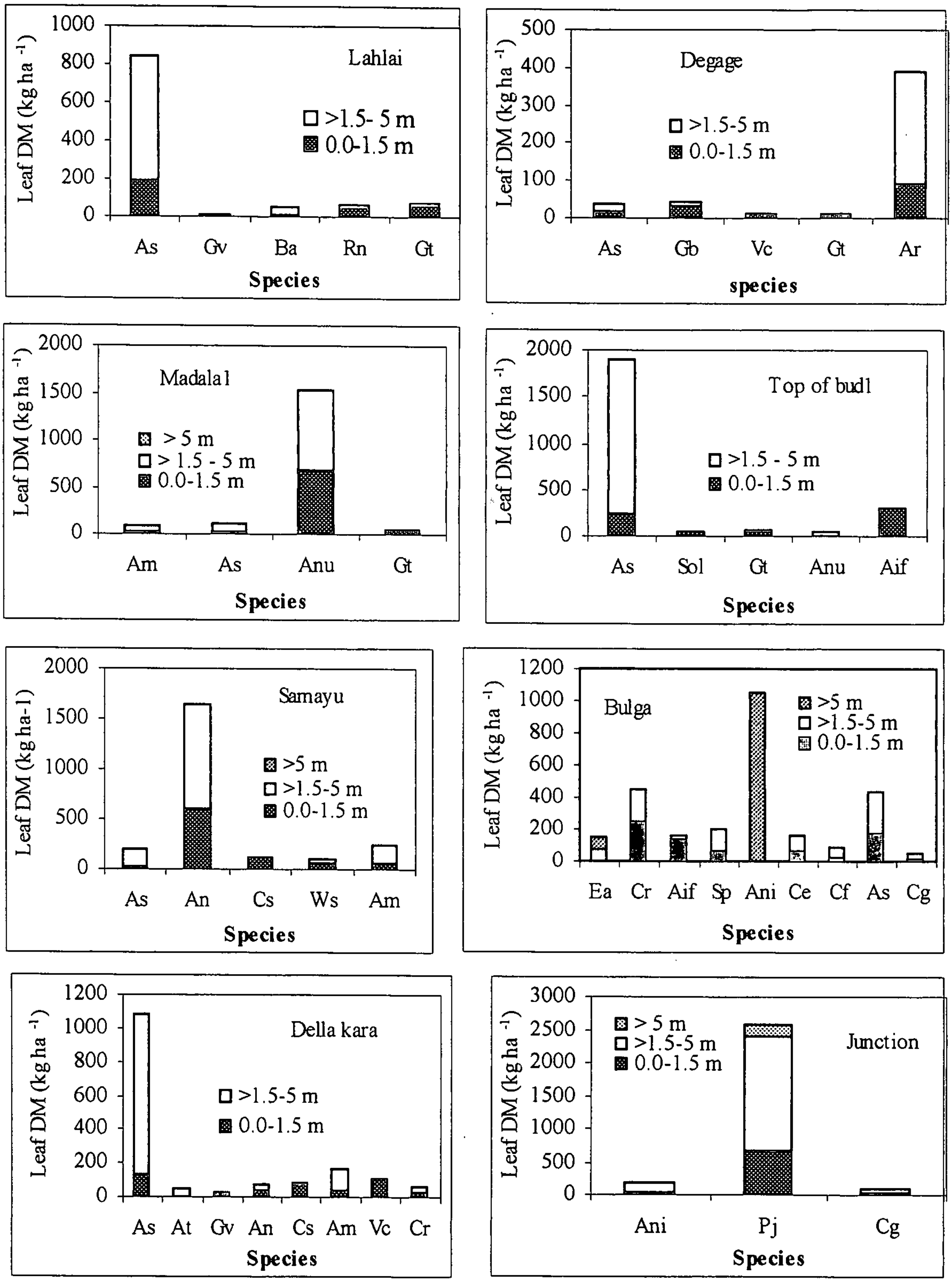


Figure 5.6. Estimates of the leaf dry mass (kg ha^{-1}) at peak biomass, with subdivision into height strata, of woody plants in Awash-Fantale district. Key to the species: As= *senegal*; Gv= *G. villosa*; Ba= *B. aegyptica*; Rn= *R. neglecta*; Gt= *G. tenax*; Ar= *A. robusta*; Am= *A. mellifera*; Anu (An) = *A. nubica*; Sol= *Solanum*; Cs= *C. sinensis*; Ws= *W. somnifera*; Ea= *E. abyssinica*; Cr= *C. rotundfolia*; Aif= *A. fruticosa* and *A. indica*; Sp= *S. persica*; Ani= *A. nilotica*; Ce= *C. equisetfolia*; Cf= *C. fascicularis*; Cg= *C. grandiflora*; At= *A. tortilis*; Vc= *V. cinerascens*; Pj= *P. juliflora*.

Madalal

The total leaf DM was 1 781 Kg ha^{-1} (**Figure 5.5.**) with 789 kg ha^{-1} and 986 kg ha^{-1} occurring below 1.5 m, and above 1.5 m up to 5 m respectively, only 6 kg ha^{-1} of the leaf DM occurs above 5 m. *Acacia nubica* contributed the highest to the total leaf DM (1 529 Kg ha, **Figure 5.6**), while three additional species contributed more than 1% to the total leaf DM. All the species had a phenological value of 1 during August and September, while all except *Acacia tortilis* had a value of 0.2 in December and January. *Acacia tortilis* had a phenological value of 0.6 during December and January.

Top of bud 1

Top of bud 1 ranked third in terms of total leaf DM (2 364 Kg ha^{-1}, **Figure 5.5**) and the leaf DM below 1.5 m was 660 kg ha^{-1}, while that greater than 1.5 up to 5m was 1 704 kg ha^{-1}. *Acacis senegal* contributed most to the total leaf DM (1 882 kg ha^{-1}, **Figure 5.6**). Four additional species contributed more than 1% to the total leaf DM and all species had a leaf phenological value of one in August and September. *Acacia senegal, solanum* species, *G. villosa* had a leaf phenological value of 0.4, while *G. tenax, A. mellifera, A. nubica, A. fruticosa* had a value of 0.2 during December and January. The leaf phenology of *Balanites aegyptica* was 0.6 for the similar time period

Samayu

The total leaf DM was 2 343 kg ha^{-1} and the Leaf DM below 1.5 m and greater than 1.5 up to 5 m was 909 kg ha^{-1} and 1 432 kg ha^{-1} respectively (**Figure 5.5**), while that greater than 5 m was 2 kg ha^{-1}. *Acacia nubica* contributed most to the total leaf DM (**Figure 5.6.**), whereas four additional species also contributed more than 1% to the total leaf DM. All the species had the highest leaf phenological value of 1 during August and September, while in December and January, *A. senegal, A. nubica, C. sinensis* and *A. mellifera* had a value of 0.4. *Withania somnifera* and *G. tenax* had the lowest leaf phenological value of 0.2, while *A. tortilis* had a value of 0.6 for the similar time period

Bulga riverside (BRS)

Bulga riverside had the highest number of woody plant species and poisonous woody plants such as *E. abyssinica* and *C. grandiflora*, although, their contribution to total leaf DM was only 196 kg ha^{-1}. The highest leaf DM was contributed by *A. nilotica* (1 054 kg ha^{-1}, **Figure 5.6**) and the total leaf DM was the second largest among the rangeland sites (**Figure 5.5**). The total leaf DM found below 1.5 m and greater than 1.5 up to 5 m was 762 kg ha^{-1} and 1 602 kg ha^{-1}, respectively (**Figure 5.6**). The Bulga riverside, also, had the highest leaf DM above 5 m (1 117 kg ha^{-1}) and nine woody species contributed more than 1% to the total leaf DM. Furthermore, this rangeland also had the highest number of evergreen woody plants such as *C. rotundfolia*, *S. persica*, *C. equistifolia* and C. *grandiflora*.

Della kara

The total leaf DM was 1 648 kg ha^{-1} (**Figure 5.5**), with a leaf DM below 1.5 m (436 Kg ha^{-1}) and greater than 1.5 up to 5.0 m of 1 212 Kg ha^{-1}. On a leaf DM basis, this rangeland site was dominated by *A. senegal* (1 080 kg ha^{-1}, **Figure 5.6**) and 7 other individual species contributed more than 1% to the total leaf DM.

Awash-Dulcha (Junction)

The highest leaf DM was recorded in this rangeland site (2 833 Kg ha^{-1}, **Figure 5.5**) and the leaf DM below 1.5 m and greater than 1.5 up to 5 m was 722 Kg ha^{-1} and 1 881 kg ha^{-1}, respectively. *Prosopis juliflora* contributed the highest to the total leaf DM (2 373 kg ha^{-1}, **Figure 5.6**) and there were only three woody species in this group, which contributed more than 1% to the total leaf DM (**Figure 5.6**).

5.3.1.2.3. Browsing capacity (BC)

In the study districts, the pastoralists own camels and goats that are browsers. The browsing height for goats is usually up to 1.5 m, while camels can reach up to 3.5 m. The leaf phenology for the months of August, September, December and January were obtained from field measurement, while for the rest of the months, it was estimated based upon the experience of the pastoralists and the rainfall pattern of the area that has a bimodal nature. In most of the rangeland sites, the woody plants were deciduous, indicating that the browsing capacity (BC) varies from season to season in accordance with leaf flushing and leaf senescense. For ease of presentation, the year was divided into two broad categories, wet months (WMS) i.e., July, August, September, March, April and May and dry months (DMS) October, November, December, January, February and June. Accordingly, the results of the approximate BC for each of the rangeland sites and for those species that contributed most to the total leaf DM is presented below.

Degage

The BC, expressed as ha BU^{-1}, for the height below 1.5 m, during the wet and dry months, was 17.14 and 25.80 respectively, while for the height greater than 1.5 up to 5 m was 7.97 to 12.00 for the wet and dry months, respectively (**Figure 5.7**). In both seasons and for both heights, the BC of *A. robusta* was higher than for others species (38.33ha BU^{-1} wet months for the height below 1.5m; 52.34 ha BU^{-1} for the height

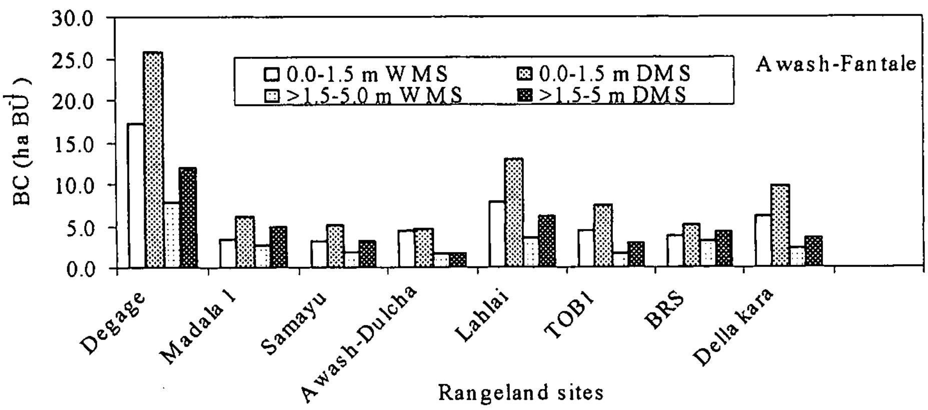


Figure 5.7. Browsing capacity (ha BU^{-1}) across the rangeland sites in Awash-Fantale district.

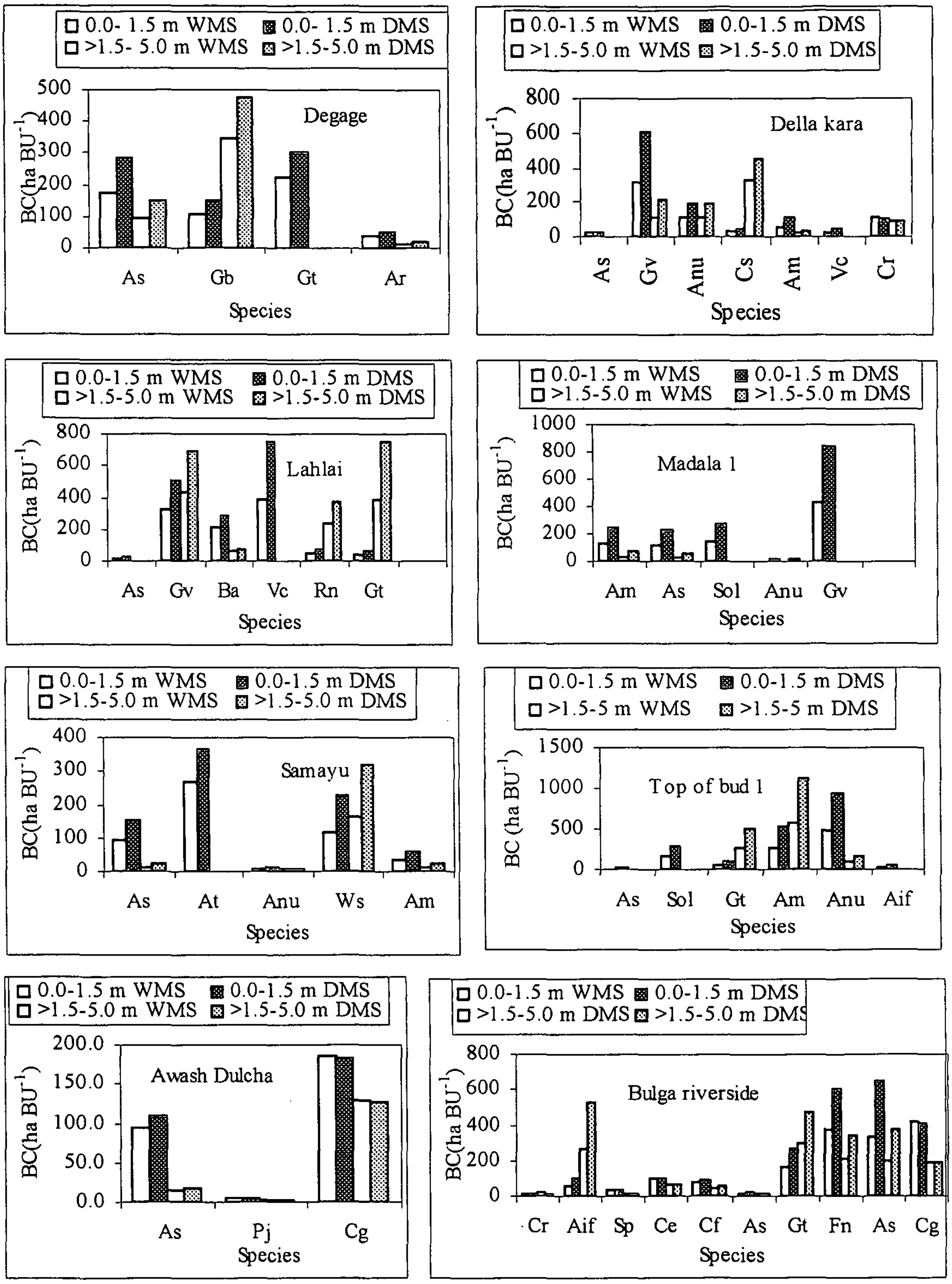


Figure 5.8. Browing capacity (ha BU^{-1}) for important species based upon their contribution to browse production in Awash-Fantale district. Key to the species: As= *A. senegal*; Gb= *G. bicolor*; Gt= *G. tenax*; Ar= *A. robusta*; Gv= *G. villosa*; Anu = *A. nubica*; Cs = *C. sinensis*; Am= *A. mellifera*; Vc= *V. cinerascens*; Cr= *C. rotundfolia*; Ba= *B. aegyptica*; Rn= *R. neglecta*; Sol= *Solanum*; At = *A. tortilis*; Ws = *W. somnifera*; Aif= *A. fruticosa* and *A. indica*; Pj= *P. juliflora*; Cg= *C. grandiflora*; Sp= *S. persica*; Ce= *C. equistefolia*; Cf= *C. fascicularis*; Fn= *F. gnaphalocarpa*.

below 1.5m dry months; 11.67 ha BU^{-1} for the height greater than 1.5 up to 5 m wet months; 15.94 ha BU^{-1} for the height greater than 1.5 up to 5 m, dry months), which was a direct reflection of the amount of leaf DM of the plant. This implied that less land is required to sustain a browser unit on *A. robusta* than on the other woody species (**Figure 5.8**).

Lahlai

The BC (ha BU^{-1}) at Lahlai was lower for the height below 1.5m than the height greater than 1.5 up to 5 m, which indicated that the leaf DM up to 1.5m was lower than the leaf DM for the height greater than 1.5 up to 5 m (**Figure 5.7**). Across the year and for the heights of 0 -1.5 m and greater than 1.5 up to 5 m, *A. senegal* made the biggest contribution to the BC, making it the most important source of browse for the area (**Figure 5.8**).

Madalal

The BC (ha BU^{-1}) over the year, for the height below 1.5 m, varied between 3.17 to 5.19 ha BU^{-1}, while that of the height greater than 1.5 up to 5 m varied between 2.01 ha BU^{-1} (Wet months) to 3.29 ha BU^{-1} (Dry months) (**Figure 5.7**). *Acacia nubica* contributed the most to the browsing capacity across the year and for both heights (5.0 ha BU^{-1} for the height below 1.5 m wet months; 9.8 dry months and 4.1 ha BU^{-1} in wet months for the height greater than 1.5 up to 5 m; 8.1 ha BU^{-1} for the height greater than 1.5 m in the dry months), which was a direct reflection of the high leaf DM (**Figure 5.8**).

Top of Bud1

The BC (ha BU^{-1}) across the rangeland site and during the wet and dry season for the height below 1.5 m was 4.37 ha BU^{-1} and 7.54 ha BU^{-1} respectively, while that of the height greater than 1.5 up to 5 m for the wet and dry months was 1.69 ha BU^{-1} and 2.92 ha BU^{-1}, respectively (Figure 5.7). *Acacia senegal* contributed the most to BC, i.e., 9.77 (wet months) to 15.68 (dry months) ha BU^{-1} for the height below 1.5 m and 1.40 (wet months) to 2.25 (dry months) for the height greater than 1.5 m up to the height of 5m (**Figure 5.8**). This result indicated that, most of the leaf DM was found above the height of 1.5 m favoring camel browsing rather than goats.

Samayu

The BC in the rangeland site and for the wet and dry seasons for the height below 1.5 m was 3.17 and 5.19 ha BU^{-1} respectively, while for the height greater than 1.5 up to 5 m for the wet and dry months was 2.01 and 3.29 ha BU^{-1}, respectively (**Figure 5.7**). The BC (ha BU^{-1}) was the highest for *A. nubica* (**Figure 5.8**, 5.71 to 9.16 ha BU^{-1} for the height below 1.5 m and 3.33 to 5.35 ha BU^{-1} for the height above 1.5 up to 5 m).

Awash-Dulcha junction

In this rangeland site, the BC below 1.5 m was 4.56 ha BU^{-1} for the wet months, while for the dry months it was 4.71 ha BU^{-1}. The BC (ha BU^{-1}) for the height from greater 1.5 up to 5 m was 1.70 (wet months) and for the dry months, it was 1.76 ha BU^{-1}. Season did not have a significant influence on the BC, as this area has the evergreen woody plants *P. juliflora* (dominant) and *C. grandiflora*. The browsing capacity for *P. juliflora* in the wet and dry months for the height below 1.5 m was 4.78 and 4.86 ha BU^{-1} respectively, while for the height greater than 1.5 up to 5 m in the wet and dry months was 1.83 and 1.86 ha BU^{-1}, respectively (**Figure 5.8**).

Bulga riverside (BRS)

The BC along the Bulga riverside for the height below 1.5 m was 3.83 ha BU^{-1} (wet months) and 5.09 ha BU^{-1} (dry months), while that of the height greater than 1.5 up to 5 m was 3.14 ha BU^{-1} (wet months) and 4.17 ha BU^{-1} (dry months) **(Figure 5.7)**. *Cadaba rotundfolia* and *A. senegal* had the highest BC (ha BU^{-1}) over the year (**Figure 5.8**) and *E. abyssinica, C. rotundfolia, S. persica, E. equistefolia* and *C. grandiflora* were evergreen species which maintained their leaves throughout the year (non-deciduous).

Della kara

The BC was higher for *A. senegal* during the wet and dry seasons for both heights (17.01 ha BU^{-1} and 27.31 ha BU^{-1} during the wet and dry months for the height below 1.5 m, respectively) and (2.45 ha BU^{-1} and 3.92 ha BU^{-1} during the wet and dry months for the height greater than 1.5 up to 5 m, respectively) (**Figure 5.8**). In this rangeland site, the BC for the height below 1.5 m for the wet and dry months was 6.24 and 9.08 ha BU^{-1} respectively, while for the height greater than 1.5 m up to 5 m was 2.25 (wet months) & 3.53 ha BU^{-1} (dry months).

5.3.1.3. Soil Parameters

The soil of the studied rangeland sites had a pH values ranging between 8.2 and 10.4 with a mean value of 8.62. The pH was highest at Asobabad and lowest along the Bulga riverside (**Table 5.5**). The electrical conductance (EC) (ds m^{-1}) varied from 0.096 to 3.69 with a mean value of 0.573. The value was highest at Asobabad and lowest at Top of bud.

The percentage sand was the highest at Asobabad and the lowest along Samayu with a mean value of 37.70% indicating that the proportion of the sand is higher than that of the other components (**Table 5.5**). Across the rangeland sites, the proportion of silt (mean value of 36.44%) was higher than the clay (25.88%). The percentage total nitrogen (N) was the lowest at Asobabad, while in the rest of the sites, the percent nitrogen ranged from 0.103 to 0.184. The percentage organic carbon across the rangeland sites varied from 0.187 to 1.214 with a mean value of 0.92. Similar to the % N, it was the lowest at Asobabad, while the ratio of carbon to nitrogen (CN ratio) varied from 6.00 to 10.00. The available phosphorus (ppm) ranged from 2 to 11.38 and the available potassium (ppm) varied from 201 to 421 with a mean value of 331.56.

Table 5.5. Physical and chemical characteristics of soils of the rangeland sites in Awash-Fantale district.

Range Land site	**Soil texture**			**Other soil parameters**						
	Sand (%)	**Silt (%)**	**Clay (%)**	**PH**	**EC (ds m^{-1})**	**N (%)**	**OC (%)**	**CN ratio**	**Available P (ppm)**	**Available K (ppm)**
Degage	35± 3.1	40± 0.6	25± 3	8.3± 0.1	0.168± 0.02	0.147 ±0.04	1.17± 0.03	8± 0.04	4.7± 0.6	409± 58.0
Madala	34± 8.02	41± 7.02	25± 2.08	8.32± 0.02	0.156± 0.01	0.174 ±0.06	0.962 ±0.05	6± 1.7	4.47± 1.7	343± 40.5
Madala 1	37± 5.0	37± 3.0	26± 3.0	8.36± 0.04	0.157± 0.01	0.184 ±0.04	1.105 ±0.1	7± 1.5	6.10± 3.4	383± 82.1
Top of bud	45± 3.06	37± 5.8	18± 6.0	8.37± 0.3	0.096± 0.0	0.112 ±0.02	0.886 ±0.2	8± 0.6	4.30± 1.9	276± 98.1
Asobabad	64± 1.5	23± 1.00	13± 1.15	10.4± 0.21	3.69± 0.10	0.03± 0.01	0.187 ±0.01	7± 0.50	7.07± 4.10	342± 40.55
Samayu	21± 1.5	30± 4	49± 5.1	8.73± 0.06	0.265± 0.03	0.116 ±0.01	1.071 ±0.1	10± 0.5	3.6± 0.8	257± 66
Top of bud1	44± 2	40± 0.0	16± 2	8.5± 0.02	0.096± 0.0	0.103 ±0.04	0.772 ±0.06	8± 0.5	4± 0.2	201± 25.5
Bulga river side	25± 0.7	50± 1.7	25± 5.5	8.21± 0.1	0.29± 0.1	0.119 ±0.03	0.90± 0.3	8± 0.6	11.38± 12.1	352± 47.04
Della kara	34± 6.11	30± 12.06	36± 6.0	8.4± 0.1	0.243± 0.05	0.135 ±0.05	1.214 ±0.42	9± 0.0	2± 0.2	421± 121

5.3.1.4. Correlation matrix among the studied variables

Among all variable correlated, the results of relationship between grass yield, basal cover and ETTE with other variables was presented in this section. The summary of the correlation matrix is shown in **Appendix 5.3.**

Among all correlated variables, grass yield was non-significantly ($P>0.05$) related with bare ground, estimated soil erosion and significantly ($P<0.001$) negatively correlated with ETTE ($P < 0.001$). The latter correlation between the yield of grass and ETTE was very strong ($r= -0.65$) which impies that there was a decrease in the DM yield of grasses with an increase in ETTE ha^{-1} value. There was a strong positive correlation ($P < 0.01$) between the DM yield of grass and basal cover, while basal cover was negatively correlated with bare ground ($P<0.01$) and ETTE ha^{-1} ($P<0.05$). The ETTE ha^{-1} values were negatively correlated with sand content ($P<0.01$) and CN ratio ($P<0.05$).

5.1.3.5. Multiple regression between grass DM yield and other parameters

The rate at which rangeland is stocked is probably the single most important management factor affecting animal performance and the profitability of a livestock system (O`Reagain & Turner 1992). Stocking rate is one of the variables under direct control of the manager, while the chosen stocking rate largely determines the degree of interaction between the grazing animal and the vegetation, which, in turn, determines production per animal and animal production per hectare (Morris *et al.* 1999). However, in a pastoral community land is owned communally, where decisions regarding rangeland resources are made collectively. In such a system, it is difficult to establish the stocking rate for the studied rangeland sites since information on animal numbers was not available. Nevertheless, in light of the results presented in the correlation matrix and taking the normal restrictions with regard to the inclusion of correlated variables in multiple regression functions into account, a series of stepwise multiple regression analyses were conducted with grass DM yield as the dependent variable in order to establish which factor or factors, among the measured environmental variables, other than the stocking rate, can be used as an indicator of the variability in grass DM yield. In agreement with the result of the correlation matrix, the stepwise regression analyses showed that ETTE ha^{-1} and basal cover were the most important factors affecting grass yield. Forty two percent of the variation in the grass yield was explained by ETTE ha^{-1} and the remaining 11% by basal cover (**Table 5.6**). The result suggested that other parameters like stocking rate needs to be included for a more complete explanation.

Table 5.6. Standard coefficient, r values, R2 increment (%), R2 values (%) and significance of multiple regression with dry matter yield as a dependent factor (N= Nitrogen; OC= Organic carbon; CN ratio = Carbon nitrogen ratio; P= Phosphorous; K= Potassium; NS= Nonsignificant; *= P<0.05; **= P<0.01)

Variables	**Standard coefficient**	**r value (from correlation matrix)**	**R2 increment (%)**	**R^2 values (%)**	**signifi -cance**
ETTE	-0.4742	-0.65	17.48	42.15	**
Basal cover	0.3709	0.59	10.69	52.84	*
Bare ground (%)		-0.25	0.05		NS
Estimated Soil erosion		-0.31	0.11		NS
PH		0.13	0.22		NS
Electrical conductivity		0.16	1.03		NS
% sand		0.32	0.04		NS
% silt		-0.02	0.50		NS
% clay		-0.38	0.13		NS
% total N		0.01	0.00		NS
% OC		-0.05	0.57		NS
CN ratio		-0.16	0.99		NS
Available P		-0.14	2.20		NS
Available K		0.06	0.93		NS
Altitude		0.33	1.54		NS

5.3.2. Kereyu-Fantale district (Oromo)

5.3.2.1. Herbaceous layer

5.3.2.1.1. Grass species composition

The most dominant grass species across the rangeland sites was *C. plumulosus*, which was followed by *S. natalensis, S. spicatus, C. dactylon, H. contortus, C. commutatus, D. aegypticum* and *C. poiflorum*, while the rest of the species were less abundant (**Table 5.7**). Based upon desirability, 23.68%, 18.42% and 57.9% were highly desirable, desirable and less desirable, respectively whereas, when expressed in terms of life form, 34.21% were annuals and 65.79 % were perennials. Forbs, generally comprised 4.14% of the composition and varied in their abundance from as low as 0.32% (Chopi) to as high as 14.53% (Mogassa) across the rangeland cites.

In five of the rangeland sites, the most dominant grass species was *C. plumulosus* (**Figure 5.9**), while at Harolel, *C. commutatus* (18.10%) and *D. aegyptcium* (15.90%) were the most abundant. Kara was dominated by *S. natalensis* (31.10%), while Mogassa by *D. aegypticum* (17.02%) and *C. dactylon* (16.78%). Grasslands along Lake Beseka were dominated by *S. spicatus*. In addition to *C. plumulosus*, at Fantale near the crater, *S. natalensis* (21.27%) and *T. triandra* (8.51%) were found in higher abundance than the other species.

5.3.2.1.2. Bare ground

The percentage bare ground (Mean ± SD), as determined by the point method, varied between 0.33 to 9.56 with a mean value of 5.02 (**Table 5.8**), which clearly indicated loss of soil from the surface. In six of the rangeland sites, the percent bare ground was greater than 5%, while it was less than 5 in the others and it was lowest at Kolbayu (0.33%) and highest at Mogassa (9.56%).

Table 5.7. Desirability, life form and frequency (%) of the different grass species in the Kereyu-Fantale district.

Species	**Desirability**	**Life form**	**Frequency (%)**
Chrysopogon plumulosus	Highly desirable	Perennial	30.37
Sporobolus natalensis	Less desirable	Perennial	12.10
Sporobolus spicatus	Less desirable	Perennial	8.37
Cynodon dactylon	Less desirable	Perennial	5.85
Heteropgon contortus	Desirable	Perennial	5.51
Cymbopogon commutatus	Desirable	Perennial	5.34
Dactyloctenium aegypticum	Less desirable	Annual	5.06
Coelachyrum poiflorum	Less desirable	Annual	3.73
Tetrapogon cenchriformis	Highly desirable	Perennial	2.40
Paspalm glumaceum	Desirable	Perennial	1.84
Setaria verticellata	Less desirable	Annual	1.69
Cenchrus ciliaris	Highly desirable	Perennial	1.46
Themeda triandra	Highly desirable	Perennial	0.90
Chloris roxburghiana	Desirable	Perennial	0.81
Eleusine indica	Less desirable	Annual	0.55
Cymbopogon excavatus	Highly desirable	Perennial	0.50
Pasapalm dilataum	Less desirable	Perennial	0.48
Panicum coloratum	Highly desirable	Perennial	0.47
Cenchrus setigrus	Highly desirable	Perennial	0.47
Panicum snowdenii	Less desirable	Annual	0.37
Urochloa panicoides	Less desirable	Annual	0.33
Digitaria milanjiana	Highly desirable	Perennial	0.31
Tragus berteronianus	Less desirable	Annual	0.30
Digitaria ternata	Less desirable	Annual	0.30
Eragrostis cilianensis	Less desirable	Annual	0.28
Aristida adoensis	Less desiable	Perennial	0.22
Sporobolus festivus	Less desirable	Perennial	0.20
Pennisetum mezianum	Less desirable	Perennial	0.15
Lintonia nutans	Desirable	Perennial	0.11
Chloris gayana	Highly desirable	Perennial	0.10
Eragrostis racemosa	Desirable	Perennial	0.08
Bothriochloa radicans	Less desirable	Perennial	0.06
Microchloa kunhtii	Less desirable	Annual	0.04
Hyparrhenia hirta	Desirable	Perennial	0.03
Sorghum purpureosericeum	Less desrable	Annual	0.02
Aristida adscensionis	Less desirable	Annual	0.02
Enneapogon schimperanus	Less desirable	Perennial	0.01
Setaria ustilata	Less desirable	Annual	0.01

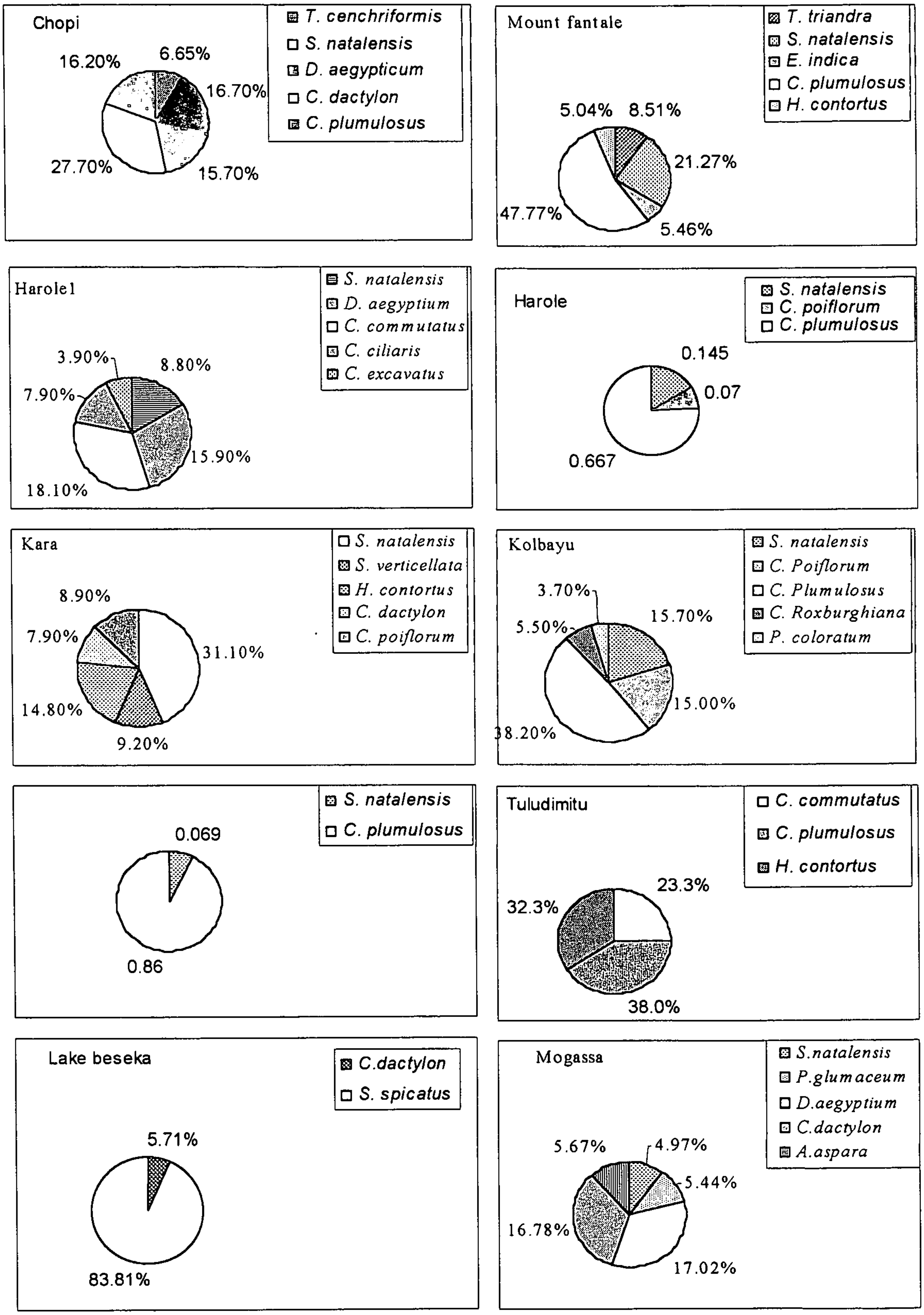


Figure 5.9. The most dominant grass species in each of the rangeland sites in Kereyu-Fantale.

5.3.2.1.3. Basal cover

The result of the percentage basal cover (mean ± SD) followed a pattern opposite to that of the percentage bare ground (**Table 5.8**). It was the highest on the rangeland site where the percentage bare ground was the lowest (Kolbayu) and lowest in the site where the percentage bare ground was the highest (Mogassa). Of the rangeland sites, 50%, 30% and 20% had a cover value ranging between 2-3, 3-4 and 4-5 respectively, which implied that in most of the rangeland sites the cover of the vegetation was low.

5.3.2.1.4. Grass DM yield

The yield of the grass layer (mean ± SD) ranged between 168.52 kg ha^{-1} to 807.69 kg ha^{-1} with an overall mean of 421.92 kg ha^{-1} (**Table 5.8**). Similar to that of the result in Awash-Fantale district, both the highest (Kolbayu) and the lowest yields (Mogassa) were recorded in rangelands with woody vegetation.

5.3.2.1.5. Estimated soil erosion

The estimated soil erosion values (mean ± SD) ranged between 2 to 4 indicating that there was a loss of soil due to erosion (**Table 5.8**). Of the ten rangeland sites in the district, 10%, 60% and 30% of the rangelands had values of 2,3 and 4 respectively, implying 10% of the studied rangeland sites had steep sided pedestals, 60% slope sided pedestals and 30% slight sand mulch.

5.3.2.1.6. Grazing capacity

The grazing capacity (mean ± SD) based upon ha LSU^{-1}, declined most at Mogassa (54.15) and was better at Kolbayu (11.15) than at the other rangeland sites, which implies that more land is required to sustain a LSU at Mogassa than at Kolbayu, i.e., a direct reflection of their grass production (**Table 5.8**). The pattern was similar for TLU (declined most at Mogassa = 33.84 ha TLU^{-1} and best at Kolbayu = 7.06 ha

TLU^{-1}). In general, the mean grazing capacity for the studied rangelands based upon LSU and TLU were 24.83 ha LSU^{-1} and 14.5 ha TLU^{-1}, respectively.

Table 5.8. Mean and standard deviation of bare ground (%), basal cover (%), grass DM yield (kg ha^{-1}) and estimated soil erosion values for rangeland sites in Kereyu-Fantale district (HL= Herbaceous layer; WL= Woody layer).

	Rangelands									
Parameters	**Aleka**	**Harol e**	**Beseka**	**Chopi**	**Mogassa**	**Kara**	**Kolba -yu**	**Tulu dimtu**	**Fantale**	**Harol e-1**
Vegatation layer studied	**HL**	**HL**	**HL**	**HL & WL**	**HL & WL**	**HL & WL**	**HL & WL**	**HL & WL**	**HB & WL**	**HL**
Bareground (%)	5.8± 0.7	5± 0.7	8.2± 1.6	9.4± 0.3	9.6 ±1.1	5.9± 1.1	0.3± 0.2	0.4± 0.0	3.4± 2.1	2.1± 1.9
Basal cover (%)	2.6± 0.7	2.7± 0.4	2.7± 0.8	2.5± 0.5	2.4 ±0.4	3± 0.4	4.7± 1.5	4.6± 0.5	3.5± 0	3.5± 0.1
Grass yield (kg ha^{-1})	391.9± 102.9	402± 38.9	350± 76.7	284.3± 22.1	168.5± 76	353.5± 38.7	807.7± 67.5	467.7± 26.6	616± 20.4	377.6± 82.9
Estimated soil erosion	2± 0.0	3± 0.5	3± 0.6	3± 0.6	4± 0.6	3± 0.6	4± 0.0	3± 0.0	4± 0.6	3± 1.0
Grazing capacity (ha LSU^{-1})	23.3± 6.6	22.7± 2.3	26.07± 6.8	32.1± 2.6	54.2± 40.0	25.8± 3	1.2± 1.0	17.1± 0.8	11.8± 0.3	24.2± 4.8
Grazing capacity (ha TLU^{-1})	13.6± 4.2	13± 1.4	14.7± 4.2	19.6± 1.6	33.8± 25.0	16.1± 1.9	6.97± 0.6	10.6± 0.5	7.4± 0.2	14.7± 3.1

5.3.2.1.7. Rangeland condition

The condition of the rangeland sites based upon the results of the point survey, varied between 37.5% (Lake Beseka) to 90.3% (Aleka), while the mean rangeland condition of all sites was 63.42%. The conditions of the rangeland sites was above the mean in 50% of them and lower than the mean in 50% of the rangeland sites.

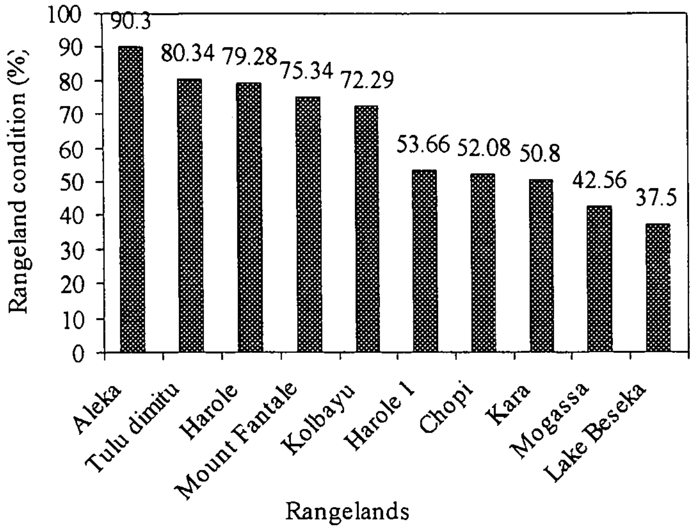


Figure. 5.10. Rangeland condition of the rangeland sites in Kereyu-Fantale district based upon desirability of species.

5.3.2.2. Woody layer

5.3.2.2.1. Woody vegetation composition, density, ETTE and palatability values

A total of 34 woody species were identified in the transects laid out for the sites (**Figure 5.11**). Similar to that of the Afars, two species of *Acalypha* were recorded, i.e., *A. fruticosa* and *A. indica*. The Solanum species consisted of *S. incanum* and *S. marginatum*. There were also other species that did not fall in the transects, but were found in the field, which actually increase the number of woody species in the area. The most abundant (%) woody species in decreasing order were *A. nubica, A. senegal, V. cinerascens, Acalypha species, G. villosa, G. bicolor* and *G. tenax*. Important tree species such as *A. nilotica*, *B. aegyptica* and *A. tortilis* were less abundant (**Figure 5.11**).

The density of woody vegetation was highest at Mogassa (4 900 plants ha^{-1}) and lowest at Tulu dimitu (600 plants ha^{-1}). When the tree density data was expressed in terms of ETTE ha^{-1}, the value ranged between 967 ETTE ha^{-1} (Tulu dimitu) to 14 178 ETTE ha^{-1} at Mogassa. When the data was expressed in terms of ETTE (%), six woody plants were most important. These in a decreasing order are *A. senegal, A. nubica, A. tortilis, G. bicolor, G. villosa* and *A. mellifera* (**Figure 5.12**).

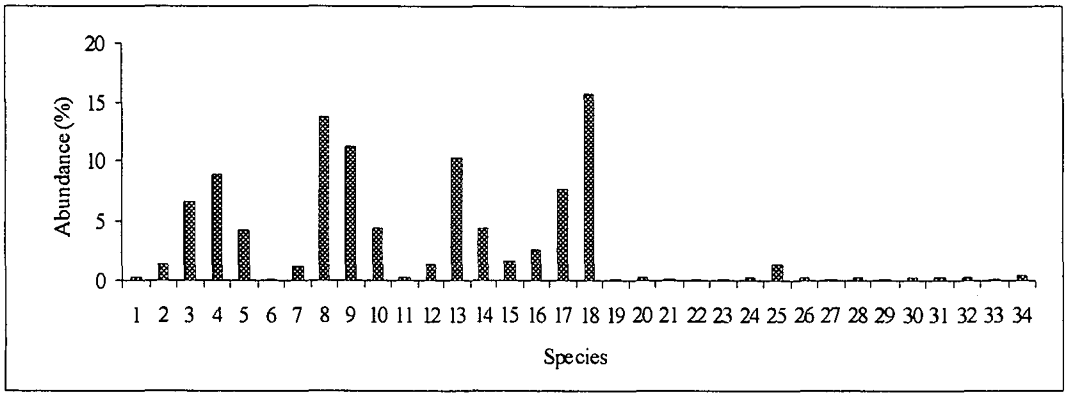


Figure 5.11. The density of woody plants expressed in abundance (%) in Kereyu-Fantale district. Key to the species: 1= *R. neglecta;* 2= *A. mellifera*; 3= *G. tenax*; 4= *G. villosa*; 5= *Solanum* species; 6= *A. nilotica*; 7= *B. aegyptica*; 8= *A. senegal*; 9= *V. cinerasens*; 10= *C. sinensis*; 11= *C. fascicularis*; 12= *S. perisca*; 13= *A. fruticosa*; 14= *D. cinerea*; 15= *L. trifolia*; 16= *A. tortilis*; 17= *G. bicolor*; 18= *A. nubica*; 19= *C. ovalis*; 20= *P .oranatus*; 21= *F.gnaphalocarpa*; 22= *C. rotundfolia*; 23= *B. aethiopum*; 24= *A. robusta*; 25= *R. natalensis*; 26= *B. oleoides*; 27= *R. commaanis*; 28= *P. africanum*; 29= *D. afromontana*; 30= *T. brownii*; 31= *C. africana*; 32= *A. seyal*; 33= *O. rochetina*; 34= *A. xanthophloea.*

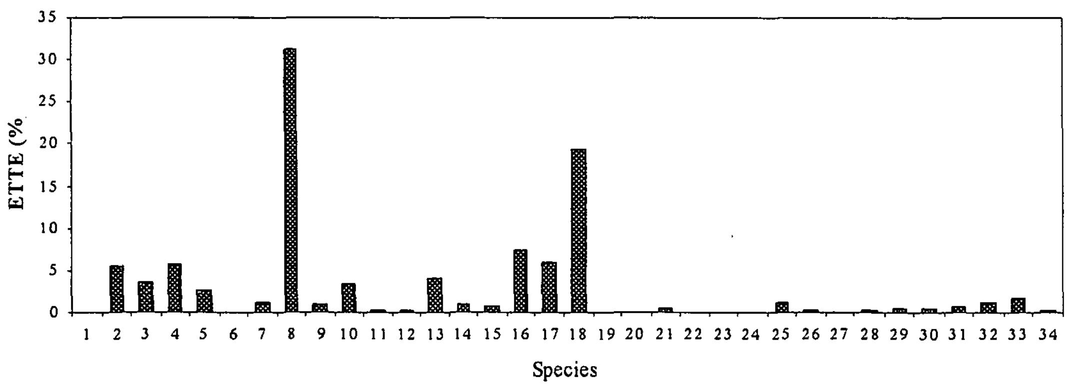


Figure 5.12. Woody vegetation expressed in terms of % ETTE in Kereyu-Fantale district. 1= *R. neglecta*; 2= *A. mellifera*; 3= *G. tenax*; 4= *G. villosa*; 5= *Solanum* species; 6= *A. nilotica*; 7= *B. aegyptica*; 8= *A. senegal*; 9= *V. cinerasens*; 10= *C. sinensis*; 11= *C. fascicularis*; 12= *S. persica*; 13= *A. fruticosa*; 14= *D. cinerea*; 15= *L. trifolia*; 16= *A. tortilis*; 17= *G. bicolor*; 18= *A. nubica*; 19= *C. ovalis*; 20= *P. oranatus*; 21= *F. gnaphalocarpa*; 22= *C. rotundfolia*; 23= *B. aethiopium;* 24= *A. robusta;* 25= *R. natalensis*; 26= *B. oleoides*; 27= *R. commaanis;* 28= *P. africanum;* 29= *D. afromontana*; 30= *T. brownii;* 31= *C. africana;* 32= *A. seyal;* 33= *O. rochetina*; 34= *A. xanthophloea.*

The ETTE ha^{-1} value was the highest at Mogassa (14 178 ETTE ha^{-1}) and lowest at Tulu dimitu (976 ETTE ha^{-1}). In two of the rangeland sites, *A. senegal* (Chopi = 6 214 ETTE ha^{-1}; Mogassa = 7 414 ETTE ha^{-1}) contributed the highest ETTE ha^{-1} value, while *A. tortilis* had the highest in two of the rangelands (Kolbayu= 847 ETTE ha^{-1}; Tulu dimitu= 335 ETTE ha^{-1}). At Fantale, *Olinia rochetina* (684 ETTE ha^{-1}) had the highest ETTE ha^{-1}, whereas, at Kara *Grewia bicolor* (642 ETTE ha^{-1}) and *A. nubica* at Harolel (6 604 ETTE ha^{-1}).

Of the identified woody species, 51.4 % were highly palatable, 18.9% intermediate and 29.7% unpalatable based upon the perception of the pastoralists (**Table 5.9**)

Table 5.9. Palatability of woody plants as rated by the pastoralists in Kereyu-Fantale district.

Highly palatable	**Intermediate**	**Unpalatable**
Acacia Senegal	*Grewia bicolor*	*Solanum incanum*
Vernonia cinerascens	*Pygeum africanum*	*Withania somnifera*
Grewia tenax	*Acacia robusta*	*Acalypha fruticosa*
Ficus gnaphalocarpa	*Acacia nubica*	*Plectranthus oranatus*
Acacia mellifera	*Cadaba rotundifolia*	*Rhus natalensis*
Acacia tortilis	*Commiphora africana*	*Olinia rochetina*
Grewia villosa		*Barbeya oleoides*
Cordia sinensis		*Ricinus communis*
Balanites aegyptica		*Terminalia brownii*
Rytigynia neglecta		*Dracaena afromontana*
Salvadora persica		*Acalypha indica*
Acacia nilotica		
Capparis fascicularis		
Acacia seyal		
Acacia xanthoploea		
Dichrostachys cinerea		
Lanthana trifolia		
Borassus aethiopum		
Cordia ovalis		

5.3.2.2.2. Browse production

Mogassa

The total leaf DM was the highest (3 311 kg ha^{-1}) at Mogassa, with a leaf DM below 1.5 m and greater than 1.5 up to 5 m of 1044 and 2 009 kg ha^{-1} respectively (**Figure 5.13**). Of the total leaf DM, 258 kg ha^{-1} was found above 5 m and on a leaf DM basis, Mogassa was dominated by *A. senegal* (1746 kg ha^{-1}) and seven other individual woody species contributed more than 1% to the total leaf DM (**Figure 5.14**). All species had a leaf phenological value of 1 (maximium leaf abundance) during August and September, whereas, during December and January *L . trifolia*, *V. cinerascens*, *R. neglecta*, *A. fruticosa*, *A. nubica*, and *G. villosa* had the lowest phenology of 0.2. *Grewia tenax* and *A. senegal* had a leaf phenology of 0.4, while *B. aethiopum*, *B. aegyptica*, *G. bicolor* and *A. tortilis* had a value of 0.6.

Kolbayu

The total leaf DM was 546 kg ha^{-1} (**Figure 5.13**), dominated by *A. tortilis* (201 kg ha^{-1}, **Figure 5.14**). Of the total leaf DM, 199, 345 and 2 kg ha^{-1} (**Figure 5.13**) was found below 1.5m, greater than 1.5 up to 5 m and greater than 5 m respectively, while 9 additional woody plants contributed more than 1% to the total leaf DM (**Figure 5.14**). In August and September all the species had the highest leaf phenology of 1, 1

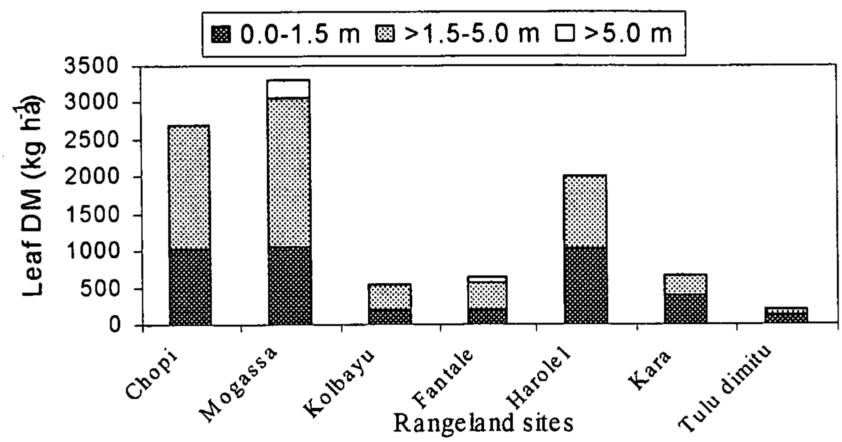


Figure 5.13. Total and stratified leaf DM (kg ha^{-1}) of the rangeland sites in Kereyu-Fantale district.

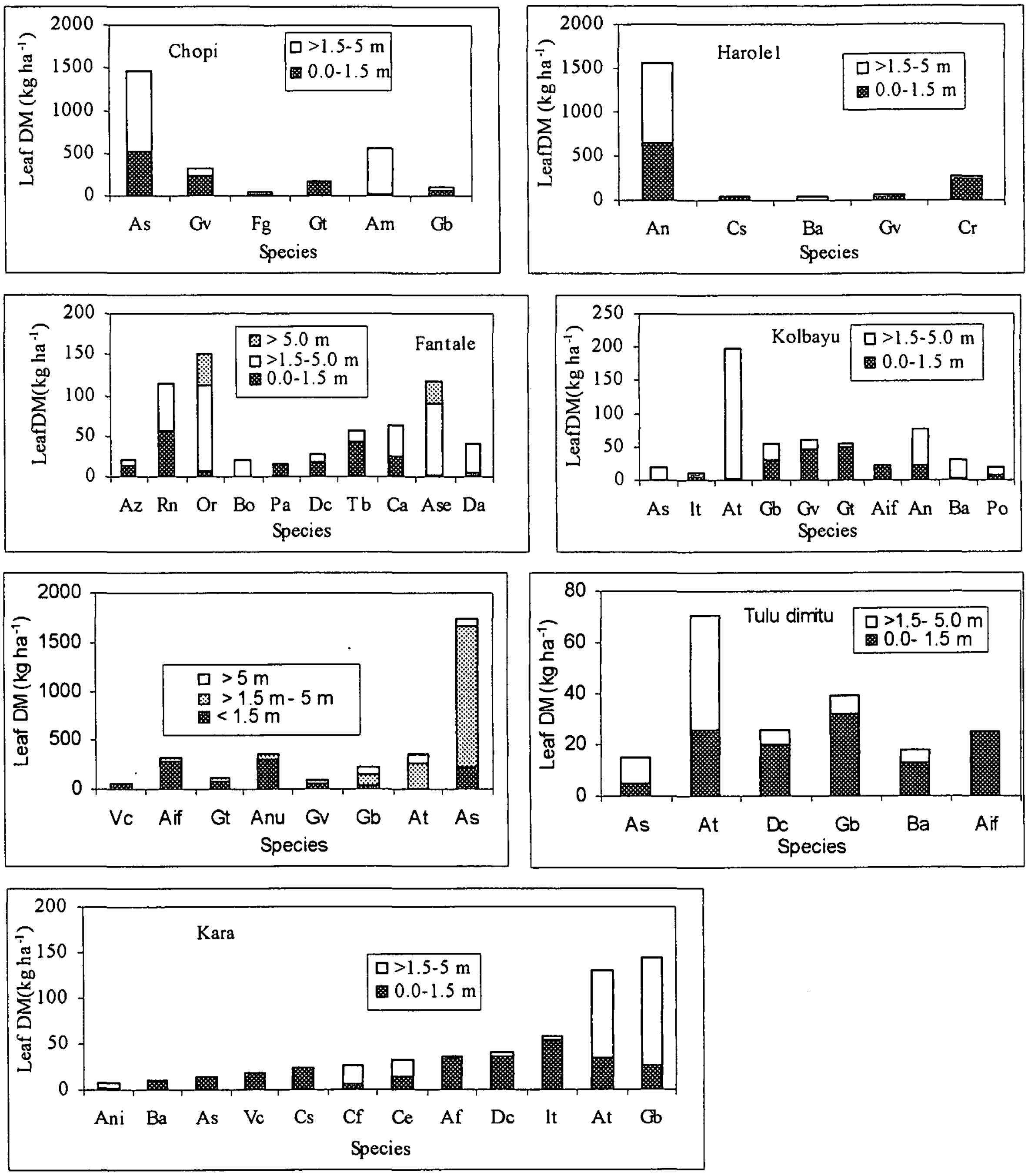


Figure 5.14. Estimates of the leaf DM (kg ha^{-1}) at peak biomass, with the subdivision into height strata, of woody plants contributing more than one percent to the total leaf DM in each of the rangeland sites. Key to the species: As= *A. senegal*; Gv= *G. villosa*; Fg= *F. gnaphalocarpa*; Gt= *G. tenax*, Am= *A. mellifera*; Gb= *G. bicolor*; Anu= *A.nubica*; Cs= *C. sinensis*; Cr= *C. rotundfolia*; Ba= *B. aegyptica*; rn= *R. neglecta*; It= *L. trifolia*; Ax= *A. xanthophloea*; Rn= *R. neglecta*; Or= *O. rochetina*; Bo= *B. oleoides*; Pa= *P. africanum*; Dc= *D. cinerea*; Tb= *T. brownii*; Ca= *C. africana*; Ase= *A. seyal*; Da= *D. afromontana*; At= *A. tortilis*; Aif= *A. indica* and *A. fruticosa*; Po= *P. oranatus*; Vc= *V. cinerascens*; Ani= *A. nilotica*; Cf= *C. fascicularis*; Ce= *C. equistefolia*; Af= *A. fruticosa*;

while in December and January the species had a variable leaf phenology. *Acacia senegal* and *G. villosa* had a value of 0.4 whereas, *L. trifolia*, species of *Acalypha* and *V. cinerascens* had the lowest phenological value (0.2). With regard to the other species, *G. bicolor*, *G. tenax*, *D. cinerea*, *Solanum* species, *B. aegyptica*, *P. oranatus* and *C. ovalis* had a value of 0.6. *Acacia tortilis* had a better leaf phenology of 0.8 in the dry season.

Fantale

The total leaf DM was 638 kg ha^{-1}, with a leaf DM below 1.5 m, greater than 1.5 up to 5 m and greater than 5 m of 192, 379 and 67 kg ha^{-1}, respectively (**Figure 5.13**) and ten individual woody species contributed more than 1% to the total leaf DM (**Figure 5.14**). *Olinia rochetina* (152 kg ha^{-1}), *A. seyal* (117 kg ha^{-1}) and *R. natalensis* (114 kg ha^{-1}) contributed most to the total leaf DM (**Figure 5.14**). The leaf phenology in August and September was 1 for all species and the species in this rangeland had better phenological values during December and January than the species in the other rangeland sites. *Rhus natalensis*, *O. rochetina*, *B. oleoides*, *R. communis*, *P. africanum* and *D. afromontana* had a phenological value ranging between 0.8 and 1. The leaf phenology of *G. bicolor*, *A. robusta*, *A. xanthophlea*, *D. cinerea*, *C. africana* and *A. senegal* was 0.4. *Terminalia brownii* and *A. tortilis* had a value of 0.6.

Kara

The total leaf DM was 658 kg ha^{-1} (**Figure 5.13**) with the highest leaf DM contributed by *G. bicolor* (143 kg ha^{-1}) and followed by *A. tortilis* (130 kg ha^{-1}) (**Figure 5.14**). Of the total leaf DM, 386 kg ha^{-1} was found below 1.5 m, while the remaining 272 kg ha^{-1} above 1.5 m up to the height of 5 m. Twelve individual woody plants contributed more than 1% to the total leaf DM (**Figure 5.14**). The leaf phenology of *R. neglecta*, *G. villosa*, *Solanum* species, *A. nilotica*, *B. aegyptica*, *C. rotundfolia* and *D. cinerea* was 0.4 in December and January, while that of *G. tenax*, *S. perisca*, *A. tortilis* and *G. bicolor* had a value of 0.6. *Acacia mellifera*, *A. senegal*, *V. cinerascens*, *C. sinensis*, species of *Acalypha*, *L. trifolia* had the lowest leaf phenology (0.2) during December and January. During the wet months (August and September) all species had a leaf phenology of 1 (at peak biomass).

Chopi

The total leaf DM was 2 692 kg ha^{-1}, with a leaf DM below 1.5 m and greater than 1.5 up to 5.0 m of 1 039 kg ha^{-1} and 1 653 kg ha^{-1} respectively (**Figure 5.13**). The highest leaf DM was contributed by *A. senegal* (1 461 kg ha^{-1}, **Figure 5.14**) and five additional woody plants contributed more than 1% to the total leaf DM. The leaf phenology, for all species in August and September was 1, while it was lowest (0.2) for *A. senegal*, *G. villosa*, *V. cinerascens*, *G. tenax* and *A. mellifera*. *Cadaba rotundfolia* had the highest (0.8) and *Solanum* and *G. bicolor* (0.4). *Ficus gnaphalocarpa* had a value of 0.6 during the dry months.

Tulu dimitu

The lowest leaf DM was recorded at Tulu dimitu (194 kg ha^{-1}), with 122 kg ha^{-1} and 72 kg ha^{-1} was found below 1.5 m and greater than 1.5 up to 5.0 m, respectively (**Figure 5.13**). Of the total leaf DM, *A. tortilis* and *G. bicolor* contributed 71 and 39 kg ha^{-1}, respectively (**Figure 5.14**) and all the individual woody species in the rangeland site contributed more than 1% to the total leaf DM (**Figure 5.14**). The leaf phenology during August and September was 1, while during December and January varied among the different species. *Acacia senegal* and *D. cinerea* had a value of 0.4, while that of *A. tortilis*, *G. bicolor* and *B. aegyptica* (0.6) and *Acalypha* species having the lowest (0.2).

Harolel

The total leaf DM was 1 999 kg ha^{-1}, with a leaf DM below 1.5 m and greater than 1.5 up to the height of 5 m of 1 022 kg ha^{-1} and 977 kg ha^{-1}, respectively (**Figure 5.13**). The highest leaf DM was contributed by *A. nubica* (1 555 kg ha^{-1}) and four other individual woody species contributed more than 1% to the total leaf DM (**Figure 5.14**). All the species had a phenological value of 1 during August and September, whereas, in December and January; *A. tortilis*, *C. sinensis*, and *B. aegyptica* had a value of 0.6. *Acacia nubica*, *A. mellifera* and *V. cinerascens* had the lowest leaf phenology (0.2), whereas, *C. rotundfolia* had the highest (0.8).

5.3.2.2.3. Browsing capacity

Harolel

The BC for the rangeland site, across wet and dry months (WMS and DMS) and for both heights varied between 2.36 and 3.80 ha BU^{-1} (**Figure 5.15**), while the BC for *A. nubica* for the height below 1.5 m for the wet and dry months was 5.43 and 10.59 ha BU^{-1} (**Figure 5.16**), respectively. The BC for *A.nubica*, for the height greater than 1.5 up to 5 m was 3.81 ha BU^{-1} (wet months) and 7.43 ha BU^{-1} (dry months) and contributed most to the BC (**Figure 5.16**).

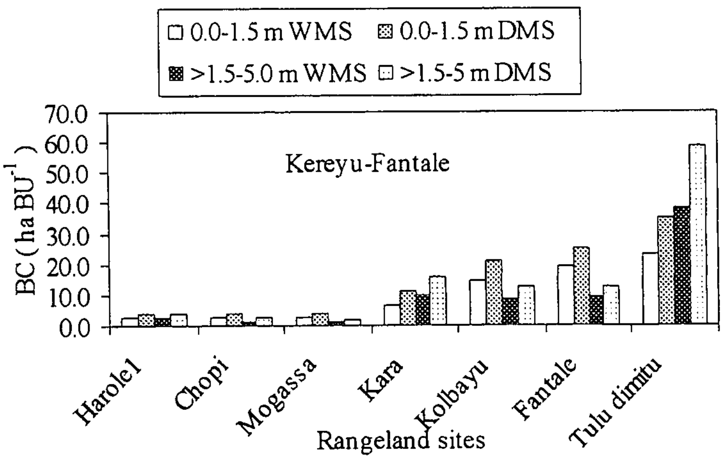


Figure 5.15. Approximate browsing capacity (ha BU^{-1}) across the rangeland sites studied in Kereyu-Fantale district.

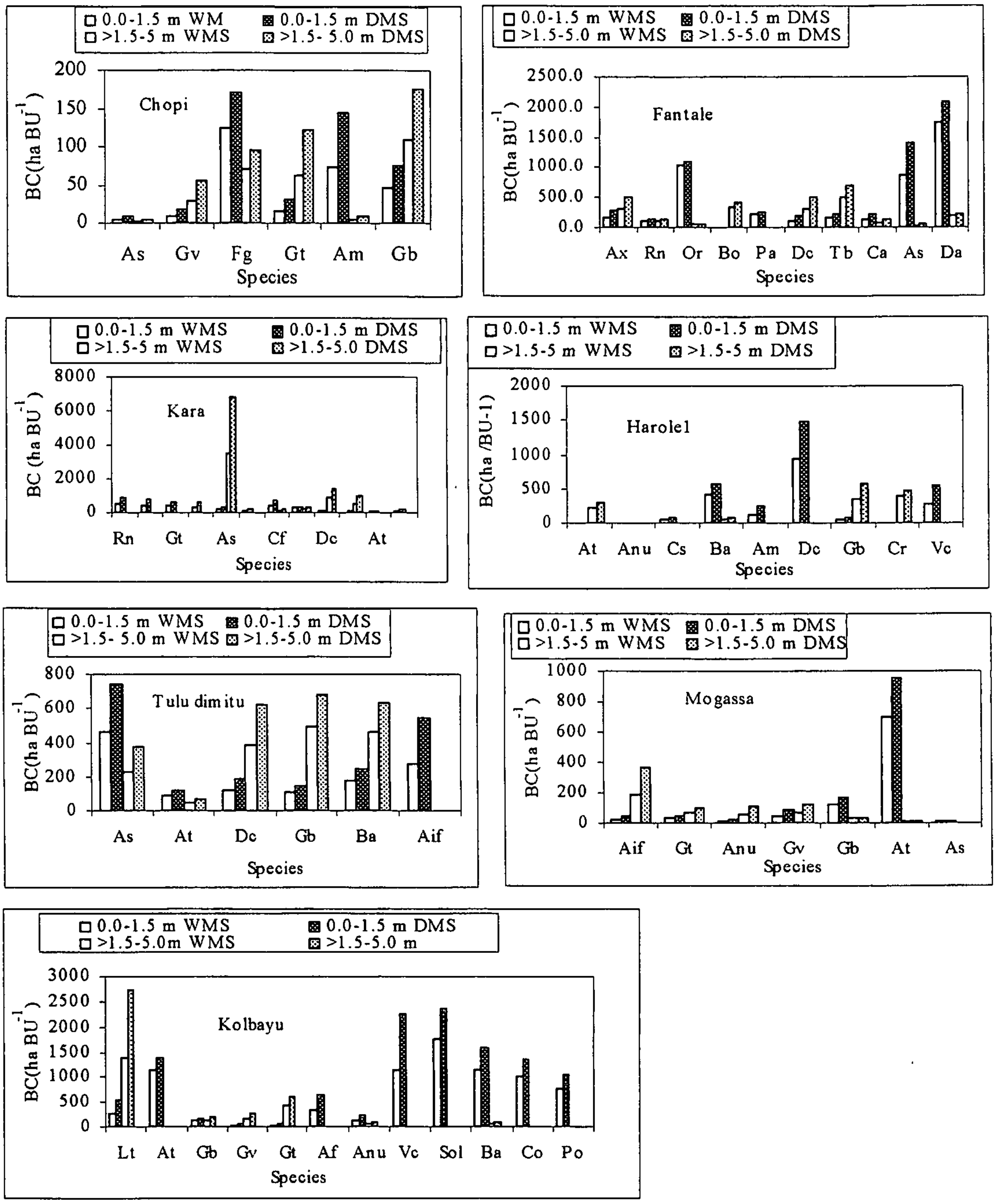


Figure 5.16. Browsing capacity (ha BU^{-1}) for the most important individual woody plants by season and height strata in Kereyu-Fantale district. Key to the species: As= *A. senegal*: Gv= *G. villosa*; Fg= *F. gnaphalocarpa*; Gt= *G. tenax*; Am= *A. mellifera*; Gb= *G. bicolor*; Ax= *A. xanthophloea*; Rn= *R. neglecta*; Or= *O. rochetiana*; Bo= *B. oleoides*; Pa= *P. africanum*; Tb= *T. brownii*; Ca= *C. africana*; Da= *D. afromontana*; Cf= *C. fascicularis*; Dc= *D. cinerea*; At= *A. tortilis*; Anu= *A. nubica*; Cs= *C. sinensis*; Ba= *B. aegyptica*; Cr= *C. rotundfolia*; Vc= *V. cinerascens*; Aif= *A. fruticosa* and *A. indica*; Lt= *L. trifolia*; Co= *C. ovalis*; Po= *P. oranatus*.

Chopi

The BC at Chopi, in the wet and dry months, for the height below 1.5 m was 2.50 and 4.16 ha BU^{-1} respectively, while it was 1.57 ha BU^{-1} (wet months) and 2.62 ha BU^{-1} (dry months) for the height greater than 1.5 up to 5 m (**Figure 5.15**). The BC for *A. senegal* was the highest (4.56 and 8.87 ha BU^{-1} for the wet and dry months for the height below 1.5 m respectively; 2.44 and 4.76 ha BU^{-1} for the wet and dry months for the height greater than 1.5 up to 5 m respectively) (**Figure 5.16**).

Mogassa

The BC at Mogassa was 2.49 and 4.14 ha BU^{-1} for the height below 1.5 m for wet and dry months respectively, while it was 1.29 (wet months) and 2.15 ha BU^{-1} (dry months) for the height greater than 1.5 up to 5 m (**Figure 5.15**). *Acacia senegal* followed by *A. nubica* had the highest BC among the individual woody species (**Figure 5.16**).

Kara

Compared to the above ones, Kara had a lower BC of 6.77 (wet months) and 11.26 ha BU^{-1} (dry months) for the height below 1.5 m and for the height greater than 1.5 up to 5 m, the BC was 9.62 (wet months) and 16.00 ha BU^{-1} (dry months) (**Figure 5.15**). Similarly, all the species had low BC (**Figure 5.16**) implying that their browse production was low.

Kolbayu

The BC in this rangeland site was slightly higher for the heights greater than 1.5 up to 5 m than the height below 1.5 m, which indicated that a large proportion of the leaf DM was found above 1.5 m (**Figure 5.15**). Similarly, the BC for the height below 1.5 m was 14.30 ha BU^{-1} (wet months) and 21.45 ha BU^{-1} (dry months), while that for the height greater than 1.5 up to 5 m was 8.27 (wet months) and 12.41 (dry months) (**Figure 5.15**). At the height below 1.5 m, *G. villosa* and *G. tenax* had better browsing capacity than other species; on the other hand, for the height above 1.5 m, *A. tortilis* had a better browsing capacity than the other species (**Figure 5.16**).

Fantale

This rangeland had low browsing capacity which was reflected in the number of hectare needed per browser unit (18.94 and 25.17 for the height below 1.5 m during the wet and dry months respectively), while the corresponding values for the height greater than 1.5 up to 5 m was 9.56 ha BU^{-1} (wet months) and 12.71 ha BU^{-1} (dry months) (**Figure 5.15**). Relatively, *R. natalensis* had better BC than the others (**Figure 5.16**) and the reason for the low BC was associated in part to the low palatability of 6 of the species found in this rangeland.

Tuludimitu

The BC at Tuludimitu was the lowest among the rangeland sites, which was a reflection of low browse production (**Figure 5.15**). The BC across the year, for the height below 1.5 m (22.89 ha BU^{-1} and 34.90 ha BU^{-1} for the wet and dry months respectively) was better than the height greater than 1.5 up to the height of 5 m (38.47 ha BU^{-1} and 58.66 ha BU^{-1} for wet and dry months respectively). Relatively, *A. tortilis* had better browsing capacity than the others (89.26 ha BU^{-1} for wet months and 14.83 ha BU^{-1} for the dry months year for the height below 1.5 m, while for the height above 1.5 up to 5 m, the corresponding values were 51.57 ha BU^{-1} and 70.39 ha BU^{-1} for the wet and dry months respectively) (**Figure 5.16**).

5.3.2.3. Soil parameters

The pH of the soils in general varied from 7.9 to 8.95 and the soil along lake Beseka was slighter higher in pH than the other rangeland sites. The electrical conductance (EC) in (ds m^{-1}) of the soil surface was highest in soil at lake Beseka than the soils in other rangeland sites (**Table 5.10**). The EC in the other rangeland sites ranged from 0.140 to 0.180.

The proportions of the components of the soil surface texture (% sand, % silt and % clay) varied from one rangeland site to the other (**Table 5.10**) and the proportions of sand, silt, and clay in rangeland sites were 40%, 35.7% and 24.3%, respectively.

The total nitrogen (%) was lowest in the rangeland site close to Lake Beseka (0.06%) and the value in the other rangeland sites ranged between 0.12 to 0.25 indicating that there was a variation in the % N from one rangeland site to the other. Similar to the total nitrogen, the % organic carbon was lowest near to lake Beseka (0.48%), while in the others it ranged from 1.14 to 2.16%. The CN ratio varied from 7 (Harole) to 13 (Fantale) and the available P (ppm) was between 1.8 to 4.93, while that of available K from 266 to 867 ppm indicating that there was wide variation in available K (**Table 5.10**).

5.3.2.4. Correlation matrix among variables studied and multiple regression of grass yield in relation to other parameters

The correlation among the variables studied, i.e., grass yield, basal cover, bare ground, estimated soil erosion value, ETTE, pH, electrical conductivity, sand, silt, clay, % total nitrogen, % organic carbon, CN ratio, available phosphorous, available potassium and altitude is shown in **Appendix 5.4**. Of these, the relationships that are considered most important were the relationship of grass yield, basal cover, ETTE ha^{-1} with the other variables measured. Accordingly, grass yield was positively correlated with basal cover ($P<0.001$), negatively correlated with bare ground ($P< 0.001$), ETTE ha^{-1} ($P<0.01$) and pH ($P<0.01$), positively correlated with the CN ratio ($P<0.01$), available K ($P<0.01$) and altitude ($P<0.01$). Basal cover was negatively correlated with bare ground ($P<0.001$) and positively correlated with available K ($P<0.01$).

Table 5.10. Physical and chemical characteristics of soils of the rangeland sites in Kereyu-Fantale district.

Range land site	Soil texture			Other soil parameters						
	Sand (%)	Silt (%)	Clay (%)	pH	EC (ds m^{-1})	N (%)	OC (%)	CN ratio	Available Phosphorous (ppm)	Available Potassium (ppm)
Aleka	52 ± 6	33 ± 5	15 ± 1	8.2± 0.19	0.16± 0.01	0.17± 0.06	1.23± 0.2	9 ± 0.6	2.6 ± 0.1	409 ± 38
Harole	3 2 ± 7.1	35± 2	33± 4.7	8.4± 0.1	0.17± 0.01	0.16± 0.02	1.14± 0.1	7 ± 0.0	3.5± 0.7	326± 36.7
Harole1	45± 17.6	28.0± 12.5	27± 12.5	8.5± 3.0	0.14± 0.1	0.19± 0.1	1.47± 0.5	9 ± 3	4.1± 1.49	266.5± 105
Chopi	32± 2	38± 0	30± 2	8.4± 0.01	0.17± 0.02	0.25± 0.01	1.9± 0.03	8± 0.0	4.3± 1.3	268± 44
Mogassa	39± 16.4	40± 12.5	21± 5.03	8.5± 0.3	0.15± 0.1	0.13± 0.02	1.1± 0.35	8± 1.2	4.93± 3.2	280± 60.6
Kara	23± 3	48± 4	29± 1	8.2 ±0.1	0.2 ±0.01	0.25 ±0.01	2.16± 0.5	9± 0.0	3.3± 1.1	431± 111
Kolbayu	27± 3	44± 2	29± 1	8.2± 0.2	0.2± 0.02	0.2± 0.02	1.7± 0.1	10± 0.5	4.8± 0.6	867± 69
Tulu Dimitu	53± 0.0	26± 1	21± 1	8.3± 0.15	0.2± 0.01	0.2± 0.01	1.5± 0.07	10± 0.01	1.93± 0.2	312.2± 20.5
Fantale	41± 1	40± 2	19± 1	8± 0.05	0.1± 0.08	0.1± 0.02	1.6± 0.1	13± 1	1.8± 0.6	323± 9.5
eseka	50± 5.5	29± 2.5	21± 3	9± 0.6	3.6± 0.03	0.1± 0.01	0.5± 0.2	8± 1.0	3.1± 0.1	426.5± 123.5

A stepwise multiple regression analyses was undertaken to have an in sight into the possible factors that give an explanation to the variation in grass yield (**Table 5.11**). Accordingly, bare ground, ETTE ha^{-1}, CN ratio and available K were selected .

Table 5.11. Standard coefficient, r values, R2 increment (%), R2 values (%) and significance with dry matter yield as a dependent factor (Multiple regression).

Variables	**Standard coefficient**	**r value (From correlation matrix)**	**R2 increment (%)**	**R2 values (%)**	**Significance**
Bare ground (%)	-0.3227	-0.69	7.21	48.20	P< 0.001
CN ratio	0.5106	0.68	23.81	73.27	P< 0.001
Available K	0.3187	0.59	8.45	83.10	P< 0.001
ETTE ha^{-1}	-0.2335	-0.50	4.47	88.0	P <0.01

5.4. DISCUSSION

5.4.1. Grass species composition

In general, the two study districts were dominated by *C. plumulosus*, different species of *sporobolus*, *C. dactylon*, *H. contortus*, *C. commutatus*, *D. aegypticum*, *P. dilatatum*, *C. poiflorum* and *T. cenchriformis*. The species identified in this study were, in general, similar to those reported by Schloeder & Jacobs (1993) from their study of the nearby Awash national park and the findings of this study generally concurs with the concept that, the potential natural community of a site, is dominated by one or a few species, which are best adapted to the specific combination of environmental factors of that site (RISC 1983). Furthermore, the dominance of *C. plumulosus* in 50% of the rangeland sites in both districts indicates the ability of this grass species to resist severe overgrazing. The abundance of *S. spicatus* and *S.*

ioclados at Lake Beseka and Asobabad was related to the adaptability of these grass species to saline soils (CADU 1974; Ibrahim & Kabuyu 1987).

In both districts, the percentage of the highly desirable (18.75% to 23.08%) species was less than the desirable (17.95% to 28.13%) and the less desirable (53.12% to 58.97%), while the grass layer was mainly dominated by *C. plumulosus*. Notwithstanding the limitations of such a classification of grass species, which is subjective, it gave an indication of the nature of the grass layer, both from an ecological (response to grazing) and palatability point of view. The highly desirable grass species are those group of grass species which include decreasers (species which dominate in good condition rangeland) and which were rated as highly palatable species by the pastoralists of the study districts. Grass species such as *C. ciliaris* (Ayana & Baars 2000; Amsalu 2000), *C. gayana* (Amsalu 2000), *D. milianjiana* (Ayana & Baars 2000; Amsalu 2000), *P. coloratum* (Ayana & Baars 2000) were grouped as decreasers, which is in agreement with the result of this study. *Themeda triandra* and the species mentioned above are also classified as decreasers in South Africa (e.g., Tainton *et al.* 1976; Van Rooyen *et al.* 1991; Van Oudtshoom 1999) and East Africa (Barker *et al.* 1989).

The desirable grass species consisted of those grass species, which are high or intermediate in their palatability and were Increaser IIa and perennial grasses. The Increaser IIa are groups of grasses, which increase with moderate over utilization (Vorster 1982). The grass species that were grouped are *C. commutatus*, *E. racemosa*, *H. contortus*, *P. glumaceum*, *H. hirta*, *P. stramineum*, *S. Ioclados*, *C. roxburghiana* and *L. nutans*. The likely reason for such variation is associated with the fact that species may possibly differ in their reactions to grazing intensity (degradation). Janse van Rensburg & Bosch (1990) argued that one species can have a different average abundance (different ecological groupings) in different topographic units and between edaphic variations within the same unit. For example, ephemeral forbs and grass species are usually classified as undesirable Increasers with a low grazing value (Fourie *et al.* 1987). However, in deserts these species are important in the diets of herbivores (Dieckmann 1980).

The less desirable grass species consisted of Increaser IIb and IIc species and according to Vorster (1982), the grass species in the Increaser IIb group increase with severe over utilization, while the Increaser IIc groups increase in abundance with severe over-utilisation. This group comprised annual and perennials with a low palatability as perceived by the pastoralists. Some of the grass species in this group are found on disturbed areas and can, therefore, be used as indicators of poor rangeland condition. For example, species like *A. adscensionsis*, *T. berteronianus*, *C. dactylon*, *D. aegypticum*, *D. ternata*, *S. verticellata*, *U. panicoides*, *P. snowdenii*, *S. ustilata*, *P. pycnothrix* were reported to occur on disturbed areas (CADU 1976; Tainton *et al.* 1976; Ibrahim & Kabuye 1987; Barker *et al.* 1989; Van Oudtshoom 1999).

The perennial grass species are better indicators of the ecological status of an area compared to annual grass species, because significant changes in abundance between Decreaser and Increaser perennial species are most likely to take place only after significant changes occurred in the degradation status of an area (Cable 1975; du Plessis *et al.* 1998; Snyman 1999a). In both districts, the percentage of perennial grasses was higher than the annual grasses. The lower abundance of the annual grass species, in this study, could be due to the reaction of annual grasses to small changes in rainfall and grazing pressure. Rainfall has a marked influence on the presence or dominance of annual species (Cable 1975; Van Rooyen *et al.* 1990) and is also the main determinant of forage production (Fourie *et al.* 1987).

In both districts, many grass species (*A. adsceniorsis*, *T. berteronianus*, *C. dactylon*, *D. aegypticum*, *D. ternata*, *S. verticellata*, *U. panicoides*, *P. snowdenii*, *S. ustilata*, *P. pychnothrix*, *A. adoensis*, *S. natalensis*, *E. cilianensis*, *C. poiflorum*, *E. indica and M. kunthii*) are indicators of changes in species composition of the grass layer that took place (CADU 1976; Ibrahim & Kabayu 1987). Long-term experiments are required to separate the effects of different interacting factors that caused the changes in species composition in the study districts. Nevertheless, studies made by others (Pressland & Graham 1989; Fabregues *et al.* 1992; Duncan *et al.* 1993; Milchunas & Lauenroth 1993; O'Connor 1994) indicated that drought and overgrazing can influence the vegetation composition of an area. Frost *et al.* (1986) and Westoby *et al.* (1989) argued that the influence of grazing on the botanical composition of rangelands is a central tenet of rangeland management, yet the population dynamics of important savanna grass species appears to be more dependent upon rainfall variability than upon grazing. The importance of adequate soil water for seedling recruitment is widely recognized (Glendenning 1941; Harradine & Whalley 1980; Cox 1984; Peart 1984; Mott *et al.* 1985; Fowler 1986; Frasier *et al.* 1987; O'Connor *et al.* 2001). Although there is no adequate data base from many sites across the rangeland sites to ascertain the significance of rainfall the 35 years data collected by Mathara Estate sugar indicated that in 42.9% of the rainfall years, the rainfall was above the long term average and in 57.2% of the years, the rainfall was below the long term average.

It was not possible to determine the stocking rate in the study area. Due to a lack of land there exist conflict over the use of available resources, further characterized by a lack of land capability planning, where pastoralists keep too many animals on a relatively smaller area, which normally leads to overgrazing of the rangeland. This can lead to wind erosion, further removing the soil from the surface. The influence of overgrazing on species composition is well documented (O'Connor & Pickett, 1992; Milchunas & Lauenroth 1993; O'Connor 1995). Livestock first select the most palatable grass species and if the grazing pressure continues, a decline in the quality and the quantity of the rangeland occurs (Lazenby & Swain 1969; Cossins & Upton 1985). This causes reduced vigour, less seed production and eventually plant death. Overgrazing can lead to extensive sheet and gully erosion (Pratt & Gwynne 1977). Therefore, to enable optimal, sustainable use of the rangeland there should be an adequate rest period for the grass species to grow, to seed, and be able to accumulate reserves for the next growing season.

In conclusion, a more comprehensive understanding of the environmental factors and population processes primarily responsible for population and community changes will, therefore, only be achieved within the context of long-term field experiments.

5.4.2. Basal cover, bare ground and estimated soil erosion values

The results of the study showed that in general, the % basal cover of the studied rangeland sites in both districts was low. In relative terms, the only exceptions on the Afars side were Top of bud and Degage with basal cover values of 4.8% and 4.6%, respectively. Kolbayu and Tulu dimitu with basal cover values of 4.7% and 4.6% from the rangeland sites in the side of the Oromos can be said to have relatively better cover values. Though the intensity of soil loss varied from one rangeland site to another, in general there was a loss of soil from the surface that was also shown in the estimated soil erosion values and percent bare ground. The results further indicated that, the % bareground was relatively high at Asobadad and Samayu (Awash-Fantale), and Mogassa, Beseka and Chopi (Kereyu-Fantale).

Normally the basal cover of excellent vegetation is expected to be greater than 12% (Baars *et al.* 1997) and if the basal cover obtained in the study districts is compared with this value, the mean basal cover values for Awash-Fantale (3.43%) and Kereyu-Fantale (3.23%) were very low. Snyman (1997) reported a low basal cover for vegetation in poor condition in a semi-arid climate. Many different factors can lead to a low basal cover and high soil loss from the surface. From this study it would appear that overgrazing (Milchunas & Lauenroth 1993; O`Connor *et al.* 2001), drought (William *et al.* 1990), poor grazing practices (Snyman & Fouche, 1993) and high tree densities (Smit *et al.* 1999; Smit 2002) are the most likely determinants. These factors are interrelated and it is difficult to separate the effect of one from the other without a long-term experiment.

Overgrazing is widely believed to cause a decline in the basal cover of the herbaceous vegetation (O`Connor 1985; Thrash *et al.* 1991). Several studies reviewed by O`Connor (1985), on the effects of grazing by livestock showed that the herbaceous stratum basal cover decreased when subjected to severe grazing. Thrash *et al.* (1991) upon their study of the impact of provision of water for wildlife on the basal cover of the herbaceous vegetation showed that the relative basal cover of the herbaceous stratum is more sensitive to the impact of the dam than the woody species. Snyman (1999a) concluded that the basal and canopy cover provided by a vegetation community protects the soil surface from raindrop impact, which causes surface sealing and splash erosion by reducing the considerable kinetic energy from the falling raindrops. The protection, which grass plants afford, the soil is normally much greater than that given by most non-grass plants. This is so because, for a given crown cover, grasses have a much greater basal cover than shrubs (Roux 1981) and provide an extremely complex network of roots immediately below the soil surface (Skinner 1964; Theron 1964; Roux 1969; Pressland 1973; Roux 1981; Elkins *et al.* 1986). In general, vegetation reduces erosion in a variety of largely unrelated ways, where the density, cover, botanical composition, canopy height and perenniality of the plant community are the most important (Snyman 1999a).

The study districts had a relatively higher proportion of perennials than annuals. It is known that stands of perennial grasses provide better cover than the annuals, because they provide a much denser and more stable cover. Basal cover has an important influence on the rate at which water infiltrates into the soil, and by promoting infiltration it reduces erosion wash (Snyman 1999a,b). O`Connor *et al.* (2001) indicated that a low basal cover also signifies an increased area of exposed soil, which is in agreement with the findings of this study. Bare ground is a good indication of over-utilisation and degree of the degradation of the vegetation. Du Plessis *et al.* (1998) made a similar conclusion from their study in the Etosha National park in Nambia.

Although the action of the hoof of animals on soil status was not addressed in the study, one can speculate that this action may have an influence on the soil condition. Because the animals are concentrated in smaller areas with a high intensity of movement in search of food it is likely to increase hoof action. In the more arid regions, the hoof action of grazing domestic animals is taken as an important factor for the initiation of erosion (Snyman 1999a).

Historical evidence indicates that natural climatic patterns produce cycles of drought, followed by periods of relatively higher rainfall. However, Snyman (1999a) reported that drought can be intensified by injudicious grazing practices or overgrazing, which can lead to man made droughts. Degradation of the rangeland ecosystem, accompanied by the loss of the soil, can result in an increased intensity of management-induced droughts and this kind of drought is usually localized (Snyman & Fouche 1991, 1993). This, in turn, results in the reduction of infiltration of rainwater into the soil, which reduces the vigor of the vegetation and this in turn, increases the severity of flooding by increasing surface runoff. Nevertheless, this argument, does not exclude the existence of sporadic climatic droughts due to a low amount of rainfall. There have been six extensive drought episodes on the African continent in the last three decades: 1965-66, 1972-74, 1981-84, 1986-87, 1991-92, and 1994-95. Drought affects the livelihood of pastoralists that in turn determine their responses to cope with the condition (Zinash *et al.* 2000). At these times, forage resources dwindle to very low levels. Plant cover also declines as plants are killed by the combined pressure of heavy grazing (Abel 1993) and a lack of plant-available water (Snyman *et al.* 1987, 1998, 1999; O'Connor & Bredenkamp 1997). The situation of the study districts with regard to rainfall was discussed in section 5.4.1.

Considering some rangeland sites in the study districts (Mogassa, Samayu and Chopi and Bulga riverside), these sites had a higher tree density compared to the others as characterized by their high ETTE ha^{-1} values. Thus, their low basal cover could be also associated with high tree densities. Smit *et al.* (1999) reported that many savanna areas are water-limited ecosystems and an increase in tree density (bush encroachment) is considered a major factor contributing to the low occurrence or even total abscence of herbaceous plants in severe cases.

The relatively better basal cover at Kolbayu and Degage can be related to the fact that these rangeland sites are found at the junction between the Afars and the Oromos where animals cannot graze as freely as they graze the other rangelands. Furthermore, because of the shortage of water in these areas during the dry season, these areas are not grazed as often as the other rangeland sites.

5.4.3. Grass DM yield, grazing capacity and rangeland condition

The mean yield of grass, for the study districts, 437.08 kg ha^{-1} for Awash-Fantale and 421.92 Kg ha^{-1} for Kereyu- Fantale districts were relatively lower than that of Amsalu (2000) who reported a yield of 533 kg ha^{-1} from his study in the mid rift valley of Ethiopia that has a comparable climatic situation. The relatively lower yield in this study could be due to fluctation in species abundance and herbaceous yield as determined by rainfall, soil type and the tree-grass ratio (O`Connor 1991).

In both districts, the yield of grass was the highest and the lowest in rangelands with woody vegetation (Degage, Kolbayu, Samayu and Mogassa). The main reason for the increase in grass production at Degage and Kolbayu could be due to the relatively better basal cover value, low tree density and low grazing intensity in these rangelands as was discussed in section 5.4.2. Increased grass production due to better plant cover is in agreement with the findings of O`Connor *et al.* (2001). O`Connor *et al.* (2001) from their study concluded that maintaining basal cover is very important for grass production, because basal cover is the primary control of water retention and growth opportunity, but composition and species identity play an additional role. The decrease in grass production at Samayu and Mogassa, when compared to the other sites, could be associated with the high tree densities in these rangeland sites as was expressed by the high ETTE ha^{-1}.

Determining grazing capacity is a controversial subject due to an abundance of factors influencing its determination (Vorster 1981a,b; Roe 1997). When one factor changes, grazing capacity changes to a greater or lesser extent. Furthermore, the system of land ownership in the pastoral community is communal, where numerous households, each making more or less independent management decisions, are using the same grazing resource. Though environmental factors determine the inherent grazing capacity (O'Connor & Bredenkamp 1997), management factors (Danckwerts & Tainton, 1996) and climatic variation (Danckwerts 1982; Van den Berg 1983; Van der Westhuizen 1994; Snyman, 1998; Van der Westhuizen *et al.* 2001) also influence the degree of variation from the potential long-term grazing capacity. Accordingly, the mean grazing capacity of 23.6 (10.7 to 35.6ha LSU^{-1}) and 14.7 (6.7 to 22.2 ha TLU^{-1}) in Awash-Fantale district and the mean grazing capacitity of 24.8 ha LSU^{-1} (11.2 to 54.1 ha LSU^{-1}) or 14.5 ha TLU^{-1} (7 to 28 ha TLU^{-1}) in Kereyu-Fantale district implies that more land is required to sustain an LSU or TLU without damaging the rangeland ecosystem. The estimation of grazing capacity in this study was undertaken to give an indication of the extent of the problem in the study districts. In comparison to others, the grazing capacity of Madalal, Top of budl, Samayu, Bulga riverside, Della kara (Awash-Fantale district) and Mogassa, Chopi and Kara (Kereyu-Fantale) were low. This could possibly be ascribed to the high tree density in these rangeland sites. An increase in the woody plant density beyond a critical density was reported to result in the suppression of herbaceous plants, mainly due to severe competition for available soil water, thus lowering the yield of the herbaceous layer and also the grazing capacity (Dye & Spear 1982; Moore 1989; O'Connor 1991; Smit & Rethman 1998b; Richter *et al.* 2001). This suppressive effect of bush encroachment is the major reason why clearing or thinning of trees is considered as a management option (Donaldson 1973; Van Niekerk & Kotze 1977; Jacoby et al. 1982; Gammon 1984; Moore *et al.* 1985; Heitschmidt *et al.* 1986; Moore & Odendaal 1987; Scholes 1987).

Rangeland condition in this study was calculated based upon the species composition and the desirability of the species under consideration. In both districts, compared to the other rangeland sites, rangeland sites along Lake Beseka and Asobabad had a low rangeland condition score. The low rangeland condition score along Asobabad and Lake Beseka could be attributed to the high percentage bare ground (8.1 to 10.8%), the high abundance of forbs (17%) at Asobabad and the fact that these rangeland sites were also dominated by *S. spicatus* which was less desirable grass species.

From the results it is clear that some rangeland sites such as Madalal, Samayu, Della kara and Bulga riverside (Awash-Fantale district) and Harolel, Kara, Mogassa and Chopi (Kereyu-Fantale district) had a lower rangeland condition score compared to the others. This is due to the presence of forbs, increased bare ground and less desirable grass species, which lower the rangeland condition score either on their own or in combination. The reasons for this and the arguments were discussed in sections 5.4.1 & 5.4.2. In some rangeland sites, the presence of desirable and highly desirable grass species resulted in a rangeland condition values as high as 90%. This, however, indicates that the use of a single factor such as grass species composition alone may not be a good indicator of rangeland condition since it was based upon the subjective allocation of the grass species to different categories. Anderson (1985) and James *et al.* (1991) stated that the method of rating rangeland condition by species composition alone appeared not to be reliable for assessing rangeland condition. Therefore, a combination of factors such as soil parameters and woody layer (where available) must be used to arrive at a more accurate rangeland condition value.

5.4.4. Woody vegetation composition

The woody vegetation composition in the study area was dominated by species of *Acacia* notably *A. senegal* and *A. nubica*. Futhermore, species of *Acalypha*, *Solanum*, *Vernonia* and *Grewia* were also relatively abundant. The woody plants identified in this study were more or less similar to those the reported by Schloeder and Jacobs (1993) from their study in the Awash National park.

Some of the woody species identified in the study districts such as Solanum species give an indication of the condition of the rangelands. According to Dale and Greeenway (1961) and Irvine (1961), *Solanum* species, are indicators of a change in the condition of the rangeland towards deterioration and are also considered as poisonous plants in Ethiopia (Mekonnen 1994).

The low density of some of the woody species such as *A. nilotica*, *A. tortilis* and *B. aegyptica* could be associated with the usage of these woody plants for fire wood and charcoal. Species of woody plants not found in the other rangeland sites, were found in the Fantale grazing land and this could possibly be associated with the higher elevation (1 650 m.a.s.l) of this area than the others. This result concurs with the findings that altitude with its influence on temperature and precipitation has a primary influence on vegetation composition of an area (Alemayehu 1979; Pratt & Gwynne 1977; Alemu 1987; Ayana & Baars 2000).

5.4.5. Browse production and browsing capacity

Browse plants play an important role in the diets of ungulates living in arid zones (Walker 1980; Nott & Savage 1985). Owing to this fact, livestock production in the study districts is based on the integration of grazers (cattle and sheep) and browsers (camel and goats). The availability of forage that can support the different livestock species is considered to be the most important factor influencing habitat selection by large herbivores (McNaughton 1987). Furthermore, the fluctuations in live biomass are extremely important in determining food habits (Kutilek 1979; Jarman & Sinclair 1979), movement patterns (Talbot & Talbot 1963; Maddock 1979), and habitat utilization (Lamprey 1963) by large mammalian herbivores. Therefore, determination of browse production for stock usage is very important.

Compared with research efforts on the grasslands in East Africa, the browse component of savanna ecosystems has for long been neglected (Pellow 1983). Accordingly, there are limited published results of browse production to make comparison of the results of this study with others. Rutherford (1982) reported a production of 1 100 kg ha^{-1} of leaves from a study of the above ground biomass of *Burkea africana-ochana pulchra* savanna and Scholės (1987) reported a yield of 801 kg ha^{-1} of leaves for *C. mopane*. In addition, the study by Walker (1980) demonstrated that production varies strongly owing both to inherent site differences (mainly soil depth) to management and reported a yield of 594 kg ha^{-1} to 2 121 kg ha^{-1} from a *C. mopane* arid shrub and tree savanna in Zimbabwe, while Dekker and Smit (1996) reported a yield of 1 224 kg ha^{-1} to 2 672 kg ha^{-1} for *C. mopane*. Therefore, in light of the existing knowledge, the total leaf DM at peak biomass produced across the rangeland sites (196 kg ha^{-1} to 3311 kg ha^{-1}) can be considered to be within acceptable ranges.

In the study districts, of the total leaf DM produced by woody plants, 4 773 kg ha^{-1} (31.2%) in Awash-Fantale and 4 003 kg ha^{-1} (39.87%) in Kereyu-Fantale, was found to be below 1.5 m which implies that this amount, at least theoretically, is available for browsing by goats. Nine thousand two hundred and forty six kg ha^{-1} (60.34%) in Awash-Fantale and 5 707 kg ha^{-1} (56.84%) in Kereyu-Fantale was found above 1.5 m up to 5 m. Although, the mean height of camels is about 3.5 m, it can be said that most of this browse is within their reach. Smaller browsers will only have access to these leaves when they dry and fall to the ground. The abundance of browse in the height above 1.5 m is in agreement with the report of Kozlowwski & Keller (1966) who reported that woody species growth is terminal and greater at the top of the plant, which implies that greater productivity occurs in the upper canopy than the lower canopy. The remaining 1 125 kg ha^{-1} (8.52%) in Awash-Fantale and 330 kg ha^{-1} in Kereyu-Fantale was found greater than 5 m height. Of the amount that was beyond 5 m, the woody plants along the Bulga riverside, mainly, *A. nilotica* and *A. tortilis* that can only be used by breaking the branches, contributed 85.6%. The browsing heights considered are mean heights and not maximum browsing heights and were only used to draw comparisons. It is known that large individuals are able to reach higher than those mean heights, e.g., 2.5 and 5.5 m for kudu and giraffe respectively (Dayton 1978), while breaking of branches may enable some browsers to utilize browse even at higher strata (Styles 1993). Furthermore, both pastoral groups lop browse trees during the dry season (refer Chapter 4).

Among the studied rangeland sites in Awash-Fantale (Awah-FantaleDulcha junction site, Bulga riverside, Top of budl, Samayu, Madalal, Della kara) and Chopi, Harolel and Mogassa in Kereyu-Fantale had a higher browse production at peak biomass than the other grazing lands and this was mainly attributed to the higher density of woody plants. Possibly more important than the amount of available browse at peak biomass is the continuity of browse availability over the seasons. Leaves retained on the trees in a younger phenological state followed by the early emergence of new season's leaves are likely to be of greater value to browsers than where the trees are leafless for some time with only dry leaves available on the ground. To this effect, a detailed study was not undertaken on the phenological behavior of the identified woody species. Nevertheless, the preliminary investigation undertaken revealed, except along the Bulga riverside, Awash-Fantale Dulcha junction and Fantale, most woody plants shed their leaves during the dry season, as the study districts were also dominated by deciduous species of *Acacia*. Deciduousness is the feature of trees within the savannas across the world with pronounced seasonal reduction in canopy cover as the dry season progresses (Williams *et al.* 1997). There appears to be a considerable variation in ecosystem level patterns of deciduousness in the world's savannas. African savannas are mainly deciduous (Menaut & Cesar 1979; Chidumayo 1990; Smit 1999a) which confirms that the availability of browse to the browsers will be low during the dry season.

In Awash-Fantale district, *E. abyssinica*, *C. grandiflora*, *C. rotundfolia*, *S. perisca* and *P. juliflora* showed a higher phenological value during the dry season as well. This might be attributed to their access to water along rivers where they can get water through their deep taproots. The abundance of browse along the rivers, in turn implies the dependency of the pastoralists to these areas as a source of browse to their stock during the dry season. However, *E. abyssinica* and *C. grandiflora* were indicated as poisonous plants by the pastoralists, which limits their use as a source of feed to livestock and also their contribution to the total leaf DM was small.

Some species (*O. rochetina*, *P. africanum*, *B. oleiodes*, *R. communis* and *D. afromontana*) along Mount Fantale also displayed higher phenological values. Nevertheless, these woody plants were rated as unpalatable by the Oromo pastoralists and hence their use as a source of browse is very limited, which concurs with the report of Grunow (1980) who indicated that browsers select among plant species as markedly as grazers do. Furthermore, chemical defences of plants may also limit the use of browses (Robbins *et al.* 1987; Bryant *et al.* 1992). The variation in leaf DM, even for a similar species across the rangelands with the same ecological condition can possibly be due to variation between the different vegetation types

(Hall-Martin & Fuller 1975; Guy *et al.* 1979) and can therefore be considered important factors that influence the distribution of herbivores.

In conclusion, in both districts, the various species of *Acacia* were the main source of browse for livestock and hence of the browsing capacity of the rangeland sites.

5.4.6. Bush encroachment

Bush encroachment is one of the most serious and conspicuous results of imbalances in savanna ecosystems (Richter *et al.* 2001) and remains one of the major structural problems limiting optimum animal production (Bester & Reed 1997). The study confirmed that substantial bush encroachment had taken place in both districts, which were dominated by species of *Acacia* (*A. senegal*, *A. nubica* and *A. mellifera*) and *P. juliflora* in the case of Awash-Fantale district. Furthermore, *C. rotundfolia* and *Acalypha* species in Awash-Fantale and *G. bicolor* and *G. villosa* in Kereyu-Fantale had a relative higher ETTE ha^{-1} value than other species. Just considering only *A. senegal*, five rangelands across the study districts were covered mainly with this encroaching plant.

In most areas of East Africa, the natural vegetation is dominated by woody species, where edaphic factors do not prevent growth of these life forms (Pratt & Gwynne 1979), bush encroachment is a wide spread phenomenon (Prins & Van der Jeugd 1992). The causal factors for bush enroachment are not absolutely clear (Prins & Van der Jeugd 1992) rather; they are diverse and complex (Smit 2002). Nevertheless Smit (2002), reported that an increase of woody plant abundance is primarily a function of two processes. The first is by an increase in the biomass of already established plants (vegetative growth) and the second is by an increase in tree density, mainly from the establishment of seedlings (reproduction). Teague & Smit (1992) further explained that, man has modified the determinants of savanna systems in most situations, either directly or indirectly. These determinants may either be primary (such as climate and soil) or secondary (fire and the impact of herbivores).

The encroachment by species of *Acacia* has been reported from different countries e.g., Ben- Shahar (1991), Stuart-Hill & Tainton (1999); Smit (1999a); Hagos (2001) in South Africa; Arntzen & Veenendaal (1986), Mcleod (1992); Dahlberg (2000) in Botswana; Prins & Van der Jeugd (1993) in Tanzania, Mugasi *et al.* (2000) in Uganda. A host of other woody species were also reported; e.g., species of *Maytenus*, *Euclea*, *Grewia* and *Dichrostachys cinerea*. *Acalypha fruticosa* was also indicated as an encroacher woody plant (Prins & Van der Jeugd 1993) in Tanzania.

Ben-Sharar (1991) studied successional pattern of woody plants in catchment area in a semi-arid region in South Africa. He reported that *A. senegal* became dominant in areas previously dominated by *A. tortilis*. The successful establishment of *A. senegal* seedlings seemed to depend on effective utilization of open spaces and probably also supported by a fast growth rate. Knoop (1982) also observed that on a site dominated by *Acacia* species, a large number of seedlings germinated and survived in an area cleared of vegetation, but that few were found in an uncleared area. Although, the role of roots was not covered in this study, other studies (Adams 1967; Hagos 2001) done on *A. mellifera* indicated that their root systems were extending laterally beyond the canopy cover and could play a part in the spacing of trees. The dispersion of roots could play a major role in the local depletion of water and nutrients around the canopy and beyond. It is generally conceded that trees are able to make more effective use of deep water than are the grasses (James 1967; Wu *et al.* 1985; Wilson 1988; Prins & Van der Jeugd 1992) so that any management actions that increase water penetration to a depth in the soil profile should stimulate growth in the already established trees.

Effective dispersal could also be brought about by means of birds or mammals that travel long distances (Gwynne 1969; Coe & Coe 1987). Although, the seeds of *A. senegal* are soft dehiscent seeds, which can be damaged when passing through the buccal cavity and alimentary systems of the herbivores (Ben-Shahar 1990), this point is worth mentioning when one looks at the migratory pattern of the different livestock species in the study districts. Camels are mobile throughout the year and the other livestock species are also moved from place to place in search of feed and water in an area of resource use conflict where shortage of land is a critical constraint. Compared to the intensity of migration, there is a chance that seeds of different woody plants can be transported from place to place.

Although contradictory reports were given to the wide spread general view that long term heavy grazing is a prerequisite for an increased rate of woody plant establishment, work done by Smit & Rethman (1992) has shown that heavy grazing is one of the most important contributing factors. The study area is an area of resource use conflict with a shortage of land. The rainfall in the study districts for many years has also been lower than the long-term average. The situation in the study districts can also incline to the common view that the destruction of grasses by overgrazing during drought offers a window of opportunity for the increase of the woody component because of reduced fire and competition (Du Toit 1972). In general, evidence from the literature and research work in different countries suggest that bush encroachment takes place as a result of the exclusive use of moisture by encroachers, high soil nutrient concentrations, low fire frequencies and high cattle selectivity (Moleele *et al.* 2002; Smit 2002).

In the Afar region, *P. juliflora* is known as undesirable noxious plant (alien species) and this plant is becoming a major problem. In Awash-Fantale district, this plant is found localized near the town of Awash and at the border areas neighbouring Awash-Fantale district and is spreading into the grazingland of the pastoralists living in Awash-Fantale. It was indicated in the study report of Gebru (2001) that this woody plant was introduced first by an Indian researcher for the purpose of soil conservation, especially targeted to the eroded areas of Western Dire Dawa in Ethiopia and later on it spread to various places of the country. A British consulting firm first introduced this plant to the Afar region either from the neighboring Sudan or Ethiopian workers during the period between 1971-1974 around the state farms in the middle Awash valley of Ethiopia. The pastoralists use the palatable pods of the plant for livestock feeding and use the plant as a source of fuel wood. Nevertheless, they strongly complained about its rapid expansion and rapid coverage of large areas of rangelands, which decreases the size of the rangelands available for grazing animals. Reynolds & Glendening (1949) indicated that between 12 to 45% of the hard *P. juliflora* seeds pass undamaged through livestock. Furthermore, Glewndening & Paulsen (1950) reported that 27% of the total seeds fed to sheep germinated after ingestion.

5.4.7. Soil

5.4.7.1. pH, electrical conductance and texture

The direct comparisons of the soil nutrient levels with other studies have limited value because of the difference in soil type and methods of analysis. As a result, the discussion below will be more generalized. The pH of the soil and associated properties strongly influence plant nutrient availability and soil productivity (Tisdale *et al.* 1993). Accordingly, the pH values of the soil in the study districts were generally alkaline. Although, sodium carbonate and bicarbonate were not analyzed in this study, the higher pH at Lake Beseka and at Asobabad could possibly be associated with the frequent occurrence of ground water containing high proportions of sodium carbonate and bicarbonate where the pH exceeds 9.5.

The size of the mineral soil particles varies across a wide continuous spectrum. Although, there were variations from one place to another, the soils on the surface generally were with a good proportion of sand and silt. Similar to the pH, the electrical conductance was found to be highest at Asobabad and along lake Beseka. Individual soluble salts were not quantified in this study, yet it is possible that the high electrical conductivity values at these places could be due to the accumulation of Na^{+} Ca^{++}, Mg^{++}, Cl^{-} and SO_4^{--} (Thompson & Frederick 1978).

5.4.7.2. Percent total Nitrogen

Nitrogen is a vitally important plant nutrient and is the most frequently deficient of all nutrients (Tisdale *et al.* 1993). Accordingly, the lowest % N was obtained along Lake Beseka and Asobabad. This could possibly be associated with the low accumulation of organic materials that can contribute to the low soil N in these grazing lands. The variations in N from one rangeland site to the other, shown in the results, might be associated with the contribution of trees to N, nitrogen fixation by Rhizobium bacteria on the roots of leguminous woody plants and also there might be the influence of grazing animals. Peterson *et al.* (1956) argued that grazing animals ingest a large amount of N in the feed, but 75% is excreted. In general, Bauer *et al.* (1987) indicated that large amounts of soil total nitrogen in grazed condition could result from a source of N extraneous to the grazed system.

5.4.7.3. Organic carbon

Soil organic matter is a key component of any ecosystem and any variation in its abundance and nature may have profound effects on soil processes. A High concentration of organic matter in soil is important, because soil organic matter concentration is one of the most important factor in the storage of nutrients and it is also important for maintaining good soil structure especially in fine textured soils (Du Preez & Snyman 1993).

In the study districts, the percentage OC was the lowest at Asobabad and along Lake Beseka and these soils are saline soils. The low percentage OC in these grazing lands could be due to the low accumulation of plant materials that can contribute to soil enrichment. The results also indicated that in both districts, the percent OC was higher in grazing lands with woody plants than those without woody plants and the relatively higher content of soil OC in the former demonstrated the soil enriching capacity of trees. The contribution of woody plants to soil nutrients is well known (Bosch & Van Wyk 1970; Kennard & Walker 1973; Tiedemann & Klemmedson 1973; Berhard-Reversat 1982; Kamara & Haque 1992; Smit & Swart 1994; Wezel *et al* 2000; Smit 2002). The reasons for the higher content could be complex (Vettas 1992). Leaf litter from leaf fall has been mentioned as a possible source (Bosch & Van Wyk 1970; Stuart-Hill *et al.* 1987; Belsky *et al.* 1989; Weltzein & Coughenour 1990). Dust accumulated on tree leaves and branches by wind blowing from the surroundings could be one possible source of nutrient, as it is washed down to under canopy soil during stem flow and through fall (Kellman 1979). Woody species have deeper taproots and extensive spreading lateral roots and such root systems are probably important in concentrating nutrients under the canopy (Kellman 1979).

Knoop & Walker (1985) suggested that nutrients found in low concentration throughout the soil profile may be taken up by the root system of mature trees and shrubs and these nutrients return back to under canopy soil when tree leaves fall and decompose (Garcia-Moya & McKell 1970).

If one looks at the grazing lands without woody vegetation (Aleka, Harole, Madala and Top of bud), except those mentioned above (Asobabad and lake Beseka), the organic carbon is not particularly low. This might be due to the effect of manure, although this was not investigated in this study. In the study districts animals are concentrated on a relatively small area, where the effect of manure might influence the soil nutrient status. Glaser *et al.* (2001) noted the influence of manure on the soil nutrient status in a semi-arid region of Northern Tanzania.

5.4.7.4. Carbon Nitrogen ratio

The zone of maximium soil OC and N accumulation is restricted to the upper soil depth (0-50 mm) (Derner *et al.* 1997) and the CN ratio defines the relative quantities of these two elements, while in determining the soils N - potentialiy, the CN ratio of the organic matter is of importance. The C/N ratio of undisturbed topsoil in equilibrium with its environment is about 10 or 12 and a narrow C/N ratio indicates that the organic matter is rich in N (Tisdale *et al.* 1993). Based upon this, in Awash-Fantale district, of the studied rangeland sites, 44.4% of them had a CN ratio of 8, while the remaining had a value of 10 (11.1%), 9 (11.1%), 7 (22.2%) and 6 (11.1%). Correspondingly, in Kereyu- Fantale district, 30%, 30%, 20%, 10% and 10% of the rangeland sites studied had a CN ratio of 9, 8, 10, 7 and 13 respectively. Barnes *et al.* (1991) argued that a relatively narrow ratio of C to N in the soil would favor N release from the organic matter.

5.4.8. Correlation among the variables studied and multiple regression between grass yield and other parameters

It was shown in the results that, in both districts, grass DM yield was negatively correlated with bare ground, estimated soil erosion value, ETTE ha^{-1} and positively correlated with basal cover, and altitude (Kereyu-Fantale district). The stepwise regression analysis indicated that grass yield was dependent on ETTE ha^{-1} and basal cover in Awash-Fantale, while on percentage bare ground, ETTE, CN ratio and available K in Kereyu-Fantale district. The difference between the two districts lies in the fact that, the total ETTE value in Awash-fantale district (65 315) was higher than that of Kereyu-Fantale district (44 221). The effect of tree density, expressed as ETTE ha^{-1} on grass yield was discussed in section 5.4.3. The influence of percent basal cover and percent bare ground on grass yield differs in such a way that, while increase in basal cover results in an accompanied increase in grass yield, on the other hand, increase in percent bare ground will decrease grass yield. These influences on grass yield might be through their influence on the water status of the soil, which was also discussed in section (5.4.3).

The positive correlation of grass yield with CN ratio could be associated with a better ratio of C to N. Barnes *et al.* (1991) argued that a relatively narrow ratio of C to N in the soil would favor N realize from soil organic matter, while the negative correlation of pH on grass yield was in agreement with the general indication suggested by Barnes *et al.* (1991) that grass yield could be influenced by pH.

5.4. CONCLUSIONS

Communal rangelands support cattle and other domestic livestock in a continuous grazing system, with several pastoralists having free access to the same grazing area. No clear management objectives have been stated for these areas, but the unwritten objective is to maximize the number of animals owned by each individual. Accordingly, the following conclusions are made from this study.

- The rangelands studied were dominated by *C. plumulosus* and the different species of *Sporobolus*. Except at the junction site between the Oromo and the Afars, the yield, basal cover and the grazing capacity of the rangeland sites was low which agrees with the perceptions of the pastoralists about the condition of the rangelands.

- The studied districts are bush encroached notably with *A. senegal*, *A. nubica* and *P. juliflora* (Awash-Fantale district). This finding is also in line with the pastoralists concern of bush encroachment.
- The results of this study support convectional wisdom, which states the effect of high stocking rates are generally an undesirable changes in species composition, reduced productivity and increase erosion (Pluhar et al. 1987). Therefore, the study area must have a proper land use plan with rangeland improvement practises such as bush control and resting of the rangelands with stock exclusions for some period.

CHAPTER 6

CONDITION OF THE COMMUNAL RANGELANDS IN RELATION TO BENCHMARK SITES

6.1. INTRODUCTION

A benchmark can be defined as a rangeland site (native pasture) with the best possible botanical composition and cover (excellent condition) in relation to prevailing climatic condition (Tainton 1999). Benchmarks are needed for rangeland managers to determine the condition and trend of the vegetation, which can provide pastoralists with information on the kind and amount of species that can be expected when vegetation is protected from grazing. It is also important for rangeland managers to be able to separate the impacts of grazing (or other consumptive uses) on the species composition and productivity of vegetation from those caused by climatic variations, explosions of insect populations or pollution (Taylor & Whalley 1976).

Danckwerts (1982) suggested that a benchmark should be an example of vegetation that is considered to provide the highest possible sustainable animal production for the rangeland type under consideration. This implies that it would have been well managed in the past. Unfortunately, under the prevailing condition in Ethiopia, there are few areas that can be classified as being in excellent condition. To overcome this problem, in relative terms, the best sites in respect of vegetation condition were identified in the study area, which could serve as a benchmark for this study. Accordingly, protected grazing reserves locally known as 'kalo' and the little used junction site between the Afars and the Oromos etnic groups were used for the study. The use of multiple benchmarks has been recommended by Wilson (1984) to minimize the bias arising from area selection. This study was, therefore, undertaken to compare the protected plots (benchmarks) with the communal rangelands and therefore get an insight into the condition of the grazing areas in relation to the protected plots (Benchmarks).

6.2. PROCEDURE

6.2.1. Identification of benchmark sites

Three benchmarks sites were identified in the study area based upon similarity in altitude, soil, and nature of the vegetation to the rangelands to which they will be compared. Two of the benchmark sites were small (0.35 to 1.5 ha) area of land protected by the Oromo pastoralists for use during the dry season, either by harvesting or allowing the animals to graze. The two sites were protected for 5 and 15 years respectively. The third one is known as the `land of fear` locally called "Lafa soda" (**Figure 6.1**). This area is located at the junction between the Oromo and Afar boundaries and has a very good vegetation cover for the mere reason that both pastoral groups do not graze their animals freely and continuously in these area in fear of prosecusion by the other group. As a result, the intensity of the grazing is low. Six sampling sites (four from the Oromo and two from the Afars) were compared with the benchmark sites.

Figure 6.1. Vegetation condition of the junction area between Afar and Oromo ethnic groups.

The rainfall both at the benchmarks and the sampling sites ranged from 550 to 620 mm and the altitude from 950 to 1040 m.a.s.l. The major focus in this study was the grass layer based on the rationale that the cattle and sheep are more affected by the change in the vegetation compared to the camels and the goats, which are also browsers.

Comparisons were made between benchmarks (Dhebeti and D/Galcha = Benchmark 1) and the sample sites (Madala1, Kachachilo and Harole1= First group). The second group contained one benchmark (Dakaakae= Benchmark II) and four sampling sites (Top of bud, Aleka, Harole 2 and Madala 2 = second group).

6.2.2. Data collection and analysis

In each of the benchmark and sampling site, 500-point observations was undertaken using the wheel point apparatus to assess the herbaceous species composition. The assessment factors and their measurements were carried out as described in **Chapter 5** (i.e., herbaceous species composition, grass DM yield, basal cover, soil parameters and estimated soil erosion). In addition, soil compaction was measured using a rod penetrometer (ELE pocket penetrometer). At each of the sample site, three representative plots of 1 m x 1 m were identified and watered artificially to a depth of approximately 10 mm. Six hours after wetting, an estimation of the soil compaction was obtained by penetrating to a depth of 6 mm of the topsoil surface (Friedel 1987). Donaldson *et al.* (1984) and Donaldson (1986) waited for 18 hours after wetting, while the measurements were taken six hours after wetting in this study. The reasons were the sandy nature of the soil and the high ambient temperature in the study area.

The herbaceous species composition; the percentage basal cover and the grazing capacity were calculated according to the method described in **Chapter 5**. The benchmarks and the sampling sites were compared for vegetation attributes following the method described by Danckwerts (1982). The method of Danckwerts (1982) is preferred over that of Tainton (1999) since the latter imposes a limit to the species composition of the sample site relative to the benchmark, while the former does not. In this study, the benchmarks are relative and therefore it was not deemed necessary to impose a limit on the species composition of the sample sites. The species at the benchmarks and the sample sites were expressed in percentage composition and were classified into highly desirable, desirable, less desirable and undesirable species. The relevant weighting score of 10, 7, 4 and 1 for highly desirable, desirable, less desirable and undesirable (Bare ground and forbs) respectively, was multiplied with the percentage species composition of each species to give the individual species score and these were added up for each sample site to give the total score for the site. The total score of the site, expressed as a percentage of the total score of the comparable benchmark, gave the percentage score of the site. The rest of the data (grass DM yield, basal cover, texture, soil compaction, percentage total N and OC) were presented in graphs using Microsoft Excel (1997). The benchmark sites were small in size and the sites could were not replicated, no statistical analysis was carried out.

6.3. RESULTS

6.3.1. Rangeland condition assessment

The condition of the sample sites (Harole1, Madala1 and Kachachilo= group 1), when calculated as a percentage of the average of the benchmarks (Benchmark = 1), was lower than the benchmarks (**Table 6.1**) and it ranged from 65.58% (Madaa1) to 90.08% (Harole 1). The condition of the second group of sample sites in relation to the respective benchmark was 97.19% (Aleka), 90.96% (Harole2), 94.27% (Madala2) and 99.09% (Top of bud). In terms of rangeland condition, Top of bud was comparable to the benchmark (**Table 6.2**).

6.3.2. Grass dry matter yield and basal cover

The DM yield of the grass (kg ha^{-1}) of the three sample sites, compared with the average of Dire galcha and Dhebeti (Benchmark 1) was 37.73% (Kachachilo), 48.20% (Madala1) and 40.79% (Harole 1). This implies that the benchmarks had a higher yield than that of the sample sites. Similarly, the yield of the grasses, for the second group of sample sites, was 44.31% (Harole 2), 52.36% (Madala 2), 50.54%

Table 6.1. Rangeland condition scores in the first group of sample sites (Kachachilo, Madala 1 and Harole 1).

Species category	Species	Factor	BM1 (Dhebeti)		BM1 (Dire galcha)		Kachachilo		Madala 1		Harole1	
			%	score	%	Score	%	score	%	Score	%	Score
Highly desirable	*Chrysopogon plumulosus*	10	71	710	86.6	866	36.79	368	54.7	547	62.4	624.
desirable	*Bare ground*	1	1	1	0.6	0.6	7.31	7.31	5.18	5.18	5.6	5.6
Less desirable	*Coelachyrus Poiflorum*	4	1	4			1.38	5.52	3.59	14.36	6.6	26.4
Less desirable	*Sporobolus natalensis*	4	2.8	15.2	8	32	48.61	194.4	0.4	1.6	20.6	82.4
Less desirable	*Panicum snowdenii*	4					1.58	6.32	0	0	3.6	14.4
Less desirable	*Forb*	1			1.6	1.6	2.96	2.92	0.8	0.8	0.8	0.8
Less desirable	*Eleusine indica*	4							0	0	0.2	2
Highly desirable	*Cenchrus setigerus*	10	0.4	4			0.98	9.8	1.6	16	0.2	2
Highly desirable	*Cenchrus ciliaris*	10							0	0	0	0
Desirable	*Heteropogon contortus*	7	20.4	142.8					0	0	0	0
Less desirable	*Setaria verticellata*	4			0.2	0.80	0.19	0.76	0	0	0	0
Desirable	*Cymbopogon commutatus*	7	3.4	23.8	1	7			0.8	3.2		0
Less desirable	*Cynodon dactylon*	4			2	8			0	0	0	0
Highly desirable	*Tetrapogon cenchriformis*	10							0	0	0	0
Highly desirable	*Panicum coloratum*	10							0	0	0	0
Desirable	*Chloris roxburghiana*	7							0	0	0	0
Desirable	*Paspalm glumaceum*	7							0	0	0	0
Highly desirable	*Chloris gayana*	10							1.4	5.6	0	0
Less desirable	*Aristida adscenionsis*	4							0.2	0.8		0
Less desirable	*Dactyloctenium aegypticum*	4							0	0	0	0
Desirable	*Cymbopogon excavatus*	10							0	0	0	0
Less desirable	*Sorghum purpureo cericeum*	4							0	0	0	0
Less desirable	*Enneapogon schimperanus*	4							0	0	0	0
Desirable	*Eragrostis racemosa*	7							0	0	0	0
Less desirable	*Tragus berteronianus*	4					0.2	0.80	0.8	3.2	0	0
Desirable	*Pennisetum stramineum*	7							30.53	213.71	0	0
Less desirable	*Eragrostis cilianensis*	4							0	0	0	0
Total score			100	900.8	100	916.0	100	595.8	100	811.45	100	758
Percentage score relative to the benchmark								65.58		90.08		83.4

Table 6.2. Calculation of rangeland condition in the study districts (Harole 2, Aleka, Madala2 and top of bud).

Species category	Species	Factor	Dekaakae		Harole 2		Aleka		Madala 2		Top of bud	
			%	Score	%	Score	%	Score	%	Score	%	Score
Highly desirable	*Chrysopogon plumulosus*	10	43.6	436	73.1	731	84.3	843	71.23	712	85.32	853
Less desirable	Bare ground	1	0.2	0.2	7.1	7.1	5	5	0.6	0.6	3.07	3.1
Less desirable	Coelachyrus Poiflorum	4	2.6	10.4	6.4	25.6	2	8	0.09	0.36	1.06	4.2
Less desirable	Sporobolus natalensis	4	2.8	11.2	4.6	18.4	5.12	20.5	9.05	36.2	8.28	33.1
Less desirable	Panicum snowdenii	4	0		4.4	17.6	1.4	5.6	0	0		
Less desirable	Forb	1	1.2	1.2	0.8	0.8	1.58	1.58	0.8	0.8	0.66	0.7
Less desirable	Eleusine indica	4		0	0	0	0.4	1.6	0	0		
Highly desirable	Cenchrus setigerus	10	1.8	18	0.8	8	0.2	0.8	0	0	0.2	2
Highly desirable	Cenchrus ciliaris	10	6.2	62	1	10			0.2	2	0.25	2.5
Desirable	Heteropogon contortus	7							0	0		
Less desirable	Setaria verticellata	4							0	0		
Desirable	Cymbopogon commutatus	7							0	0		
Less desirable	Cynodon dactylon	4	0.4	1.6					0.6	2.4		
Highly desirable	Tetrapogon cenchriformis	10	15	150					0	0		
Highly desirable	Panicum coloratum	10	9.8	98					0	0		
Desirable	Chloris roxburghiana	7	4.2	29.4					0	0		
Desirable	Paspalm glumaceum	7	1.6	11.2	0.2	1.4			0	0		
Highly desirable	Chloris gayana	10	2	20					1.01	7.07		
Less desirable	Aristida adscenionsis	4	0.2	0.8					0.8	3.2		
Less desirable	Dactyloctenium Aegypticum	4	0.2	0.8	0.6	2.4			0	0	1.16	4.64
Desirable	Cymbopogon commutatus	7	5	35					0	0		
	Cymbopogon excavatus	10	2.2	22								
Less desirable	Sorghum purpureo cericeum	4	0.6	2.4					0	0		
Less desirable	Enneapogon schimperanus	4	0.4	1.6					0	0		
Desirable	Eragrostis racemosa	7			1	7			0	0		
Less desirable	Tragus berteronianus	4							2.82	11.3		
Desirable	Pennisetum stramineum	7							10.79	75.5		
Less desirable	Eragrostis cilianensis	4							2.01	8.04		
Total score			100	912	100	829.3	100	886	100	859.5	100	903
Percentage score relative to the benchmark						90.96		97.2		94.27		99.1

(Top of bud) and 53.11% (Aleka) of that of the benchmark (Dakaakae). Similar to the yield, the basal cover of the benchmark was higher than that of the sample sites in both cases (**Figure 6.2**).

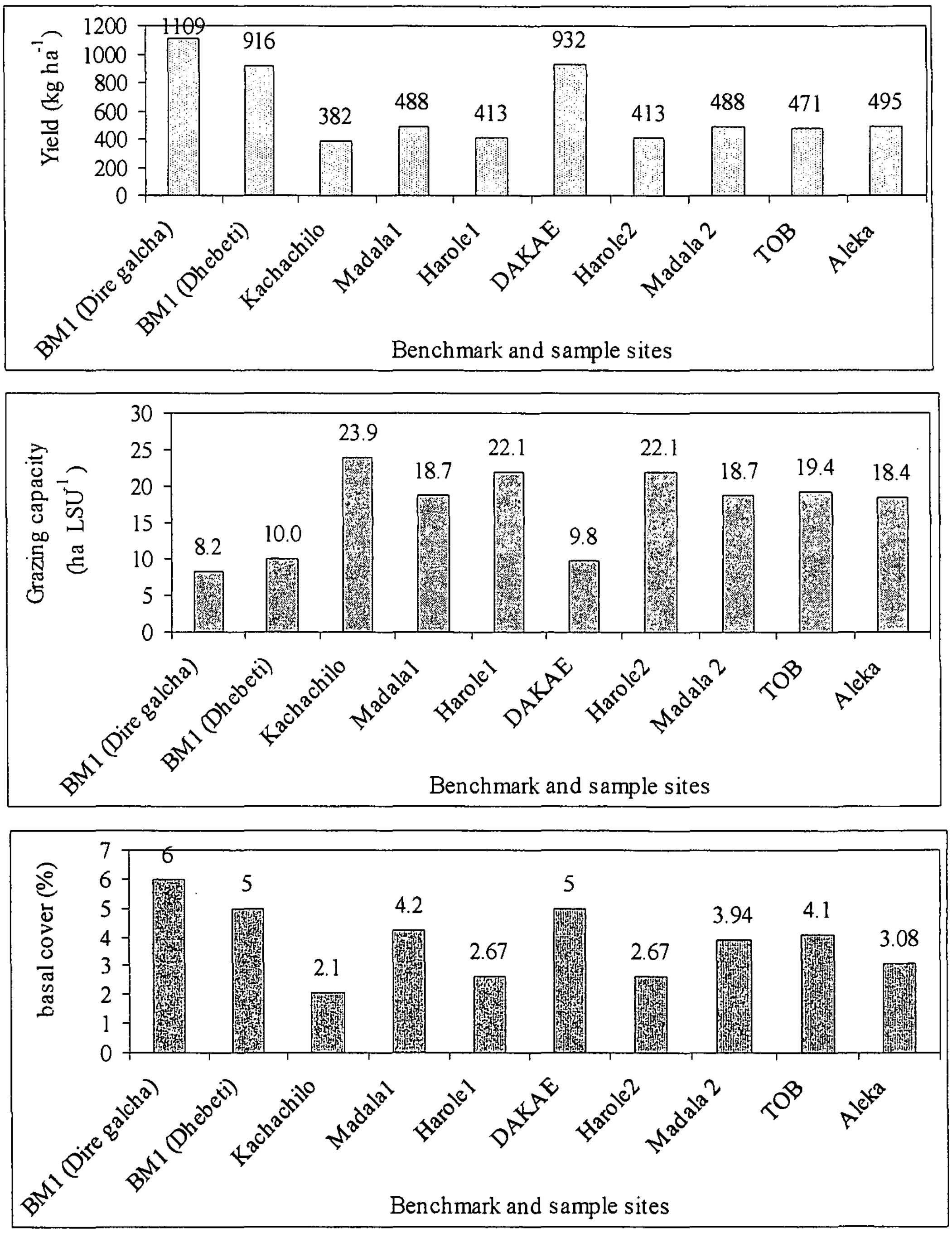


Figure 6.2. Grass dry matter yield, grazing capacity and basal cover of sample sites and the respective benchmark sites.

6.3.3. Grazing capacity

In both benchmark sites and across the sample sites (**Figure 6.2**), the grazing capacity improved from as low as 23.9 ha LSU^{-1} (Kachachilo) to 8.2 ha LSU^{-1} (BM1) and this result indicated that, given proper management of the rangelands, there can be a considerable improvement in the grazing capacity of the rangelands.

6.3.4. Soil parameters

6.3.4.1. Percent sand, silt and clay

The benchmark sites (Benchmark1) and their corresponding sample sites (Kachachilo, Madala1 and Harole1) in the first group had a comparable sand, silt and clay fractions. It was also similar to the second group of sample and benchmark sites (**Figure 6.3**).

6.3.4.2. Percentage total nitrogen

Compared with the benchmark sites (Benchmark 1), sample sites (Kachachilo and Madala 1) had a lower percent total N, whereas, Harole1 had a slightly higher percent N. Similarly, two of the sample sites (Harole2 and Top of bud) had slightly lower N than their corresponding benchmark site and two of the sample sites (Madala 2 and Aleka) had slightly higher percent N than Dakaakae (**Figure 6.3**).

6.3.4.3. Percentage Organic carbon (OC)

Kachachilo, Madala1 and Harole1 had lower percentage OC than their corresponding benchmark sites (Benchmark 1). In the second group of sample sites (Harole2, Madala2, Top of bud and Aleka), three of them had lower OC than the benchmark site (Dekaakae), while Aleka had a slightly higher percent OC than the Benchmark site (**Figure 6.4**).

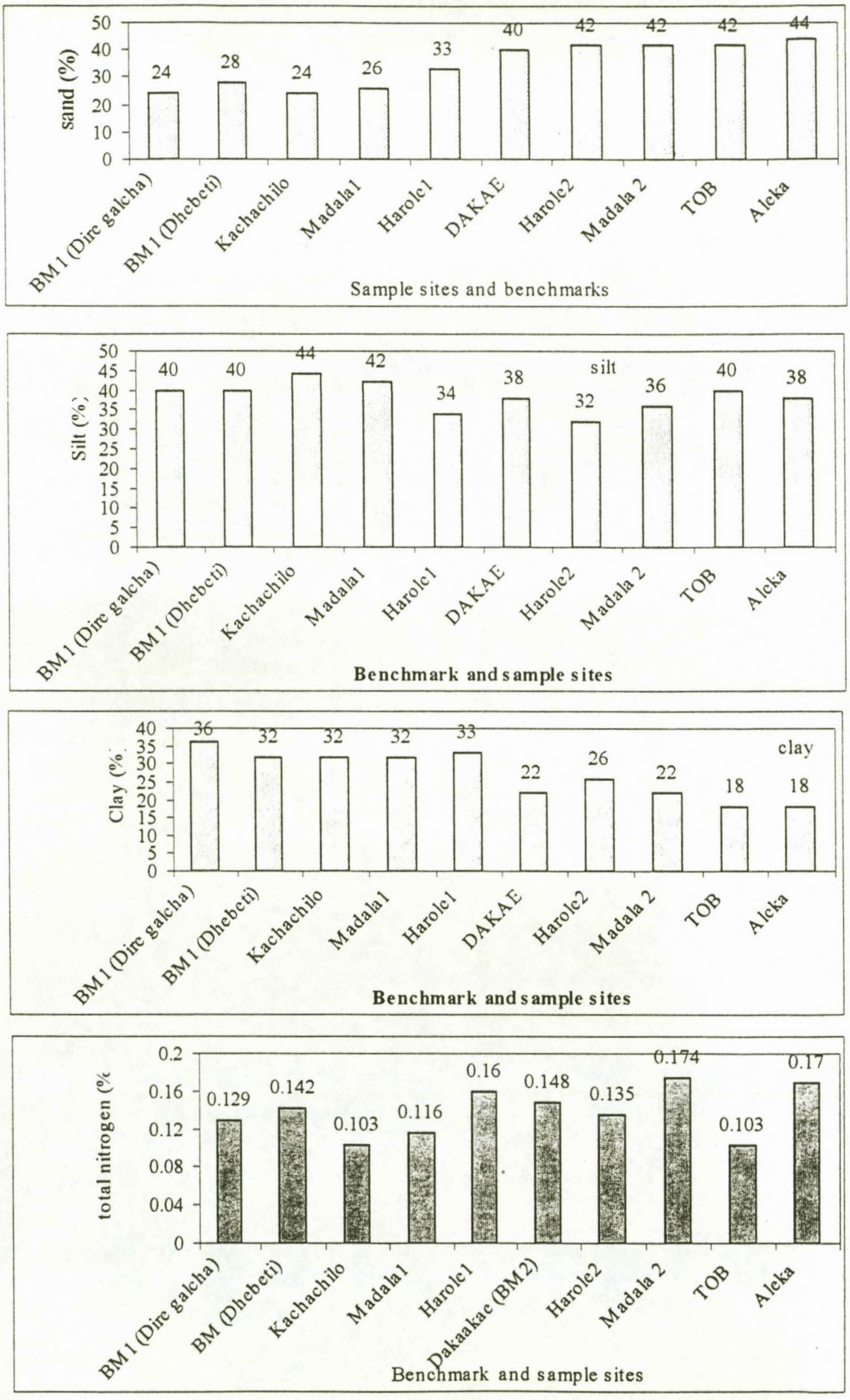
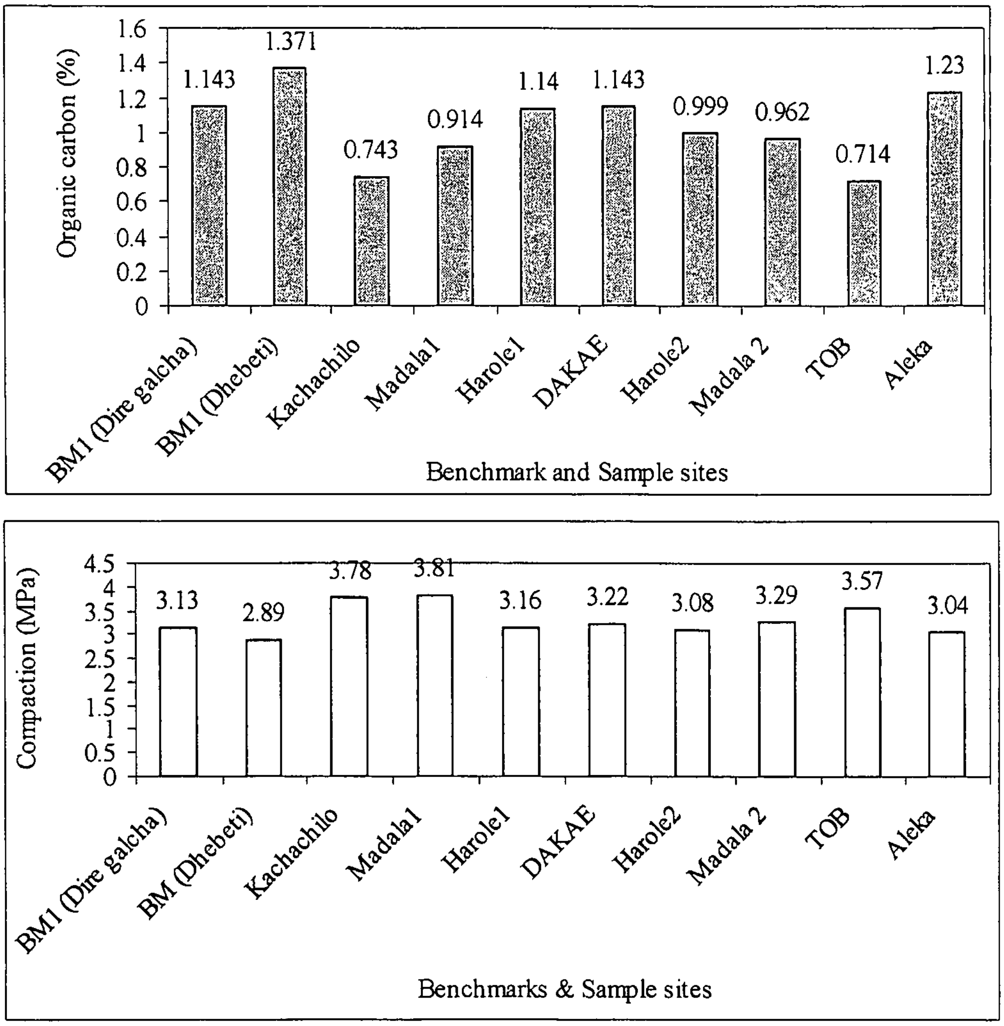


Figure 6.3. Soil characteristics at the sample and benchmark sites in the study districts.

6.3.4.4. Soil compaction

The compaction of the topsoil surface was lower at benchmark 1 than the corresponding sample sites, namely, Kachachilo, Madala1 and Harole1. Compared to the average of the protected plots, the compaction at the sample sites was higher by 25.58% (Kachachilo), 26.58% (Madala1) and 4.98% (Harole 1). In the second group, two of the sample sites had slightly higher soil compaction than the benchmark site and two of the sample sites had slightly lower soil compaction than the corresponding benchmark site (**Figure 6.4**).



Fgure 6.4. Soil organic carbon and compaction values in the sample and benchmark sites in the study districts.

6.4. DISCUSSION

6.4.1. Rangeland condition

With an objective of developing better and faster methods of rangeland evaluation, numerous researchers have contributed to the refinement of the available techniques as well as the variables that need to be measured for rangeland evaluation. Accordingly, the benchmark method was developed as one method of rangeland evaluation technique. However, limitations to the benchmark method have been suggested by Mentis (1983); Barnes *et al.* (1984) and Martens *et al.* (1996). One of the drawbacks of the rangeland evaluation techniques is that they usually lack universal applicability. Thus, the choice of which method to use usually depends on the local condition. Accordingly, an assessment of vegetation was undertaken using the benchmark method. Except at Kacachilo, where the rangeland condition was low relative to the benchmark sites, the rest of the sample sites had a comparable condition with the benchmark sites. This could be due to the relatively short period of years that the benchmarks have been protected. Therefore, the grass species are more or less similar at the benchmark and the sample sites. It can also be concluded that the current benchmark sites are not a good indication of the true potential of the area.

6.4.2. Grass dry matter yield, basal cover and grazing capacity

Compared to the benchmark sites, the sample sites had a substantially lower grass DM yield, basal cover and grazing capacity, which implies that there had been a deterioration in the condition of the rangelands. The specific reasons for the degradation are many and varied. However, the most likely reason for the deterioration in rangeland condition manifested in lower yield, basal cover and consequently reduced grazing capacity, is associated with overgrazing of the rangeland by animals. The sample and the benchmark sites are found in the same ecological unit, where one can assume that the influence of climate is the same for both. Overgrazing and the associated decrease in basal cover and lowered grazing capacity is well documented (e.g. O'Connor 1985; O' Connor 1991; O'Connor 1994; Snyman 1999a; Van der Westhuizen *et al.* 2001). Lazenby & Swain (1969), Cossins & Upton (1985), O'Connor (1985) and Snyman (1999a) argued that overgrazing lead to a decline in the quality and productivity of the rangelands. Though it is very difficult to determine grazing capacity of rangelands under the pastoral production system where communal ownership of the land predominate the management, it is essential to estimate grazing capacity. This can serve as a guide for sustainable rangeland utilisation. The improvement in the grazing capacity from the protected plot is a clear indication that, given proper management of the rangeland, there is room for improving the condition of the rangeland.

6.4.3. Nitrogen, Organic Carbon and soil compaction

With regard to percent total N, it was shown in the result that, in some cases, the benchmark sites had a slightly higher N than the sample sites and in other cases the sample sites had a slightly higher N than the Benchmark sites. Such slight difference in soil is not unexpected as the soil can vary naturally within a short range. According to Manley *et al.* (1995) the available data on the response of OC and N to grazing does not indicate any single or consistent response to grazing and this might be the reflection of the different environments, soil and grazing managements. The slight increase in N in the sample sites compared with the benchmark sites can be associated with the influence of animal excreta and the length of time the benchmark sites have been protected. Lavado *et al.* (1996) argued that grazing influences the flux of nutrients in grasslands in different ways (trampling, consumption, excreta deposition and redistribution and export). An increase in nitrogen is related to excreta returns, and losses are related to net export of nutrients or erosion. These processes are a function of the stocking density and the initial nutrient status of the soils. In most of the sample sites, the OC was lower than the benchmark sites and this could be associated with the influence of grazing.

Compaction is a most complex soil feature having significant interrelationships with most of the recognized physical, chemical and biological properties of soils as well as with environmental factors such as climate (McKibben 1971). Both internal and external factors affect the compaction of a given soil (Bennie & Krynauw 1985) and of the internal factors affecting soil compaction, organic matter is one of them. In general terms, the findings of this study indicated that those sites with a low OC content had a higher compaction. Woodward (1996) argued that negative effects on seedling establishment and growth are often attributed to changes associated with soil compaction, including reduced water infiltration rates, decreased diffusive and mass flow of nutrients and solutes through the soil, anoxia and increased resistance to root penetration (Greacen & Sands 1980). The loss of vegetative and litter cover with degradation (Warren *et al.* 1986; Thurow *et al.* 1988; Holm *et al.* 2002) allows direct impact of raindrops on soil (Lal & Elliot 1994; Russel *et al.* 2001) and may also produce hydrophobic substances that can reduce infiltration (DeBano *et al.* 1970, 1976; Emmerich & Cox 1992; Snyman 1999 a,b).

6.5. CONCLUSION

- The most noteworthy differences between the benchmark and sample sites were found to be in basal cover and grass yield, which indicates that, with proper management, it is possible to improve the grazing capacity of the study rangelands. Two of the benchmarks used in this study are plots protected by the community and such efforts need to be encouraged and supported technically. It is also possible to organize the community in the form of cooperatives so that the community is involved in conservation activities.
- In both the benchmark and the sample sites, *Chrysopogon plumulosus* was the dominant grass species. Therefore, future studies should focus on the ability of this grass species to resist heavy grazing pressure.
- The result of this study demonstrates that, given proper management like resting of the grazing land, the rangeland will bounce back remarkably well.

CHAPTER 7

THE INFLUENCE OF TREES AND LIVESTOCK GRAZING ON GRASS SPECIES COMPOSITION, YIELD AND SOIL

7.1. INTRODUCTION

Trees may have negative and positive effects on their immediate environment and the net result of the negative and positive interactions is dependent on tree density. Established trees create sub-habitats, which differ from the open habitat and which exert different influences on the herbaceous layer (e.g., Kennard & Walker 1973; Stuart-Hill *et al.* 1987; Belsky *et al.* 1989; Frost & McDougald 1989; Smit & Swart 1994; Asferachew *et al.* 1998). Trees are also known to improve the soil status under their canopies and thereby increase crop productivity when isolated trees are found on the farm. Depending on tree density, they also reduce soil erosion, improve soil fertility and reverse desertification (Nair 1984; Young 1989).

Compared to their neighbouring grasslands, soil under tree crowns have higher concentrations of organic matter, higher concentrations of available nitrogen and other important nutrients, better physical structure, and better water infiltration (Tiedemann & Klemmedson 1973; Kellman 1979; Bernard-Reversat 1982; Belsky *et al.* 1989; Young 1989; Vetaas 1992; Smit & Swart 1994).

Most studies related to the importance of tree canopies have been conducted in lightly grazed areas and to this effect, work done in the Awash National Park of Ethiopia under lightly grazed conditions on floristic composition and soil characteristics has also indicated a similar pattern (Asferachew *et al.* 1998). However, no information is available on the effects of trees along a grazing gradient, which includes the communal grazing lands where the influence of livestock grazing is also considered in Ethiopia. The only study that can be cited along this line is that of Belsky *et al.* (1993) in Kenya. However, wide variability exists between sites and countries. This study was, therefore, undertaken with the objective of studying the effects of trees in light, medium and heavily grazed sites on grass species composition, yield and some soil parameters.

7.2. PROCEDURE

7.2.1. Site, trees and sub-habitats selection

Three sites having a similar altitude (957-1064 m.a.s.l), annual rainfall (550-620 mm) and sandy soils (FAO 1965; UNDP 1984) were identified for the study based on their grazing histories and the presence of widely spaced, mature trees of *Acacia tortilis* and *Balanites aegyptica*. The grazing histories were determined by interviewing herders and employee of the Awash National Park who have stayed long in the area. The inclusion of these two woody species is based on the fact that previous studies had indicated that these tree species are important for the function of the ecosystem (Asferachew *et al.* 1998). Two of the sample sites were located in the Awash National Park of Ethiopia and the third site in the Kereyu pastoral grazing land. The three sampling sites represented three different grazing gradients, namely heavy, medium and light. The distance from the heavily grazed site to the medium site was approximately about 25 km and from the medium to light site approximately 12 km. The three sites were characterised by an extended flat land and the dominant tree species across three sites were *A. tortilis*, *A. senegal* and *B. aegyptica*, while the dominant grass species were *Chrysopogon plumulosus*, *Cymbopogon commutatus*, *Cymbopogon exacavatus*, and different species of *Sporobolus*. Legumes such as *Tephrosia subtriflora* and *Crotolaria spinosa* are also found (FAO 1965) A brief description of each of the sites is given below.

7.2.1.1. Lightly grazed site

The specific site representing light grazing is located about mid way between the head office of the park (Gotu) and the Kereyu hotel. The site serves as a grazing area for wildlife and is grazed only for a few months intermittently and thus the vegetal cover and the composition is in good condition.

7.2.1.2. Medium grazed site

The specific site for the medium grazing was located about 16 km North East of Mathara town, within the territorial zone of the Awash National Park on the opposite side of the main gate of the park on the way to the hot spring (Filwoha). It is located approximately 3 km from the main gate. This site was located adjacent to the neighbouring pastoral grazing lands and because of the nearness of the area, illegal grazing is more common throughout the year. Thus, this area serves as a grazing site for both wild herbivores such as oryx, summering gazelle, warthog, rabbit, dik dik and the pastoral's domestic animals such as cattle, donkeys and camels.

7.2.1.3. Heavily grazed site

The heavy grazed site was located in the Kereyu`s pastoralists grazing land. According to the information obtained from the surrounding pastoral people, this area used to be open grassland with no woody vegetation and the herbaceous layer consisted of very dense and tall grasses of diverse species, providing year round grazing to the pastoral animals. However, the former excellent grass cover that used to provide an excellent carpet to the soil gradually vanished due to continuous heavy grazing. The animal species seen grazing were cattle, sheep, goats, donkeys and camels, while game animals such as wart hogs, rabbits and dik diks were also reported.

7.2.1.4. Tree and sub-habitat selection

At each of the grazing intensity sites, five trees of each species were selected randomly and the heights and canopy diameters of these trees are given in **Table 7.1**. In three of the sites, the data needed for the study was collected from two sub-habitats, i.e., under the tree canopies (located directly beneath the tree crown) and in the open grassland (located beyond the influence of the roots). Fieldwork was carried out during the middle of August, 2001 at the time when most plants were in flowering stage.

Table 7.1. Heights and canopy diameters of the tree species studied.

Tree species	Height (m)	Canopy diameter (m)
Acacia tortilis	6.10 ± 0.60	11.90 ± 1.80
Balanites aegyptica	5.10 ±1.10	6.60 ± 1.1

7.2.2. Sampling of herbaceous vegetation

Grasses and other herbaceous species were harvested in quadrats (0.5m x 0.5m), randomly placed in each of the two sub-habitats (20 quadrats per sub-habitat) at the time when the plants where approximately 50% flowering. Each quadrat was clipped at the ground level using hand shears by species. The harvested material was weighed using a portable scale, placed in paper bags and labelled. The samples were subsequently sun-dried until such time that it was oven-dried at 105°C for 24 hours. During sampling, care was taken that neighbouring trees, their shade and other influences were avoided.

7.2.3. Soil sampling and analysis

Topsoil samples at two depths (0-5 cm, 5-10 cm), were taken at each tree, at ten random locations per sub-habitat using a sharp knife and one meter tape. Initially, the sample site was dug to a depth of 15 cm; after which the first 10 cm depth of the soil was sub-divided into two parts by marking them with a sharp knife. Thereafter, the soil sample was taken carefully by digging the respective depth. The samples were kept in plastic bags, labelled, sealed and transported to the National soil laboratory in Addis Ababa where it was analysed for pH, texture, electrical conductance (EC), percent total nitrogen (N) and percentage organic carbon (OC). The method of analysis was described in Chapter 5.

7.2.4. Data analysis

The sample sites, were classified into 6, namely, heavy grazing canopy (1), heavy grazing open (2), medium grazing canopy (3), medium grazing open (4), light grazing canopy (5) and light grazing open (6). The sample sites and the grass species recorded in each of the six sample sites were ordinated using DECORANA (Hill 1979). Furthermore, grass DM yield and soil parameters data were analysed across sites (to compare under-canopy and grassland zones) by analysis of variance (ANOVA) using a randomised complete block design with replications nested within a site (SAS 1987). In the presence of significant F-values, treatment means were separated by the least significant difference (LSD) method at the 5% significance level.

7.3. RESULTS

7.3.1. Grass species composition

Fourteen grass species were identified at the heavy grazed sites (**Table 7.2**). The grass species recorded under tree canopy and in the open grassland were more or less similar and the yield of each species was also low (**Table 7.2**). Furthermore, most of the grass species were annuals. The grass species composition in the medium and light grazing plots, both under the canopies of the two tree species and in the open grassland were more or less similar. The biggest difference between these two grazing intensities lies in the presence of *Panicum maximum* under canopy in the lightly grazed plots (**Table 7.2**).

The result of the ordination indicated a clear separation of the sample sites at the heavy grazing site from the medium and the light grazing sites (**Figure 7.1**). The separation of the medium and the light grazing sites was not very distinct. A similar trend was also observed in the grass species ordination (**Figure 7.2**).

Table 7.2. Grass species (yield kg ha^{-1}) occurring under tree canopies and in open grasslands in three sites having different grazing intensities in and near Awash National Park.

Grazing site	**Under canopy**		**Grassland zone**	
	Species	**Yield kg ha^{-1}**	**Species**	**Yield kg ha^{-11}**
Heavy	Tragus berteronianus (A)	239	*Tragus berteronianus* (A)	262
	Sporobolus natalensis (P)	255	*Sporobolus natalensis* (P)	235
	Cenchrus setigerus (P)	234	*Cenchrus setigerus* (P)	234
	Eragrostis cilianensis (A)	315	Eragrostis cilianensis (A)	295
	Cynodon dactylon (P)	313	*Cyndon dactylon* (P)	281
	Eleusine indica (A)	217	*Eleusine indica* (A)	186
	Coelachyrum poiflorum (A)	243	*Coelachyrum poiflorum* (A)	199
	Urochloa panicoides (A)	255	*Urochloa panicoides* (A)	233
	Digitaria ternata (A)	221	*Digitaria ternata*	164
	Chrysopogon plumulosus (P)	377	*Chrysopogon plumulosus* (A)	387
	Dactyloctenium aegypticum (A)	206	*Chloris pychnothrix* (P)	211
	Aristida adscensionis (A)	162	*Cenchrus ciliaris* (P)	188
			Aristida adoensis (P)	183
Medium	*Sporobolus natalensis* (P)	1 021	*Sporobolus natalensis* (P)	1 809
	Eragrostis cilianensis (A)	1 548	*Eragrostis cilianensis* (A)	64
	Chrysopogon plumulosus (P)	2 648	*Chrysopogon Plumulosus* (P)	1 257
	Cymbopogon commutatus (P)	1 749	*Cymbopogon commutatus* (P)	952
			Setaria verticellata (A)	818
Light	*Sporobolus. natalensis* (P)	2 509	*Sporobolus natalensis* (P)	1 450
	Eragrostis cilianensis (A)	2 818	*Eragrostis cilianensis* (A)	341
	Chrysopogon plumulosus (P)	3 892	*Chrysopogon plumulosus* (P)	2 295
	Cymbopogon commutatus (P)	2 851	*Cymbopogon commutatus* (P)	2 571
	Cymbopogon excavatus (P)	3 247	*Lintonia nutans* (P)	868
	Panicum maximum (P)	1 369		

A= annual ; P= Perennial

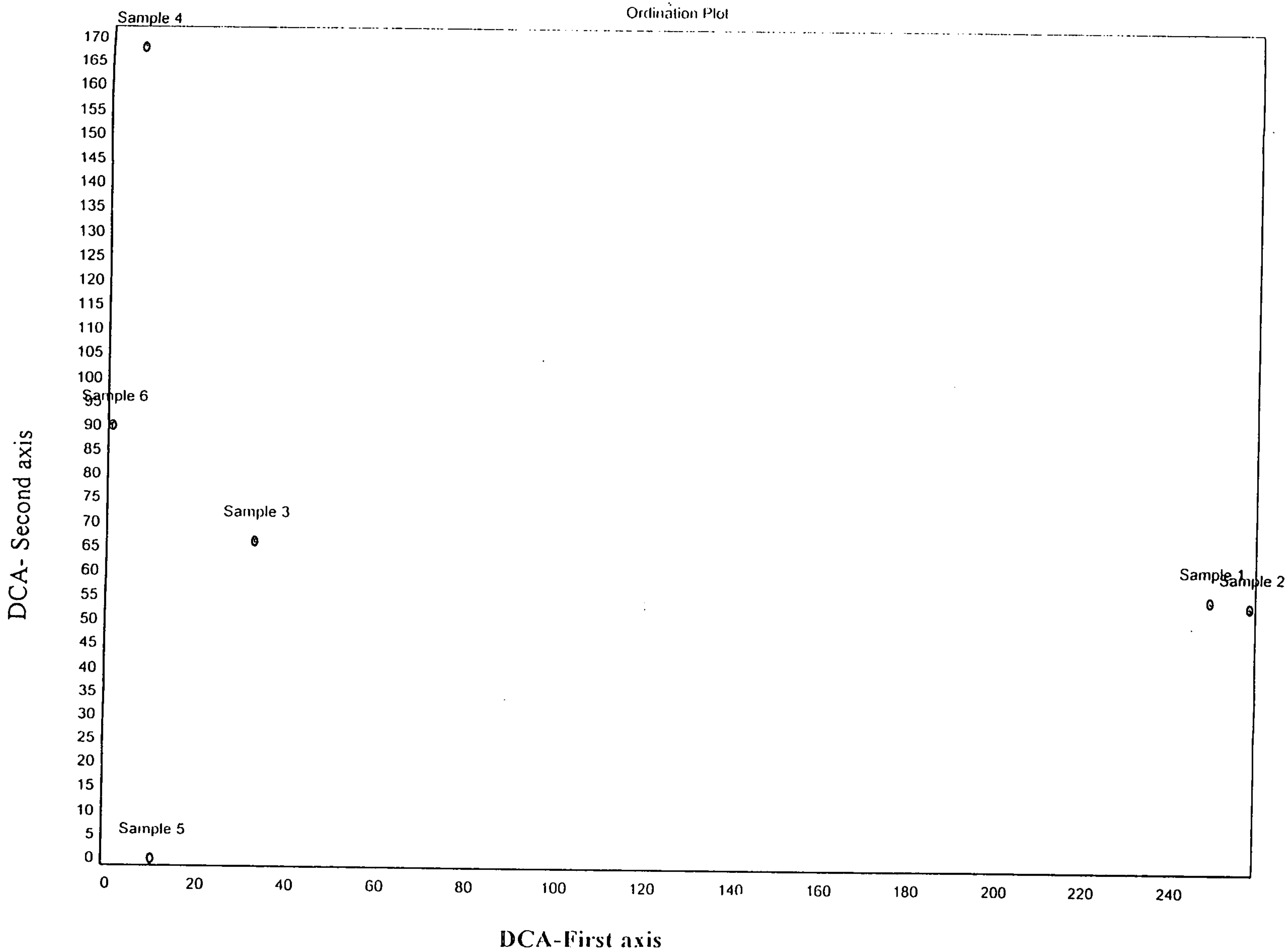


Figure 7.1. Ordination of sample sites by grazing intensity and sub-habitats. Key to the numbers: 1= Heavily grazed under canopy; 2= Heavily grazed open grassland; 3= Medium grazed under canopy; 4= Medium grazed open grassland; 5= Lightly grazed under canopy; 6= Lightly grazed open grassland.

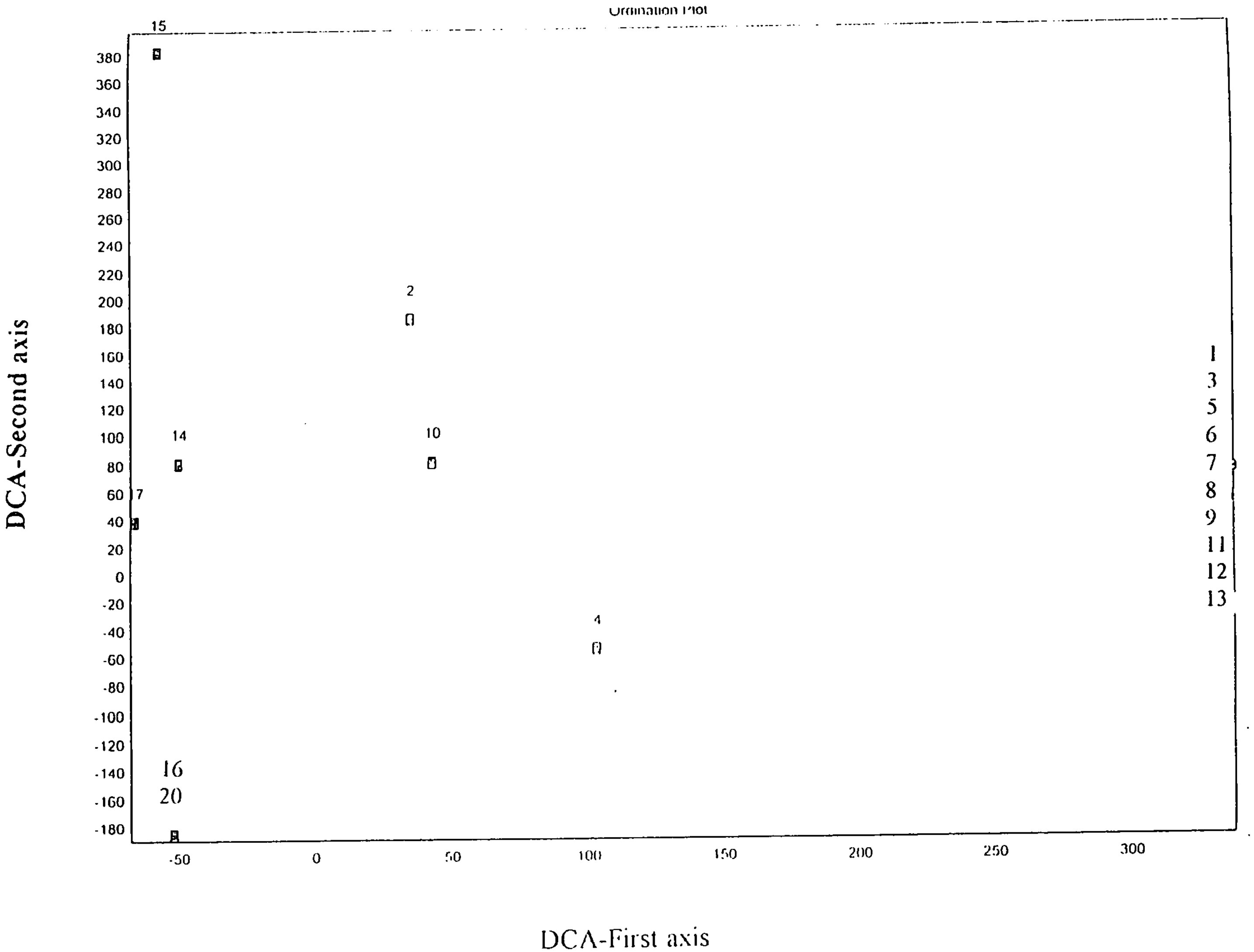


Figure 7.2. Detrended correspondence ordination of grass species under different grazing intensity in and around the Awash National Park of Ethiopia. Key to the number: 1= Tragus berteronianus; 2= Sporobolus natalensis; 3= Cenchrus setigerus; 4= Eragrostis cilianensis; 5= Cynodon dactylon; 6= Eleusine indica; 7= Coelachyrum poiflorum; 8= Urochloa panicoides; 8= Digitaria ternata; 10= Chrysopogon plumulosus; 11 = Dactyloctenium aegypticum; 12= Aristida adscensionis; 13= Chloris pychnothrix 14= Cymbopogon commutatus; 15= Setaria verticellata; 16= Cymbopogon excavatus; 17= Lintonia nutans; 18= Cenchrus ciliaris; 19= Aristida

7.3.2. Grass dry matter yield

7.3.2.1. Heavy grazed site

The DM yield of the grass at the heavily grazed site varied from 293.91 to 332.81 kg ha^{-1}. Neither tree species nor sub-habitat had a significant (P>0.05) influence on the yield of the grasses (**Table 7.3**).

7.3.2.2. Medium grazed site

There was no significant (P>0.05) difference between the two tree species in terms of their effect on the grass DM yield, while the yield of grasses (kg ha^{-1}) was increased (P<0.001) under tree canopies in comparison to that in the open grassland.

7.3.2.3. Light grazed site

Similar to the result found in the medium grazing site, the DM yield of grass was significantly (P<0.001) higher under tree canopies than the corresponding open grasslands. There was no difference (P> 0.05) between the two tree species in terms of their effect on grass yield (**Table 7.3**).

Table 7.3. DM yield of the natural pasture (Mean & SE) under two sub-habitats along different grazing intensities in and near Awash National Park (NS= Non-significant; *** = P<0.001).

Grazing Site	DM Yield of the grass layer (kg ha^{-1})					
	Acacia tortilis		*Balanites aegyptica*		Tree species effect (Prob)	Zone effect (Prob)
	Under canopy	Grassland Zone	Under canopy	Grassland Zone		
Heavy	316.92 (53.05)	304.06 (64.39)	293.91 (71.32)	332.81 (85.39)	NS	NS
Medium	2 051.41 (92.33)	1 149.62 (108.94)	1 904.21	1 326.66	NS	***
Light	3 209.70 (106.86)	2 350.49 (86.44)	2 947.83 (91.68)	2 442.04 (97.24)	NS	***

7.3.3. Soil parameters

7.3.3.1. Heavy grazed site

The effect of tree species, sub-habitat and soil depth on soil pH was not significant (P>0.05) (**Table 7.4**), whereas the electrical conductance (EC) of the soil was higher (P<0.001) under tree canopies compared to the open grasslands. An increase in soil depth decreased (P<0.01) EC. The soil texture (sand, silt and clay percentage) was not influenced (P>0.05) by sub-habitat or soil depth. The percentage total nitrogen was higher (P<0.05) under tree canopies compared to the open and was decreased (P<0.001) with an increase in soil, depth particularly for soil under tree canopies. The organic carbon (OC) followed a similar pattern to that of percentage total nitrogen. There was no difference (P>0.05) between the two tree species in terms of their effect on the soil parameters studied.

7.3.3.2. Medium grazed site

At the moderately grazed site, no difference was observed between the tree species in terms of their effect on the soil parameters studied except for OC. Percentage organic carbon was higher (P<0.05) under the canopy of *A. tortilis* than under the canopy of *B. aegyptica*. Soil under tree canopies had a higher pH (P<0.01), EC (P<0.001), percentage total N (P<0.01) and percentage OC (P<0.001), whereas the EC of the soil, percentage total N and OC (P<0.001) decreased with increase in the depth of the soil. The texture of the soil was not influenced much (P>0.05) by either sub-habitat or soil depth (**Table 7.4**).

7.3.3.3. Light grazed site

Soil under tree canopies had a higher pH (P<0.05), EC (P<0.05), total N (P< 0.05) and OC (P<0.05) than their corresponding open grasslands, while the effect of depth of soil on soil pH was non significant (P>0.05). The EC (P<0.001), percentage total N (P<0.001) and OC (P<0.01) decreased with an increase in soil depth. Similar to the moderately grazed site, *A. tortilis* had a higher (P<0.05) OC than *B. aegyptica*. The

Table 7.4. Chemical properities of soils occurring under tree canopy and open grasslands at two depths at different grazing intensity gradients in and near the Awash National Park of Ethiopia (NS= non-significant; * = P<0.05; **= P<0.01; ***= P<0.001).

Grazing site	Soil parameter	Soil depth	*Acacia tortilis*		*Balanites aegyptica*		Tree specie s effect	Sub-habitat effect	Zone effect difference between depths
			Under canopy	Grass land zone	Under canopy	Grass land zone			
Heavy	PH	0-5 cm 5-10 cm	8.12 8.16	8.12 8.16	8.18 8.32	8.12 8.18	NS	NS	NS
Medium	PH	0-5 cm 5- 10 cm	8.26 8.34	8.16 8.18	8.24 8.28	8.24 8.20	NS	**	NS
Light	PH	0-5 cm 5- 10 cm	8.22 8.34	8.16 8.18	8.22 8.18	8.12 8.16	NS	*	NS
Heavy	Electrical conductance (EC) (ds m^{-1})	0-5 cm 5- 10 cm	0.174 0.126	0.132 0.096	0.147 0.106	0.105 0.09	NS	***	***
Medium	(EC)	0-5 cm 5- 10 cm	0.23 0.137	0.136 0.102	0.221 0.154	0.147 0.117	NS	***	***
Light	(EC)	0-5 cm 5- 10 cm	0.200 0.126	0.160 0.138	0.193 0.142	0.147 0.121	NS	*	***
Heavy	% sand	0-5 cm 5- 10 cm	54.00 55.00	53.20 54.60	53.20 54.60	53.00 54.00	NS	NS	NS
Medium	% sand	0-5 cm 5- 10 cm	53.40 53.80	53.80 54.60	53.30 53.80	53.60 54.20	NS	NS	NS
Lightly	% sand	0-5 cm 5- 10 cm	53.2 53.4	53.60 53.40	53.00 53.60	53.60 53.80	NS	NS	NS
Heavy	% silt	0-5 cm 5-10 cm	24.60 24.80	25.80 24.60	25.60 25.60	24.80 24.60	NS	NS	NS
Medium	% silt	0-5 cm 5-10 cm	27.00 26.20	27.20 25.60	27.40 27.20	27.40 26.00	NS	NS	NS
Light	% silt	0-5 cm 5- 10 cm	27.00 26.00	27.00 27.00	27.00 27.00	27.00 26.00	NS	NS	NS
Heavy	% clay	0-5 cm 5-10 cm	21.40 20.20	21.00 20.80	21.40 20.40	21.00 20.00	NS	NS	NS
Medium	% clay	0-5 cm 5-10 cm	19.60 20.00	20.00 19.80	19.40 19.00	19.00 20.20	NS	NS	NS
Lightly	% clay	0-5 cm 5-10 cm	19.60 20.40	19.20 20.00	19.60 20.00	19.60 19.80	NS	NS	NS
Heavily	% total N	0-5 cm 5- 10 cm	0.172 0.099	0.1526 0.1294	0.172 0.089	0.154 0.130	NS	*	***
Medium	% total N	0-5 cm 5- 10 cm	0.240 0.105	0.172 0.140	0.227 0.106	0.167 0.149	NS	**	***
Light	% total N	0-5 cm 5- 10 cm	0.268 0.135	0.193 0.183	0.262 0.160	0.185 0.160	NS	*	***
Heavy	% OC	0-5 cm 5-10 cm	1.443 0.845	1.171 0.936	1.429 0.657	1.06 0.81	NS	*	***
Medium	% OC	0-5 cm 5- 10 cm	2.052 0.912	1.452 1.202	1.912 0.971	1.408 1.132	*	***	***
Light	%OC	0-5 cm 5-10 cm	2.24 1.43	1.73 1.52	1.90 1.52	1.49 1.39	*	*	**

rest of the parameters were not influenced (P>0.05) by any of the variables understudy **(Table 7.4.)**.

7.4. DISCUSSION

7.4.1. Effect of grazing on grass layer and soil parameters

Many of the grass species identified at the heavily grazed site were annuals and consisted mostly of less desirable species (**Refer Chapter 5**). Species such as *T. berteronianus, S. natalensis, E. cilianensis, C. dactylon, E. indica, C. poiflorum, U. panicoides* and *D. ternata* were reported by others as indicators of deteriorating rangeland condition (CADU 1976; Tainton *et al.* 1976; Ibrahim & Kabayu 1987; Barker *et al.* 1989; Van Oudtshoom 1999). The ordination results of the grass species indicated a change in grass species composition as the grazing intensity increases. The change in species composition and the associated decrease in grass DM yield due to grazing effect is in agreement with the report of others (e.g., Frost *et al.* 1986; Westoby *et al.* 1989; O`Connor 1994). The influence of grazing on grass species composition and yield was discussed in detail in **Chapter 5**. The number of different grass species found in the medium and lightly grazed was lower than that of the heavily grazed, yet most of them were perennials and grasses with a better desirability value than those found at the heavily grazed site. In relation to annuals, perennial grass species are better indicators of ecological status of an area (du Plessis *et al.* 1998; Snyman 1999a). In general, there was a tremendous increase in grass DM yield with decreasing grazing intensity (1 608 kg ha^{-1} for medium and 2 737.5 kg ha^{-1} for lightly grazed sites. A higher yield of the natural pasture as the grazing intensity decreases is in agreement with the report of Belsky *et a*l. (1989).

The results of this study further showed that, there was an improvement in soil nutrient status as the grazing intensity decreases from heavy to light. Tiedemann & Klemmedson (1973); Belsky *et a*l. (1993); Campbell *et al.* (1994) made a similar observation in their study. Under the condition of this study, the improvement in soil nutrient status is mainly attributed to the effect of tree canopies, which is dicussed in section 7.4.3.

7.4.2. Effect of tree species on the grass layer and soil

Except for OC at the medium and lightly grazed sites, the results of the study showed that there was no difference between the two tree species in terms of their effect on the studied parameters and this is in agreement with the reports of others relating to soil (Belsky *et al.* 1993; Asferachew *et al.* 1998) and grass yield (Belsky *et al.* 1993). Both tree species in this study are leguminous. Differences between leguminous and non-leguminous species are reported in the literature (Smit & Swart 1994).

7.4.3. Effect of sub-habitats on grass layer and soil parameters

There are contradictory views regarding the influence of sub-habitats on grass species compositon and yield. For example, Kennard & Walker (1973), Stuart-Hill *et al.* (1987), Belsky *et al* (1989), Veenendaal *et al.* (1993), Smit & Swart (1994) and Asferachew *et al.* (1998) reported a grass species turnover from under canopy to the open areas, while, De Ridder *et al.* (1996) and Moyo & Campbell (1998) reported that there was no effect of canopy on grass species. The result of the present study revealed that there was no difference in grass species composition due to sub habitat effect at heavy and medium grazing. However, at the lightly grazed site there was a difference in grass species composition, which was reflected by the presence of *Panicum maximum* under tree canopies. Interestingly, the result of this study adds knowledge to both contradicting ideas with regard to grass species composition. The existence of *P. maximum* exclusively under tree canopies agrees with the report of others (Bosch & Van Wyk 1970; Kennard & Walker 1973). Bosch & Van Wyk (1970) explained that this association is due to a high soil nutrient status under trees.

The increase in the grass yield could be attributed to the improvement in soil physical properties (Elwell 1986) and exchange capacity of the surface soil due to the improvement in soil nutrient status as a result of high volume of leaf fall under trees (Kennard & Walker 1973; Campbell *et al.* 1994), droppings from birds and mammals (Belsky *et al.* 1989) and the concentration of nutrients from areas beyond the crowns by means of lateral tree roots (Tiedemann & Klemmedson 1973). The other possible reason is the lower understorey solar radiation and soil and plant temperatures (Tiedemann & Klemmedson 1973) resulting in reduced evapotranspiration, which creates mesic under storey patches which are colonized by palatable perennial grass species that have a higher water-use efficiency (Amundson *et al.* 1995).

Soil under tree canopies had a higher pH at the moderate and light grazing sites, a higher EC, OC and N at all levels of the grazing. The importance of canopies in soil enrichment is well documented (Bosch & Van Wyk 1970; Kennard & Walker 1973; Tiedemann & Klemmedson 1973; Kellman 1979; Bernard- Reversat 1982; Belsky *et al.* 1989; Young 1989; Smit 1994; Smit & Swart 1994; Hagos 2001). Although, the question and mechanism of soil enrichment under tree canopies remains largely unexplained (Smit 2002), many theories have been presented, such as leaf litter from leaf fall (Bosch & Van Wyk 1970; Stuart-Hill *et al.* 1987; Belsky *et al.* 1989), stem flow and through fall (Kellman 1979; Williams *et al.* 1987; Potter 1992).

There is a lack of consensus in published literature on the influence of trees on pH. While Bosch & Van Wyk (1970); Kennard & Walker (1973); Palmer *et al.* (1988); Young (1989) reported a higher pH under tree canopies, Belsky *et al.* (1989) and Hagos (2001) reported a lower pH at the base of *Acacia* trees than further from the trunk. The results of this study support the former view. Based on the positive association between increases in exchangeable cations and soil pH (high base saturation) (Barnard & Fölscher 1972; Kennard & Walker 1973; Hatton & Smart 1984) a higher pH under canopies of savanna trees conforms more logically with the higher content of exchangeable cations in this sub-habitat (Smit 2002).

7.4.4. Effect of soil depth on soil parameters

The effect of depth of soil, in this study, was observed in EC, percentage total N and percentage OC, which implies that there was a decrease in these soil parameters with increase in soil depth and this agrees favourably with the report of others for EC (Asferachew *et al.* 1998), N (Bernard-Reversat 1982; Asferachew *et al.* 1998) and

OC (Bernhard-Reversat 1982; Asferachew *et al.* 1998). Bernhard- Reversat (1982) argued that OC and N content of soils of the savannas in north Senegal were concentrated in the first few centimetres of soil and increased under tree canopies (*A. senegal* and *B. aegyptica*).

7.5. CONCLUSION

This study investigated the effects of tree species and livestock grazing on the grass layer and soil parameters. The following conclusions can be made from this study:

- Heavy grazing resulted in a decreased grass yield with grasses of less desirability. There were also more species of annual grasses at the heavily grazed site than at the medium and lightly grazed sites. There was a significant improvement in grass DM yield as the intensity of grazing pressure decreased.
- Heavy grazing also influenced the soil nutrient status. The percentage N, percentage OC and electrical conductance were significantly lower at the heavily grazed site compared to the lightly and medium grazed sites.
- Except for OC, there was no difference between the two tree species in terms of their effect on grass DM yield and soil nutrient status.
- Tree canopy in semi-arid areas have often been found to create microhabitats of improved soil physical and nutrient status. These encourage the growth mesic, palatable and high yielding perennial grasses in otherwise arid environment. Accordingly, the significance of the tree canopy in this study was shown by the increase in grass DM yield, improvement of the soil nutrient status and the creation of sub-habitat that is suitable for important grass species *P. maximum.*

CHAPTER 8

CONCLUDING REMARKS AND RECOMMENDATIONS

Pastoralism is a significant but declining economic sector in North East Africa (Djibouti, Ethiopia, Somalia and the Sudan). Indigenous resource tenure systems in Africa have evolved to meet the constraints and opportunities of often-difficult biophysical environments, while facilitating the operation of complex spatial and temporal land use patterns. Traditional systems provide security of tenure in culturally relevant ways that permit adaptation to new circumstances. Pressure on limited land resources and unsuitable environmental policies have led to a pastoralist's crisis in the arid rangelands of Africa, for which the pastoralists themselves are often blamed. The pastoralists are immediately and directly affected by drought and famine. However, this is not the only reason for the decline in these communities. Misconceptions have been translated into misguided policies or even a failure to monitor and account for the sector in the central planning process. On the other hand, imposed tenure structures in Africa have often not strengthened individual rights and have blocked tenure development and adaptation in response to new situations. Pastoralists in Africa have in particular been negatively affected by the imposition of national tenure systems, which in many cases have often served to marginalize nomadic populations with repercussions in terms of land degradation, food security and instability. Land scarcity, changing land and resource use, unclear land tenure and ownership arrangements create a complex array of problems. The problems faced by the pastoralists living in the Middle Awash Valley of Ethiopia are quite similar to those faced by many pastoralists in the arid areas of Africa.

This study has generated results by combining both aspects of social and biological sciences through a questionnaire survey and the application of different rangeland evaluation techniques to gain insight into the local people's understanding of changes in their natural resource base and quantative data on the condition of the rangelands. This combination of the two types of surveys tends to have a lower degree of bias associated with the findings, as opposed to findings of pure ecological or socio-economic studies. Thus, a combination of the two furnishes adequate information on the condition of the rangelands, people's life style and the environment.

The general conclusion that can be made from the results of the four studies (the pastoralists perceptions and the rangeland evaluation studies using different methods and arguments), is that the condition of the rangelands has deteriorated. Although there was variation from one rangeland site to another, generally the rangeland sites had a low herbaceous basal cover and grazing capacity indicating that the rangelands are in of need improvement. Furthermore, the ecological destruction will continue unless corrective measures are taken in time. Encroachment of the rangeland with woody plants of different species confirms the need for careful and participatory interventions to improve the condition of the rangeland. Accordingly, the following recommendations and scope for future research are made in order to improve the situations existing in the study districts.

The problems facing the pastoralists in the Middle Awash Valley have been created over many years and the solutions also require time. The solutions to the condition of the existing rangelands require the clear commitment and full participations from the side of the pastoralists, government and non-government organizations directly or indirectly involved in rangeland resources utilisation, management, protection and other related activities. A better understanding of the situation of the pastoralists and the different elements of the ecosystem must be made and a co-ordinated strategy be devised considering the different elements of the ecosystem in a such a way that one is complementary to the other. There must be a multidisciplinary approach towards the study of ecological stress, to look at demographic, sociological and political factors, as the study area is also very important from a conservation point of view. The conservation of the rangeland resource must receive top priority, whether the land is used for conservation, livestock production or for that matter any kind of production.

Pastoralists in the study districts acknowledge the vital role of trees and shrubs since they provide a range of products and services in their daily life. Therefore, selective protection and management of naturally occurring trees and shrubs, which are of high importance for livestock feeding and other functions such as *Acacia tortilis*, *A. nilotica*, *Balanites aegyptica* and others must be undertaken. To this effect, use of the indigenous technical knowledge of the communities augmented by scientific methods is crucial in the protection and rational use of woody and other plants in general. The undiscriminating cut of trees for fuel wood and charcoal, particularly along the high ways must be controlled through teaching the community about the importance of conserving the trees and careful use of these woody plants in the ecosystem. Management and future research should seek ways of regeneration of preferred multi-purpose trees and shrubs. Future research should also focus on developing of mechanisms in which disappearing valuable plants could be propagated. Furthermore, focus must be given on the multiplication of drought resistant fodder and tree species. The seeds of most important grass species, legumes and tree species must be collected and conserved.

In order to improve the rangeland condition, the grazing lands should be given adequate rest, preferably with stock exclusion. This can be done in parts with the effort of the community. Short-term protection from grazing would go a long way toward restoring plant cover. Longer periods of protection would be needed because rainfall is lower and vegetation might be less persistent in some rangeland sites. In the lower rainfall areas the provision of seedling rests to improve the botanical composition of rangeland has proved to be reasonably successful. Rests should be designed both to promote seed production and to encourage the development of seedlings. Such protective measures could be enforced by elders and village leaders and should be adopted as part of a general management plan.

For rangeland improvement, the best is to stick with the most promising native species of grasses and browse. Indigenous species has the advantage of proven adaptation to the environment. Herbaceous exotics in particular, appear to have their growth constrained by low rainfall. Therefore, the use of indigenous plants grasses and browses must be given due attention if improvements are to be made in the rangelands.

Interventions must also be undertaken with forage improvement programmes. It is contended that forage extension should focus on plants that help the people feed themselves first. To this effect, the use of dual-purpose legumes such as cow pea and intercropping of legumes with other food crops are important as a source of food for human beings and feed for the animals. Research works undertaken in the lowlands of Ethiopia like the Borana and the mid rift valley areas have shown these activities to be viable and advantageous to the pastoralists. The improvement of grazing areas through the introduction of high yielding and nutritionally quality species such as the legumes can be considered along the river lines where usage of irrigation can be possible. The study area is naturally endowed with many rivers passing through the study districts and usage of irrigation is already under way for food crops.

Some members of the Oromo pastoralists are already acquainted with the protection of small plots, locally known as 'kalo' for use during the dry season, either by harvesting or grazing by animals. The better option for calf feeding is the use of the grass produced in the kalo. Such a practice has been shown to be very important in other rangelands of Ethiopia such as the Borana rangelands. In this study, kalo sites were used as benchmark sites and have proved that they are very important for studying rangeland conditions as well. Therefore, such efforts of the community need to be appreciated and encouraged. There is already a good will of the community to get involved in such practices provided they are encouraged and supported technically. Furthermore, such practises must be extended to the neighbouring districts through education and field demonstration.

The yield of browse, their phenology and the DM yield of grasses is affected by season, therefore such studies needs to be undertaken over years and during different seasons. Studies related to the persistency of some of the grass species like *Chrysopogon plumulosus* under the existing grazing condition in the study districts need to be carried out. Furthermore, research should include rangeland ecological monitoring to learn the trend in the vegetation. It is also important to distinguish between climatic and man-made droughts. Although the pastoralists blame drought for poor animal production, in most cases the main reason is poor rangeland condition. Rangeland in poor condition will create pseudo-droughts. In addition, the methods of rangeland assessment used in this study need to be evaluated and be modified to suit the local condition if necessary. The results of the rangeland condition study showed that interacting factors such as drought, overgrazing, and high tree density affect the grass species composition, yield and basal cover of the rangeland. Therefore, long-term experiments are required to study the relative importance of each of these factors on the rangeland ecology of the study districts.

One of the areas that deserve attention should be the conservation of soil and water resources. Soil and water conservation measures are, therefore needed in the grazing lands. Use of trees and shrubs is a key way for assisting in the rehabilitation of gullied areas and abandoned fields. Every encampment in the study districts had tonnes of manure piled next to the corrals from years of corral cleaning. But this huge amount of manure is not used. Therefore, education on the importance of using manure as fertilizer and practical demonstration of its use must be undertaken in the study districts. This manure at least can be used to fertilize land in the backyard where dual-purpose legumes can be produced and the manure can also be used to improve the soil status. Future research should also focus on the effect of soil on vegetation distribution and/or vice versa.

Future water development programs should distinguish between water for human, calf and other livestock use. The community highly appreciates the contributions made by government and non-government organisations in water development activities. Still there is an inadequacy of water supply, both in terms of quantity and quality. Strong efforts must be made to develop methods of rainwater harvesting as the water harvested in such way can be used for many activities, including irrigation of pastures and consumption by livestock. Water development activities must be increased with due consideration of the effect of establishing watering points on the vegetation in close proximity of the watering points.

The community's effort of regular monitoring of rangeland resource problems is not backed up technically. Therefore, strong efforts must be made to assist the pastoralists technically and by creating forums for discussion among the pastoral groups. The two pastoral groups have developed a good culture along this line and the involvement of all groups in the community in seeking solutions and appropriate resource management practices should deserve attention. The role of women in handling livestock and rangeland management activities needs to be appreciated and encouraged. Such type of activities can be more effective in collaboration with the concerned offices including the Environmental Protection Authority (EPA), the agricultural offices and other NGO`s involved in natural resource conservation. One of the major problems for proper rangeland use is conflict between the two pastoral groups. Accordingly, efforts must continue in reducing land use conflicts between the different ethnic groups by promoting amiable sharing of resources.

From studies undertaken in Ethiopia and elsewhere it is well known that the presence of woody plants in savanna is associated with positive and negative aspects, which is closely related to tree density or tree abundance. Considering the decline in the production potential of rangeland as a result of bush encroachment, it is a national interest that encroacher plants are controlled. Combating bush encroachment, however, will require a proper understanding of the mechanisms of invasion, which has been adequately dealt in the thesis. Contrary to the common believe that bush encroachment is detrimental to grazers, but not browsers, there are indications that bush encroachment may also be detrimental to some browsers. High-density stands may therefore not only be poorly suited to grazers because of reduced growth of the herbaceous plants, but also to browsers because of their relatively poor browse supplying characteristics (Smit 1999). Therefore, the control of encroacher plants must be part of the rangeland management practice.

Control should start with key areas where young tree populations have invaded and should not be indiscriminate but selective. The problem of bush encroachment in the study districts can be tackled from two directions, i.e., prevention of bushes from encroaching and the control woody plants in already encroached areas. In the former situation, the preventive measures may include occasional hot fires and various biological control methods such as browsing by browsers. A combination of fire and biological methods will give better result than applying one of them only. Under the condition of bush encroachment, the control measures that can be used are mechanical methods combined with chemicals (herbicides) or mechanical methods combined with repeated cutting or mechanical methods combined with heavy browsing by goats. The last alternative seems more practical for the study area as it is possible to use a high density of goats to browse a specific area. After applying mechanical cutting the goats should graze the area at a high stocking rate. Heavy grazing will prevent coppice-growth of the woody plants. Big areas can be divided into smaller areas and the control methods applied accordingly.

Although, the problem of *Prosopis juliflora* is not wide spread in Awash-Fantale district, the pastoralists are concerned that this plant will cover wide area in short period of time. One of the reasons for its rapid expansion is seed dispersal by animals feeding on the ripe pods and spreading the seeds in their dung. In order to prevent it from spreading, the above-mentioned methods (hot fires and biological control methods) can be used. Furthermore, it is preferable not to allow the animals to graze the plant at the pod or seed stage. The pods (seeds) need to be collected by the available labour (children) and it should be grounded before feeding it to animals. In this way the seeds are destroyed, while utilising the high protein content of the pods and seed. In areas where it is difficult to apply the mentioned methods, economic use of the encroacher plants can be sought.

In all circumstances the application of bush control methods, the focus should be on the bushes rather than the trees. The existence of the big trees have numerous advantages of which one being their ability to suppress the growth of new seedlings in addition to their stabilization role in the ecosystem. The big trees need to be preserved. The rapid establishment of tree seedlings after the removal of some or all of the mature woody plants may reduce the effective time span of bush control measures. In many cases the resultant re-establishment of new seedlings may in time develop into a state that is in fact worse than the original state. It is hypothesised a more stable environment can be created, which is not as prone to the rapid regeneration of new woody plants by making use of system dynamics (Smit *et al.*

1999). Here the natural functioning of the savanna system is allowed to stimulate the development of an open savanna comprised mainly of large trees. It is based on the principle that the distance between a tree and its neighbour of the same species is not determined purely by chance, but that tree spacing is normally distributed. The larger the individual, the greater is the distance between it and the nearest individual of the same species. This is particularly noticeable with *Acacia* species (Smith & Goodman 1986; 1987).

It is important for any land manager to realize that there is no quick solution to the problem of bush encroachment. Effective management of bush encroachment should not be considered a once-off event, but rather a long-term commitment. This may involve alternative approaches that are not necessarily the simplest or cheapest. It has been proven time and time again that the least expensive method of killing trees may not be the most economical approach in the long term. It is also very important to avoid or minimise other direct or indirect causes of bush encroachment. Of these sound grazing management practise, which will ensure a vigorous and competitive herbaceous layer, is of critical importance.

Development projects should help farmers to improve farming techniques and use suitable seeds for the lowlands. There is a need to develop farming systems according to the potential of the land. One of the areas that can be exploited in the study districts is the development of Apiculture. Owing to the presence of different kinds of woody plants this area can be a viable enterprise if well managed and can provide extra income for the households.

The primary constraint on increasing the productivity of livestock in pastoral systems is the acute shortage of feed during the dry season and the poor quality of what feed is available. Owing to the abundance of browse plants and their primary role in livestock feeding in the study districts, evaluation of the nutritive value of browse species and other feed resources must be undertaken in the study area. Supplementation strategy in the study area should focus on leguminous trees like *Acacia tortilis, A. nilotica, A. senegal, A. nubica, Balanites aegyptica* and others.

The study districts are located in between many research centres. Despite this advantage, studies have not been conducted to investigate the potential of the local animals and improvement of the performance of the animals through breeding and/or improved management practices. With the current positive attitude of the government to the local pastoralists and with the emphasis given to the dry land, research studies need to be undertaken on ways of improving the productivity of their animals.

The community appreciates the efforts made by the government and the NGO's operating in the study area in improving the veterinary services in the study area. However, the supply of medications and other services is not adequate. This is evident through sporadic heavy losses of small ruminants (particularly sheep). Accordingly, improvement of animal health services and disease control measures, particularly for calves and small ruminants, needs much attention. The use of local plants as a source of medicine is practised in the community and research should be undertaken on the importance of such activities.

One of the most interesting results obtained in the study, particularly on the side of the Afar pastoralists was that their second most important source of income was from the sale of milk and milk by-products. The milk by-products are processed using local materials. These products, however, are easily perishable owing to the high ambient temperature and the long distance that must covered to reach market places. Therefore, efforts must be made to improve the milk products and by-products processing techniques through educating and demonstrating better techniques and equipments. To this effect, there is good expertise in the International Livestock Research Centre (ILRI) in Ethiopia. Furthermore, the livestock marketing, marketing infrastructures and supply livestock market information must be improved through research and development in such a way that livestock marketing maximizes the income of the pastoralists and at the same time reduce the pressure of the livestock on the rangeland.

One of the major problems in developing the rangelands of Ethiopia in general is the lack of adequate numbers of trained personnel in the different areas of rangeland sciences. The country has a high potential to develop its resource base, be it in livestock production, wildlife, crop production and some other agriculture related areas as was reviewed in from literature. Yet, it should not be a surprise that most development projects related to the rangelands are developed by expatriate staffs, while the country should have developed it's own nationally capability rather than relying on expatriate staffs. In most of the pastoral districts, it is unlikely to find even one person trained in rangeland management. Therefore, it will be very difficult to think of rangeland development in the absence of trained staff. Accordingly, education must be given at different levels (from national to the grass root level in different rangeland considerations, conservation, improvement and environmental management and wildlife management). Therefore, having a college or other teaching institution responsible to educate and teach at different levels in rangeland, wildlife and related disciplines must be one of the top priorities. Owing to it's numerous advantages like accessibility, proximity to the capital city, the existence of the different elements of the rangeland and the pastoralists, the Awash National Park can be one possibility. It is also an area where education on the conservation of natural resources can be effectively taught. Human resource development must be accompanied by creating a favourable environment for the staff and the provision of necessary facilities.

Studies in many countries with pastoral communities and supported by the results of this study have showed that the pastoralists in general have a good knowledge of rangeland ecology. Nevertheless, owing to the internal and external problems facing the pastoralists relying solely on indigenous knowledge of the pastoralists is not adequate. Therefore, traditional experiences, skills and strategies accumulated by the pastoralists over the centuries should instead complement modern scientific knowledge rather than be ignored.

Linkages among development entities, research institutions, the pastoralists and other non-government organisations working in rangeland resource management must be strengthened. Solutions to the problems in the study area are possible through collaboration between all parties involved. Rangeland policies based on solid scientific and indigenous knowledge systems need to be formulated that can improve the condition of the rangelands.

CHAPTER 9

SUMMARY

Four studies were conducted in the Middle Awash Valley of Ethiopia in order to determine the condition of the rangelands commonly grazed by the animals of the pastoralists. The perceptions of the pastoralists about the rangeland resource must be taken into consideration in order to develop possible intervention strategies to minimize further degradation of the rangeland ecosystem. The two pastoral groups (Afar and Oromo) live in an area characterised by resource use conflicts (state and privately owned agricultural enterprises, conservation areas and use by the local people). The study of the pastoralists perceptions was undertaken through group discussions and interviewing of the individual households using a structured questionnaires (90 households from the Oromo and 55 households from Afar). In the second study, evaluation of the condition of the rangeland (11 sites in Awash-Fantale and 10 sites in Kereyu-Fantale) was undertaken considering aspects of the herbaceous layer, woody layer and the soil. The variables studied were grass species composition, basal cover, estimated soil erosion, grass DM yield, woody species composition, density, browse production and leaf phenology. The soil was analysed for pH, texture, electrical conductance, percent total nitrogen, percent organic carbon, available K and available P. In the third study, the condition of the rangeland sites was evaluated using the benchmark method. Three benchmark sites (two pastoral protected small plots and one junction site between the two neighbouring districts) were used. Six sampling sites (four from the Oromo and two from the Afar) were identified to be compared with the identified benchmark sites. In the fourth experiment, the influence of tree species and livestock grazing on grass species composition, yield and soil parameters was studied in three grazing gradients and two sub- habitats.

The results of the study on pastoralists perceptions generally indicated that there was deterioration in the conditions of the rangeland evident in an increase in bush encroachment (mainly different species of *Acacia)* and a decrease in the abundance

of grasses and important legumes. In the case of the Afars, there was also an increase in the abundance of poisonous plants. Drought and overgrazing were indicated as the major causes of rangeland degradation. Furthermore, population pressure, immigrants and the expansion of crop production were also among the factors influencing rangeland condition. Poisonous plants of both woody and herbaceous species were identified to affect livestock production in the study area. The pastoralists, through their long-term tradition, have developed traditional methods of intervention when toxins of plant origin poison an animal. However, these traditional methods are not completely successful and need to be studied. Woody plants play an important role in the farming system and have a wide range of uses. Some of their uses were very interesting like the use of *Grewia tenax* bark to soften ladies hair by soaking it in water overnight. Traditional people use woody plants as a source of medicine for human and veterinary purposes. Such practices also need to be studied in depth for better development in the area of ethno botany. The majority of the pastoralists replied that the grazing lands are bush encroached notably by *Acacia Senegal, A. nubica* and the other species *Prosopis juliflora*. Although it was difficult for the pastoralists to clearly state the exact causes of bush encroachment, which actually is also true for the scientific community, they have attributed possible reasons that are acceptable within the scientific context. The pastoralists also indicated that the intensity of conflict between them has increased owing to the nutritional constraints of their animals. The main problem regarding livestock production inclines more to nutritional constraints.

The results of the rangeland condition study indicated that in general, the dominant grass species in the study districts were *Chrysopogon plumolosus* and different species of *Sporobolus*. The rangelands sites were also characterised by a high percentage bare ground, low basal cover, with a loss of soil from the surface and low grazing capacity. The only exceptions were grazing sites at the junction between the Oromo and the Afar pastoralists with relatively better cover values and higher grass yields. The highest browsing capacity for camels and goats was contributed by *A. senegal* and *A. nubica*. The soils around lake Beseka and Asobabad were found to have a high electrical conductance, pH and low percent total nitrogen and organic carbon. The results of the correlation matrix and the stepwise multiple regression indicated that grass DM yield was affected by ETTE ha^{-1}, basal cover, bare ground, CN ratio and available K. The results of the analysis of the benchmark study revealed that the sample sites had a substantially lower basal cover and grass DM yield. In terms of grass species composition and other parameters, the benchmark and the sample sites were comparable.

The results on the influence of tree species found under different grazing intensity, revealed that the grass DM yield increased significantly with a decrease in the grazing pressure. Areas under tree canopies subjected to medium and light grazing pressures had a higher grass DM yield ($P<0.001$) than the corresponding open grasslands. The soil nutrient status was also improved due the effect of sub-habitat and with a decrease in grazing pressure. In general, for the sustainability of the rangelands, overgrazing must be avoided and the rangeland given a rest period for recovery. The scientific findings coincided with the pastoralists perceptions of their environment, which shows that the pastoralists were quite aware of what is going on in the rangelands.

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Appendix 4.1. Questionnaires used in the household survey

Region Zone District
Pastoral Association (PA)-------------------Village---
House hold no--------------------------Date-------------------------------------
Respondants name--------------------Age-------------------------------------
Sex-------------------------------------
Ethnic group 1. Afar/Denebe 2. Afar/Waima 3. Karayo/Baso
4. Karayo/Dulcha 5. Itu- 6. Somalia- 7. Others-

Educational background: 1. Formal education----- 2. Read and write------ 3. None-----
4. Other (specify)------------------

PART 1. General

1. For what purpose were you using your land 10-20 years back

   1. Crop production------ 2. Grazing only------------ 3. Grazing and crop production---------
   4. Others-----------------------

2. What is your current land use? (ha)

   For cultivation For grazing (if private)

3. Compared to the past (10-20 years), how is the trend in land utilization for cultivation and grazing

Trend 1. Increasing 2. Decreasing 3. Constant

Land use	Trend	Reason
Cultivation		
Grazing		

4. What is your main source of money (Multiple response question)

   4.1.Sell livestock 4.2. Sell milk and milk products 4.3. Other (specify)

PART 2. Natural mineral sources and utilization (Like Haya, Boji etc)

1. Do you give natural minerals to your animals? A.Yes B. No

2. If the answer to the above question is yes, mention in the table types of mineral sources, animal species offered, season, the frequency of offer and the form of offer (Multiple response question)

Type of mineral sources	Animal species Offered	Season	Frequency	Form of offer

PART 3. Poisonous plants

1. Do you know any kind of poisonous plant that affect your livestock production?

Yes---------No--------Indifferent

2. If the answer is yes, indicate in the table the animal species affected, season and traditional control measure

1. Animal species affected
1. Camel 2. Cattle 3. Sheep 4.Goat
2. Season when the effect of poisonous plants on animals is highest
1. Dry 2. Wet season 3. Both

Poisonous plant name	Animal species affected	Season	Traditional control method

PART 4. Bush encroachment

1. Do you observe an increase in bush/shrubs in your grazing land?

Yes No Indifferent

2. What problem did you face due to these encroaching bushes/shrubs? (Multiple response question)

1. Decrease production of grasses-------- 2. Accident due to wild animals-----------
3. Difficulty in herding----------- 4. Other (specify)----------------------------

4. What do you think are the possible reasons for the increase of bushes/shrubs? (Multiple response question)

1. Increased livestock population leading to overgrazing-------------------

2. Uncontrolled livestock and wild life movement from place to place------
3. Lack of burning---------------------------------------
4. Drought---
5. I do not know---
6. Other (specify)---------------------------------------

PART 5. Water resources and utilization

1. Mention the sources of water to your livestock by season? (Multiple response question)

Dry season	Distance in Km (hr)	Wet season	Distance in Km (hr)

2. Is the water clean and adequate?

Cleanness Clean Dirty
Quantity Adequate---------Inadequate----------

3. If inadequate, specify months of inadequacy (--------------to-----------months)

4. What alternative do you have when you face water shortage

A) Buy water from pump B) Move to very distant water source C) Others (specify)
5. Do people and animals use the same sources of water?

Yes-----------------------------
No-------------------------------
+
If no,
Human water source---------------------------------------
Livestock water source-------------------------------------

6. Is there any grazing land that you do not utilize in the dry season due to lack of water to your animals?
Yes No

7. If yes, mention their names

Dry season----------------------

PART 6. Feed resource and utilization

1. How many months do each of the following livestock feed resource cover for you in a year?
(Name the months)

1.Grazing-----------------------
2.Browse trees---------------------
3. Crop residues-----------------
4. Weeds/crop thinning------------------------
5. From migration-------------------------------
6. Sugar cane by-products/molasses------------------
7. Other (specify)-------------------------------------

2. Is there period of critical feed shortage? 1=Yes 2= no

3. If yes, state the period and the major measure you take to overcome the problem

Period (Months)--

4. Measures taken:

1= Sale animals---------------------------
2= Buy feed --------------------------------
3= Move animals---------------------------------
4= Use reserve feed --------------------------(specify)
5= social alliance (explain)------------------------------------
6= Lopping browse trees (name)---------------------
7= Use non-convectional feeds (name)-------------

4. Do you collect and feed sugar cane tops?
Yes No
5. If you are not feeding sugar cane tops/molasses to your animals what is the reason?

1.Transport problem-----2. Financial shortage---3. Lack of knowledge of its usage--------

4.Other (specify)-----------------5.Accessibility-------------------------------------

6. Do you give supplement to your animal during the dry season?

Yes---------------------------------
No----------------------------------

7.If the answer to the above question is yes, what type of feed do you give as supplement and to which class of animals do you give priority? (Multiple response question)

Supplement type	Animal given priority	Reasons to priority

8. Do you conserve feed for dry season? 1= Yes 2= No

9. If yes, state the type of feed you mostly conserve (Multiple response question)

1= Standing hay-----------------2= Cut hay---------3= Crop residues----4= Browse (pods, leaves, etc)

5= Others (name)-----------------6= None

10. Do you use browse for livestock feeding? 1= Yes 2= No

11. What is the major problem in utilizing browses (Choice)?

1. They will dry soon after the rain--------------------------
2. Stage at which they will be poisonous is not known----
3. They are long enough to be reached by animals---------
4. Other (specify)---------------------

12. Do you know browse plants used for medicine purpose? Yes-------- No-------------

If yes, mention their names

13. For which of the following activities do you use trees/shrub/bushes (Rank)

1. House construction
2. Fire wood/charcoal making
3. Browsing
4. Fencing
5. Wild fruit
6. Other (specify)

14. Does such usage (other than browsing) affect the availability of browse to your animal? Yes No

PART 7. Rangeland management

1. Does your community allocate grazing lands according to season?

Yes---------------------
No----------------------
Indifferent------------

2. If the answer to the above question is yes, what criteria do they use to sub-divide?

Suitability of the grazing lands in terms of availability of grass and browse.......
Suitability to human beings in terms of health--------------------------------
Other (specify)--------------------------------

3.If the answer to the above question is no, what is the reason-----------------------

4. Currently are there rules that govern the use of grazing lands and water within your community?

Type of use	Response	
	Yes	No
Water		
Grazing land		

5. If the answer to the above question is yes, how is the grazing land and water use governed?

6. If the answer to the above question is no, what are the possible reasons?

7. Do you practice range plant harvesting?

Yes-------------------------
No--------------------------
If yes how and by whom-------------------
If no, why----------------------

8. Which range condition improvement practices do you apply?

1. Burning 2. Irrigation 3. Over-sowing 4. Fertilizer use 5. manure use
6.Range exclosure 7. Resting 8. Others (specify) 9. None

9. If you are not practicing any of them, what is the reason---------------------------

10. Which type of ownership of the grazing land do you like in the future?

Type of ownership 1. Private 2. Communal 3. Both4. Open access

Type of ownership	Reason for the choice

11. Compared to the past how is the trend of grasses, legumes and trees

Trend 1. Increasing 2. Decreasing 3. Constant

Plant category	Trend	Reason
Grasses		
Legumes		
Trees/bushes/shrubs		
Poisonous plant		

12. How is the condition of the rangelands

1. Poor2. Fair 3. Good 4. Very good 5. Excellent

13. If it is a poor, what are the possible consraints (Rank)

Increment in livestock population-------------------------------
Drought (Low rainfall)---
Increased human population-------------------------------------
Lack of technical knowledge (Mismanagement)---------------
Little support from the government-----------------------------
Over grazing /overstocking due to shortage of land-------
Immigration--
Bush encroachment--
Poisonous plant--
Poor in soil fertility
Change in the direction of Bulga river----------------------
Expansion of the towns
None---------------------------------

14. Does your community make periodic assessment of the condition of the grazing land?

1.Yes 2. No
If No, give reason------------------------------
If Yes, by whom and how----------------------

15. Generally compared to the past 5 years, how is the intensity of the conflict?

A. Increased b. Decreased

16. If decreased, why?---

17. If increased why?---

18. What do you suggest to improve the condition of the rangeland?

19. Do wild herbivores share grazing lands with your animals?

Yes
No

20. How much forage do the wildlife animals graze?

1. More than your livestock
2. Same as livestock
3. Less than your livestock

23. Does wildlife utilize the same water sources as livestock? Yes No

24. Do you graze your animals in the national park and when?

1. Yes and when
2. No

PART 8. Migration pattern

1. Do you move livestock to other places in search of feed and water? Yes No

2. In the table given below, mention the type of animals involved, place moved and distance in Km (hr)

Animal category	Place moved	Distance in Km (hr)

Rank	Cattle disease	Sheep disease	Goat disease	Camel disease

3. What problems do you face in the migration?

    1. Death of animals 2. Problem of wild animals
    3. Feed and water shortage 4. Disease problem
    5. Other (specify)

4. Is the frequency of migration increasing?

    Yes---------------------------------------
    No______________________________-
    If yes, why-----------------------------------

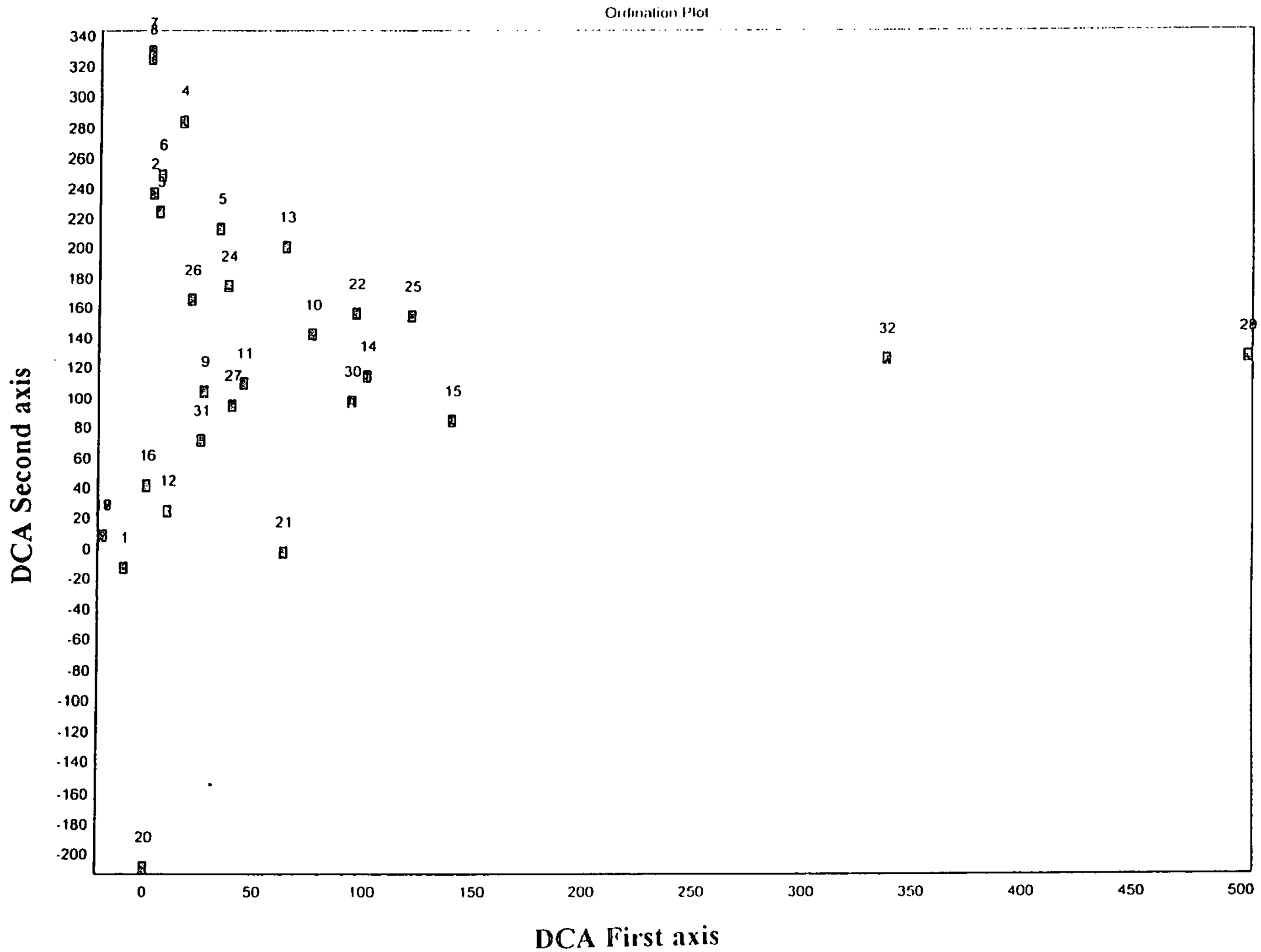
5. What do you suggest regarding migration?

PART 9. Livestock

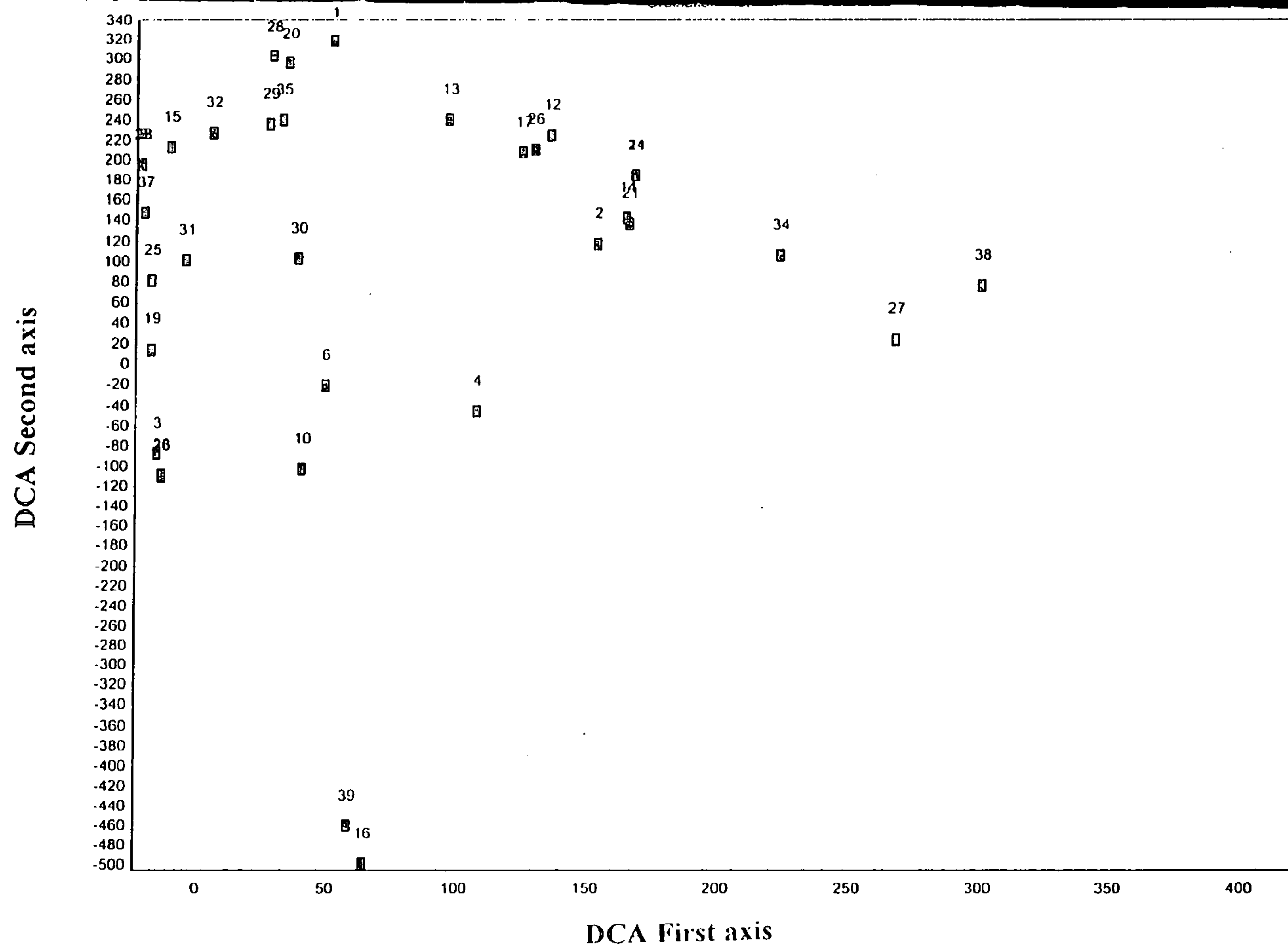
1. Livestock ownership/household

Cattle (Cow, heifers, calves, bulls& oxen)
Sheep (Male, Female)
Goat (male & Female)
Camel (male & Female)

2 What are the major reasons for keeping mixture of livestock?



Appendix 5.1. Ordination of the different grass species using DECORANA in Awash-Fantale district. Key to the numbers: 1= *Chrysopogon plumulosus*; 2= *Cymbopogon commutatus*; 3= *Cymbopogon excavatus* 4= *Tetrapogon cenchriformis*; 5= *Dactyloctenium aegypticum*; 6= *Aristida adoensis*; 7= *Eragrostis racemosa*; 8= *Heteropogon contortus*; 9= *Sporobolus natalensis*; 10= *Panicum coloratum*; 11= *Setaria verticellata*; 12= *Cenchrus ciliaris*; 13= *Cynodon dactylon*; 14= *Urochloa panicoides*; 15= *Urochloa panicoides*; 16= *Coelachrum poiflorum*; 17= *Chloris pychnothrix*; 18= *Sorghum purpureooserice um*; 19= *Enneapogon schimperanus*; 20= *Aristida adscensionis*; 21= *Tragus berteronianus*; 22= *Paspalm glumaceum*; 23= *Sporobolus ioclados*; 24= *Cenchrus setigerus*; 25= *Paspalm dilatatum*;26= *Chloris roxburghiana*; 27= *Lintonia nutans*; 28= *Sporobolus festivus*; 29= *Sporobolus spicatus*; 30= *Hyparrhenia hirta*;31= *Digitaria ternata*; 32= Bareground.



Appendix 5.2. Ordination of the different grass species using DECORANA in Kereyu- Fantale district. Key to the numbers: 1= *Urochloa panicoides*; 2= *Tragus berteronianus*; 3= *Themeda triandra*; 4= *Tetrapogon cenchriformis*; 5= *Sporobolus spicatus*; 6= *Sporobolus natalensis*; 7= *Sporobolus festivus*; 8= *Sorghum purpureosericeum*; 9= *Setaria vstilata*; 10= *Setaria verticellata*; 11= *Pennisetum mezianum*; 12= *Paspalm dilatatum*; 13= *Paspalm glumaceum*, 14= *Panicum snowdenii*; 15= *Panicum coloratum*, 16= *Microchloa kunhtii*; 17= *Lintonia nutans*; 18= *Hyparrhenia hirta*; 19= *Heteropogen contrortus*; 20 = *Eragrostis racemosa*; 21= *Eragrostis racemosa*; 21= *Eragrostis cilianensis*; 22= *Enneapogon schimperanus*; 23= *Eleusine indica*; 24= *Digitaria ternata*; 25= *Digitaria milanjuana*; 26= *Dactyloctenium aegypticum*; 27= *Cynodon dactylon*; 28= *Cymbopogon excavatus*; 29= *Cymbopogon commutatus*; 30= *Coelachrum poiflorum*; 31= *Chrysopogon plumulosus*; 32= *Chloris roxburghiana*; 33= *Chloris gayana*; 34 = *Cenchrus setigerus*; 35= *Cenchrus ciliaris*; 36= *Bothriochloa radicans*; 37= *Aristida adscensionis*; 38= Bare ground; 39= *Aristida adoensis*.

Appendix 5.3. Correlation matrix among variables studied in Awash-Fantale district (NS= Non significant*= P < 0.05; ** = P<0.01; *** = P < 0.001). Correlation coefficients for the vacant cells were non-significant (P >0.05) (GY= grass DM yield kg ha^{-1}; BC= % basal cover; BG= % bare ground; ESE= estimated soil erosion; ETTE= Evapotranspuration tree equivalent ha^{-1}; EC= Electrical conductivity ds m^{-1}; Sa= Sand (%); Si= Silt (%) ; Cl= Clay (%); TN%= % total nitrogen; OC%= % organic carbon; CN= carbon nitrogen ratio; P= available phosphorous; K= available potassium; Al= altitude).

Parameters	GY	BC	BG	ESE	ETTE	PH	EC	Sa	Si	Cl	TN%	OC%	CN	P	K	Al
GY		0.59	-0.25	-0.31	-0.65	0.13	0.16	0.32	-0.02	-0.38	0.01	-0.05	-0.16	-0.14	0.06	0.33
BC	**		-0.57	-0.13	-0.47	-0.18	-0.22	0.25	0.08	-0.38	0.18	0.12	-0.15	-0.17	0.07	0.18
BG	NS	**		0.08	0.04	0.52	054	0.04	-0.29	0.21	-0.42	-0.38	0.06	0.18	-0.05	-0.04
ESE	*	NS	NS		0.49	-0.40	-0.43	-0.62	0.29	0.52	0.15	0.46	0.58	0.14	0.11	0.02
ETTE	***	*	NS	**		-0.33	-0.32	-0.51	0.25	0.43	0.14	0.35	0.41	0.29	0.12	-0.07
PH	NS	NS	**	*	NS		0.97	0.70	-0.62	-0.31	-0.71	-0.78	-0.18	0.04	-0.07	-0.20
EC	NS	NS	**	*	NS	***		0.69	-0.54	-0.38	-0.67	-0.77	-0.27	0.16	0.05	-0.27
Sa	NS	NS	NS	***	**	***	***		-0.58	-0.73	-0.46	-0.74	-0.54	-0.06	-0.16	-0.34
Si	NS	NS	NS	NS	NS	***	**	**		-0.13	0.36	0.41	0.01	0.29	0.18	-0.17
Cl	NS	NS	NS	**	NS	NS	*	***	NS		0.23	0.54	0.68	-0.15	0.04	0.56
TN%	NS	NS	*	NS	NS	***	***	*	NS	NS		0.77	-0.22	-0.13	0.20	0.40
OC%	NS	NS	NS	*	NS	***	***	***	*	**	***		0.41	-0.10	0.31	0.50
CN	NS	NS	NS	NS	*	NS	NS	**	NS	***	NS	*		-0.01	-0.01	0.27
P	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS		0.12	-0.24
K	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		0.20
Al	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Appendix 5.4. Correlation matrix among the variables studied in Kereyu-Fantale district. (NS= Non significant*= $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$); .GY= grass DM yield kg ha^{-1}; BC= % basal cover; BG= % bare ground; ESE= estimated soil erosion; ETTE= evapotranspuration tree equivalent ha^{-1}; EC= electrical conductivity ds m^{-1}; Sa= sand (%); Si= silt (%); Cl= clay (%); TN%= % total nitrogen; OC%= % organic carbon; CN= carbon nitrogen ratio; P= available phosphorous; K = available potassium; Al = altitude).

Parameters	GY	BC	BG	ESE	ETTE	PH	EC	Sa	Si	Cl	TN%	OC%	CN	P	K	Al
GY		0.61	-0.69	0.27	-0.50	-0.52	-0.13	-0.13	0.17	0.05	-0.12	0.20	0.68	-0.27	0.59	0.46
BC	***		-0.74	0.30	-0.25	-0.31	-0.19	-0.08	-0.14	0.03	0.19	0.25	0.23	-0.16	0.53	0.31
BG	***	***		-0.05	0.41	0.36	0.32	-0.14	0.21	-0.02	-0.18	-0.30	0.29	0.24	-0.40	-0.32
ESE	NS	NS	NS		0.20	-0.08	0.06	-0.27	0.27	0.17	-0.17	0.01	0.29	0.08	0.44	0.17
ETTE	**	NS	*	NS		0.15	-0.28	-0.06	0.08	-0.01	0.25	0.19	-0.11	0.54	-0.25	-0.19
PH	**	NS	*	NS	NS		0.61	0.39	-0.48	-0.16	-0.31	-0.55	-0.60	0.08	-0.20	-0.50
EC	NS	NS	NS	NS	NS	***		0.22	-0.21	-0.16	-0.57	-0.62	-0.14	-0.06	0.09	-0.29
Sa	NS	NS	NS	NS	NS	*	NS		-0.90	-0.80	-0.26	-0.38	-0.11	-0.37	-0.35	0.04
Si	NS	NS	NS	NS	NS	**	NS	***		0.46	0.21	0.40	0.29	0.37	0.36	0.08
Cl	NS	NS	NS	NS	NS	NS	NS	***	*		0.26	0.24	-0.15	0.25	0.24	-0.19
TN%	NS	NS	NS	NS	NS	NS	***	NS	NS	NS		0.90	-0.21	0.27	0.02	0.16
OC%	NS	NS	NS	NS	NS	**	***	*	*	NS	***		0.17	0.20	0.16	0.44
CN	***	NS	NS	NS	NS	***	NS	NS	NS	NS	NS	NS		-0.21	0.16	0.59
P	NS	NS	NS	**	**	NS	NS	*	*	NS	NS	NS	NS		0.29	-0.49
K	**	**	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		-0.09
Al	*	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	*	***	**	NS	